Report to Congress

Desalination and Water Purification Research and Development Program

Department of the Interior
Bureau of Reclamation

May 2001

This report to Congress fulfills the requirements of P.L. 104-298: Water Desalination Act of 1996:

> *"As soon as practicable and within three years after the date of enactment of this Act, the Secretary shall recommend to Congress desalination demonstration projects or full-scale desalination projects to carry out the purposes of this Act and to further evaluate and implement the results of research and studies conducted under the authority of this section. Recommendations for projects shall be accompanied by reports on the engineering and economic feasibility of proposed projects and their environmental impacts."*

The Desalination and Water Purification Research and Development Program, authorized under the Water Desalination Act of 1996, promotes research to reduce costs of advanced water treatment technologies to treat previously unusable sources of water such as brackish groundwater, coastal waters, irrigation drainage, sewage, and other impaired water sources in order to augment the U.S. water supply.

DWPR Report #67

Report Contents

Recommendations for Desalination Demonstration Projects

Program. -The Desalination and Water Purification Research and Development (DWPR) Program partnered in developing cost-effective, technologically efficient, and practical ways to desalinate water. The program first received funding in October 1997 and started to award research and studies projects and pilot-scale investigations in September 1998. For fiscal years 1998 through 2001, program funding totaled $6.15 million for 35 projects as well as workshops and technology transfer. Projects had an average cost share or cooperative agreement of 50 percent.

Recommendations. -Based on DWPR program findings, Bureau of Reclamation (Reclamation) recommends the projects listed in the summary table of recommendations on the next page be funded for demonstration. As resources are limited, the program can only fund a few of the many worthy projects for demonstration, as was the case in previous research and studies. Further research and studies may be needed to further enhance the understanding of the recommended demonstration projects. One significant example is the need to find sustainable ways to use byproducts or safely dispose of them.

Generally, demonstration-phase projects desalinate between 250,000 - 1,000,000 gallons per day (GPD). Demonstration projects will give researchers, engineers, environmentalists, planners, designers, government entities, and the general public the opportunity to see the technology in operation and to suggest changes before a full-scale project. Demonstration will also allow full-scale capital and operation and maintenance (O&M) costs to be more accurately verified. Full-scale projects are not recommended for demonstrations because they are larger and more costly. Demonstration projects will provide the information needed for the private sector to move forward to full-scale.

The program will use these demonstrations to advance the interests and well being of the U.S. public and military, protect the environment and public water supplies, create new sources of water, and assist the U.S. water treatment industry to become more competitive in world markets by introducing advanced technologies. These technologies can help resolve complex issues such as public health, environmental protection, storm-water drainage, irrigation return flows, industrial wastewater, water reuse, and water quality issues such as pharmaceutically active compounds, arsenic, and disinfection byproducts.

Further information. -Attachment A provides detailed explanations of each of the recommended demonstration projects. Attachment B details program accomplishments. Attachment C lists partners and cost-share cooperators for the program. More information on the program, projects results, and full text copies of the final reports are at <http://www.usbr.gov/water/desal.html>.

Engineering, Economic, and Environmental Feasibility

The program's research, studies, and pilot-scale findings strongly indicate the recommended demonstration projects are feasible. While the recommended technologies proved successful so far, they have not been extensively tested in the field.

However, all research, studies, and pilot-scale results indicate the engineering and technologies are sound and cost effective.Costs for desalination technologies explored in this program were found to be lower than existing technologies. Based on these prefeasibility studies, it would be beneficial to examine the economic values of these technologies in greater detail.

There are no adverse environmental impacts associated with the recommended demonstration projects. Detailed engineering, economic, and environmental impacts must be examined on a site-specific basis. Prior to construction of these projects, Reclamation will comply with all environmental compliance requirements, including the National Environmental Policy Act, and will incorporate mitigation measures if necessary.

Summary table of demonstration recommendations

Project	Description	Benefits	Estimated time and total cost in millions
Membrane bioreactors	Wastewater reclamation technology that may be combined with desalination technologies to purify wastewater to a level that meets or exceeds stringent drinking water standards.	Help allay fears about the purity of treated wastewater. Uses less space, equipment, chemicals, and energy to be cost competitive with conventional methods and protect the environment.	3 years Government costs $4 million / Partner cost share $4 million
Innovative membrane test bed for seawater desalination	Combines three innovative research components (pretreatment intake system, advanced membranes, and high pressure pumping system). Will allow continued research to develop environmentally acceptable concentrate disposal methods.	Will determine the combined cost reductions and efficiency improvements. Each component has proven to reduce costs and advance techonologies.	3-4 years Government costs $2 million / Partner cost share $2 million
Dewvaporation	Process humidifies/ dehumidifies to evaporate water from saline solutions. Innovative technology uses inexpensive materials and recycled energy to evaporate water.	Provide a new, low cost, low maintenance treatment option for small communities. Unit is inexpensive to manufacture, energy efficient, and suitable for all water sources.	2 ½ years Government costs $500 thousand / Partner cost share $500 thousand
Clathrate desalination	Improves freeze desalination techniques by using guest molecules to form ice-like structures at warmer temperatures.	Demonstrate effectiveness of freeze desalination compared to membrane processes. This process operates at low pressures and is relatively insensitive to source water quality.	2 years Government costs $1.25 million / Partner cost share $1.25 million

Attachment A: Detailed Descriptions of Recommended Desalination Demonstration Projects

Membrane Bioreactors

Description

Membrane bioreactors separate out constituents in wastewater for advanced water purification and can treat primary effluent municipal wastewater to a purity higher than conventional methods or even higher than most natural water sources. Studied worldwide, these reactors promise alternative water sources as conventional water supplies become overburdened. They combine the process elements of many secondary, tertiary, and advanced wastewater treatment into a single-unit operation, which is then directly connected to a desalination process.

Significant benefits

Membrane bioreactors represent a step change in technology and a major improvement over conventional wastewater treatment processes. The water produced meets, and usually exceeds, most discharge permit requirements and is suitable as a feedwater to a water treatment plant, a desalination membrane system, or even direct introduction into a municipal water supply. Current information indicates that the process is less expensive than conventional wastewater treatment processes because it requires less space and equipment, has reduced energy requirements, and uses fewer chemicals. However, the full economic savings realized from the use of this technology are yet to be demonstrated.

Validating this technology is a necessary step to demonstrate that the treatment process is economically viable at full-scale production levels. As membrane bioreactors become more cost effective and are shown to be feasible, more water reclamation and reuse processes will incorporate this technology. Membrane bioreactors will be considered in planning new or expanding existing facilities and in meeting site-specific treatment goals.

This demonstration will evaluate a specific membrane bioreactor application to reduce the costs and increase the efficiency of systems to provide more usable water through water reclamation. This project should result in:

1. A novel water treatment/desalination process for water repurification projects
2. Reduced cost of water treatment and desalination

Recommended activities

Build and operate a 1.0 million gallon per day (MGD) facility for 3 years to:

- Provide enough data to design a full-scale 20 MGD facility suitable for a large community and address potential issues involved in full-scale operations.
- Evaluate the long-term performance of the membrane bioreactors technology, including O&M issues.
- Provide real life information on system performance, effluent quality, ease of operation, O&M requirements, and system stability.
- Develop more accurate and refined capital and O&M costs.
- Provide a site for public education and awareness in advanced water treatment technologies.

Successful wastewater reclamation pilot-scale projects using membrane bioreactors have been completed in San Diego, California, and McAllen, Texas, making both cities a candidate for a demonstration-phase project. Many other cities could also benefit from this demonstration.

A 1.0 MGD membrane bioreactor unit would cost approximately $7 million. A demonstration project will take three years to implement: one year to construct the membrane bioreactors system and two years to operate and evaluate its performance. Operating the unit during the demonstration is estimated at $1 million. Thus, the total estimated project cost is at $8 million.

Innovative Membrane Test Bed for Seawater Desalting

Description

The membrane test bed demonstration will test several successful individual components co-funded under DWPR program research, studies, and pilot-scale projects. The tests will be conducted in parallel with a conventional system. These innovative technologies represent major improvements over conventional seawater desalination processes. They will help provide sustainable water supplies at lower costs and with fewer environmental impacts in water short regions in the U.S. and world-wide. Each individual component represents a step change over existing technologies.

- *Pretreatment process.* –A novel seawater pretreatment process termed subfloor water intake system structure or SWISS provides both a water intake structure and a natural *in situ* media filter. A unique well screen creates a slow sand filter under the sub-floor of a water body (such as an ocean or lake) and, therefore, provides natural filtration of particles as small as to 1-10 microns. SWISS works for both salt and freshwater intakes. The implementation of this technology at new or existing plants will reduce both capital and O&M costs for feedwater intake systems by as much as 50 percent.

- *Advanced membranes.* –Reverse osmosis processes drive water through a semipermeable membrane under pressure, then concentrate and discharge the salts and impurities. In most systems, the feedwaters must be treated with chlorine to kill microorganisms that cause fouling. Fouling reduces productivity and makes frequent chemical cleanings necessary. Existing membranes deteriorate with repeated exposure to chlorine. The DWPR program co-funded several chlorine-resistant membrane studies which developed a polyamide membrane that shows improvement in chlorine-resistance when compared with existing commercial membranes in both laboratory and pilot-scale testing. Demonstration is required to prove the long-term resistance of the new polyamide membrane to chlorine. This demonstration will also allow for testing of other advanced membranes.

- *Energy recovery system*In addition to allowing testing of other energy recovery devices, this demonstration will test an integrated high pressure pumping and energy recovery system, termed VARI-RO, that dramatically improves seawater desalination. The system: uses up to 50 percent less energy than conventional reverse osmosis systems with energy recover and 90 percent less energy than multi-stage flash distillation; can use low cost waste heat or renewable energy; and can reduce carbon dioxide emissions by nearly a factor of 10 from conventional distillation methods, thereby significantly reducing green house gases.

- *Concentrate issues.* – As the membrane drinking water industry advances, the technical, economic, environmental, political, and social issues associated with bringing a new membrane plant into operation has become increasing complex. As a result, a gap has developed between the reality of membrane technology's cost-effective, environmentally-safe, technically-sound capabilities and the perception of the technology by many regulators, legislators, decision makers, and the public. Further research and studies are needed to extend the understanding of concentrate issues. This demonstration would allow research and testing of seawater desalination issues in a production setting, rather than in a laboratory.

Significant benefits

Each component will reduce capital and O&M costs, lower energy use, and further protect the environment. This demonstration will provide the information needed to better understand the individual components and maximize the overall efficiency and benefits of the combined processes. This demonstration will allow real world research into the testing of concentrate issues, thus resulting in sustainable ways to use or safely dispose of concentrate byproducts. Developing these sustainable methods would represent a major advancement in applying desalination technologies.

Recommended activities

A 1.0 MGD test bed is recommended for a three to four year operating period to determine the effects of seasonal variations on water quality and performance. Individual equipment components will be based on design criteria established during prior research. During demonstration, all individual equipment O&M data parameters will be collected and analyzed. These parameters will be compared to the performance of conventional intake systems, membranes, pumps, and concentrate disposal methods to determine how well they work. Installation, construction, and O&M data will be used to determine life-cycle costs of each component so that actual cost benefit analyses can be performed. It is recommended that the test bed be placed in side-by-side operation with a conventional system–possibly at an existing site with a conventional plant–so that O&M data can be directly compared.

In addition, research and studies funding will be made available to perform concentrate disposal pilot-scale work using the reject from this test bed demonstration.

Although each equipment component manufacturer has suggested specific sites for demonstration of their technology, obviously one test bed location would be selected to demonstrate all components. The test bed could be constructed and tested at any coastal site, probably in either Texas, Florida, or California–and ideally co-located with an existing treatment or powerplant. The total estimated project cost for all components is $4 million.

Low Cost, Small System, Desalination Using Evaporation

Description

Low-cost desalination using evaporation, termed dewvaporation uses heated and cooled air to evaporate water from saline feeds and to form pure condensate from dew at constant atmospheric pressure. This technology was successfully pilot tested using a nominal 1000 GPD facility and has proven to be a low cost, low maintenance desalination alternative for very small inland and coastal communities.

The dewvaporation unit is a tower of plastic heat transfer walls. Cool outside air (about 70 degrees Farenheit) is blown into the bottom of the tower. Saline water is fed through the top. Air is heated. As the air heats, it rises along the heat transfer walls and saline water evaporates. When the rising (and now very humid) air reaches about 190 degrees Farenheit, it is removed from the tower top and is heated further with steam or any waste heat. This hotter and more humid air is returned to the tower top on the opposite side of the heat transfer walls. The returned humid, warmer air cools. This cooling air forces the evaporated waters in it to condense (forming dew). This condensation releases heat. The heat then travels through the heat transfer walls and supplies the energy needed to repeat the process. The feed saline waters that do not evaporate leave the tower at the bottom as more concentrated brine. The very pure condensate exits the tower at the bottom along with the now cooler air stream.

Significant benefits

The exciting benefits of this technique include low capital ($2,000 for a 1,000 GPD plant) and operating costs ($3 per 1,000 gallons) for very small communities. Further it can be constructed with off-the-shelf materials and constructed and operated by non-technical labor. The energy efficient tower uses waste heat, solar heat, or easily made atmospheric steam and very little electricity (for a fan and some small pumps). Since the tower is made of inexpensive thin plastics, it is inexpensive to manufacture, maintain (corrosion does not occur), and operate.

Dewvaporation represents a new desalination technique that can reclaim brackish or seawater. It can desalinate waters other processes cannot, such as water with small particulates, computer chip manufacturing wastewaters, and waters with arsenic, MBTE, and other hazardous volatile organic compounds. The technology could treat concentrate flows from reverse osmosis desalination plants, thus gaining more water and reducing evaporation pond sizes.

Recommended activities

A 1,000 GPD mobile unit is recommended for a 2-½ year operating period. In addition, further research and studies to continue to optimize the process would be conducted. Any inland or coastal small community could benefit from demonstration of this technology. The total estimated project cost is $1 million. This technique began in the U.S., and reflects our support of technological innovations with world-wide applications.

To attract attention to this innovative technology and to test the applicability in a wider range of conditions, a mobile unit will operate on steam produced from natural gas combustion, waste oil combustion, and solar energy use. The design, procurement, and construction of the pre-manufactured main tower and mobile unit will require 1-½ years. The project will operate for three months at four sites to demonstrate the versatility of the dewvaporation technology at several locations and water sources. Options for demonstrating the desalination unit include treating:

- Well water in Phoenix, Arizona
- Seawater in Port Hueneme, California
- Colorado River water or irrigation drainage at Reclamation's Water Quality Improvement Center in Yuma, Arizona
- Water from computer chip makers in Albuquerque, New Mexico
- San Francisco Bay water for Alcatraz visitors in partnership with the National Park Service

Clathrate Desalination

Description and benefits

The clathrate desalination process adds one or more chemicals, called guest molecules, to salty water. The guest molecule forms crystal ice-like structure, called a clathrate, which excludes salt – enough that crystals form at temperatures warmer than ice, in some instances as warm as 53.1 degrees Farenheit. This system permits crystals to grow until they are large enough to be collected and processed to remove any salty water clinging to the crystals. Because the process works at low temperatures, and at relatively low pressures, the system saves energy and construction and operating costs.

As this process is relatively insensitive to the quality of the salty/brackish water being processed, this system offers desalination alternatives where reverse osmosis may not be well suited. Further, the process is particularly well adapted for cogeneration and permits water and power production from a cogeneration facility with very high efficiency. This combination allows the process to be applicable virtually worldwide, even to regions with relatively high water temperatures, such as the eastern Mediterranean Sea.

Significant results

Clathrate desalination offers the prospect of producing better quality water than the dominant competing system at lower cost. The current dominant technologies are mature, and improvements in cost and water quality tend to be marginal improvements. This technology is novel and can be significantly improved, yet it already appears to be cost competitive with other more mature technologies while producing superior quality water.

The project will demonstrate the capability to produce substantial quantities of high quality fresh water from seawater at an economical price. The demonstration plant operation and maintenance cost analysis will determine costs to operate and maintain production plants, and will permit assessments of detail changes in the design to improve operating economies. As the first-of-a-kind large-scale plant, it will provide the basis for determining the capital cost of production units as learning experiences lower costs in subsequent units manufactured.

Recommended activities

The recommended demonstration project would be to design, construct, and operate a facility for desalting seawater using clathrates. In addition, further research and studies would be conducted on identifying higher temperature clathrate forms. A modular design is recommended for the demonstration with a total capacity of 1.0 MGD. The individual modules will allow flexible operation and will incorporate materials and equipment that will allow facility operation for an extended period (20 years), rather than the demonstration period.

The design process will include a market survey to determine the appropriate plant size for the site, consistent with the current and 20-year demand forecast for household and irrigation water in the service locale that would be served.

The demonstration project would take 2 years: in the first year, the site would be selected and the plant would be designed; and in the second year, the plant would be constructed and operated. The operational testing phase will last 6 months. At the conclusion of the demonstration, the plant will be turned over to the local water utility or site owner for O&M. The total estimated project cost is $2.5 million. The demonstration plant costs are proportionately higher because the design effort required for the first unit is greater than the design effort for subsequent units.

The ideal candidate sites will have deep cold ocean water available close to shore. Possible sites include Hawaii, the coast of California, the East Coast, and several islands in the Pacific Trust Territory.

Attachment B: Desalination and Water Purification Research and Development Program Accomplishments

The DWPR program has:

- Improved existing technologies, e.g., reduced membrane fouling, improved pretreatment, increased energy recovery in high pressure pumps
- Developed new desalination processes, e.g., low cost evaporation, chlorine resistant membranes, membrane distillation
- Developed partnerships with industries, research organizations, municipalities, and more
- Increased desalination expertise in U.S. private, academic, and government sectors
- Reduced desalination costs
- Expanded economic development and competition in the U.S. and world markets

This has been accomplished through a merit reviewed, competitive cost-share process. Ten priority areas, developed with extensive input from several workshops with constituents interested in desalination from 1989 to 2001, provide the focus for the DWPR program:

- Membrane process research and development studies
- Thermal process research and development studies
- Nontraditional/alternative desalination process research and studies
- Water recycling and reuse
- Ancillary and economic improvements
- Concentrate issues
- Pilot-scale systems
- Partnerships
- Designing, constructing, and testing plants and modules
- Technology transfer

We continue to work with our constituents to define priorities and develop and follow roadmaps for the future. Attachment C lists some of our past cooperators by state.

Federal cost sharing stimulates additional investment by forming a broad coalition of private and public organizations. The resulting partnerships have addressed the water related issues associated with population increase, demographic shifts, reliability of supplies, public health and the environment, and regulatory requirements.

The cost shared funding incentive of federal demonstration stimulates additional investment by a broad coalition of private and public organizations. The resulting business operations will repay the cost of the federal contribution many times over, through the increased economic activity associated with desalination plant design, construction, and operation.

The program awarded thirty-five cooperative agreements, as well as grants and contracts, with various research partners from 1998 - 2001. Some significant findings are:

- *Successfully treated screened and degritted sewage with membrane bioreactors.*–This technology produces water suitable for advanced treatment with desalting processes and increases efficiency over conventional systems by providing a smaller footprint, higher quality sludge residuals, and a much higher quality product water. The treatment cost is competitive with conventional systems, with less impact on the environment due to reduced chemical usage.

- *Advanced membrane materials and technology.*–Several research projects into membrane fouling increased membrane life, reduced chemical cleanings, reduced environmental impacts, and lowered capital and O&M costs. In addition, a project jointly funded with the Army Tank Automotive Command and Research, Engineering and Development Center, made strong progress toward the "Holy Grail" of membrane research - a chlorine-resistant membrane.

- *Advanced water pretreatment in several membrane projects.*–One project used special submerged pipes in a beach to filter seawater, and another project did an excellent job of using bacteria to treat feedwater prior to membrane application. Both techniques have less impact on the environment than conventional technologies. Larger scale studies are needed to determine the extent of cost savings possible with these new technologies.

- *Developed an advanced high pressure seawater pump.*–This pump uses 35 percent less energy than pumps with conventional energy recovery. Since energy consumption for seawater reverse osmosis (RO) and the amortized capital cost associated with energy recovery equals about 50 percent of the total water production cost, this could result in a significant cost savings.

- *Developed an innovative, low-cost system based upon evaporation.*–This system was built with low-cost materials and could be built and operated by unskilled laborers. It uses low-grade heat to produce extremely high quality water with very little operator involvement. While the process is unlikely to be used in large cities, the capital and O&M costs are much lower than any other desalination system available for rural communities.

- *Sharing desalination technology.*–We share our results through case studies, workshops, conferences, newsletters, website <http://www.usbr.gov/water/desal.html> with full reports, reports distribution, a CD-ROM with all final program reports, handbooks, and a database of abstracts and reports on a CD-ROM.

- *Additional needs.*–Through various partnerships, Reclamation has identified future needs in desalting and water purification. These can be found in Report #56, *Growing the U.S. Water Supply through Purification Technologies Workshop;* Report #63, *AWWARF/U.S. Bureau of Reclamation Membrane Workshop* in partnership with the American Water Works Association Research Foundation; and Report #64, *Desalination Research & Development Workshop* in partnership with the National Water Research Institute.

In fiscal year 2001, four to five research and study agreements and one pilot-scale agreement will be awarded, subject to project approvals.

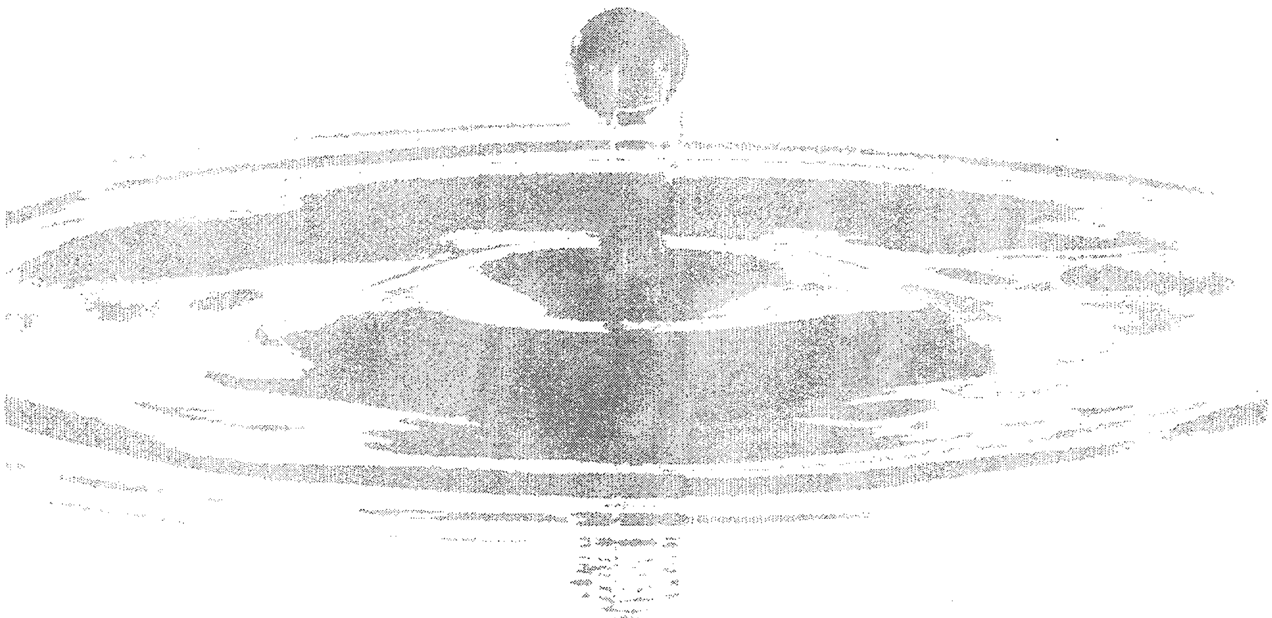
Attachment C. List of Cost Share Cooperators and Partners in the Desalination and Water Purification Research and Development Program

Federal		
	Army Center for Health Promotion & Preventative Medicine Army Corps of Engineers Army Tank-Automotive Command & Research, Engineering, & Development Center Department of State Centers for Disease Control	Environmental Protection Agency Los Alamos National Laboratory National Institute of Standards and Technology National Renewable Energy Laboratory National Science Foundation Naval Facilities Engineering Service Center Naval Surface Warfare Center
Local government		
AZ	Arizona Department of Environmental Quality Arizona Department of Water Resources Central Arizona Water Conservation District City of Marana City of Oro Valley City of Phoenix	City of Tucson Metropolitan Domestic Water Improvement District Navajo Nation Pima County Flood Control District Pima County Wastewater Management Tucson Regional Water Council
CA	California Energy Commission Central & Southwest Energy Services City of San Diego City of San Jose, South Bay Water Recycling Project	Metropolitan Water District of Southern California Orange County Water District San Diego County Water Authority San Diego Gas & Electric
FL	City of Jupiter South West Florida Water Management District	Tampa Bay Water
ID	Idaho National Engineering & Environmental Laboratory	
KS	City of Burrton	Kansas Corporation Commission
NC	Dare County Water	
NM	Pojoaque Pueblo Tribe	
NY	New York State Department of Health	
TX	City of McAllen City of Harlingen	City of Sherman Texas Water Development Board

Universities		
AZ	Arizona State University	
CA	San Diego State University	University of California at Los Angeles
CO	University of Colorado at Boulder	University of Denver
CT	Yale University	
DE	University of Delaware	
FL	University of Central Florida	
IL	Illinois Institute of Technology Southern Illinois University	University of Illinois at Urbana-Champaign
MT	Montana State University at Bozeman	
NC	University of North Carolina	
NJ	New Jersey Institute of Technology	
NM	New Mexico State University	
NY	Rensselaer Polytechnic Institute	
NV	University of Nevada at Reno	
TX	University of Houston	University of Texas at El Paso
UT	Utah State University	
Research organizations		
CA	Electric Power Research Institute National Water Research Institute	WateReuse Foundation
CO	American Water Works Association Research Foundation	National Science Founation Center for Membrane Applied Science and Technology
MT	NSF Center for Biofilm Engineering	
OH	North American Membrane Society	
VA	Water Environment Research Foundation	

Industrial associations		
CA	American Membrane Technology Association (formerly ADA)	WateReuse Association
CO	American Water Works Association	
MA	International Desalination Association	
OK	National Rural Water Association	
Private sector		
AZ	Carollo Engineers	CH2M Hill
CA	American States Water Co. Cal-West Machining Chevron Petroleum Technology Co. Clorox Co. Essef Corp. (CodeLine™) Flow Energy Engineering (Science Applications International Corporation) Fluid Systems Corp. General Atomics, Inc. Hydranautics Law Offices of Huali G. Chai	Montgomery Watson Pacific Research Group Performance Steam International Science Applications International Corp. Separation Consultants, Inc. Separation Systems Technology, Inc. SEPRO, Inc. Shore Western, Inc. Vari-Power Company Zemarc Corp.
CO	Aqua Resources International Phil Hernon, Consulting	Mickley and Associates Horizontal Well & Environmental Consultants
CT	Poseidon Resources Corp.	
DE	DuPont Biochemical Sciences & Engineering	Irving Moch and Associates
FL	AEPI/Ros-Tek, Inc.	S&W Water, LLC
GA	Ciba Vision	
IA	American Tool & Engineering Corp.	
IL	Nalco Chemical Co.	
KT	C. Lee Cook	
MA	Ionics Kendall Healthcare Products Co. Koch Membrane Systems, Inc.	Millipore Corp. W.L. Gore & Associates

MD	Jack C. Jorgensen, Water Resources Consultant	
MI	Dow Chemical Co.	
MN	3M Corporate Research FilmTec Corp.	Osmonics
MS	Mississippi Chemical Corp.	
MT	MSE Technology Applications, Inc.	
NJ	Allied Signal (now Honeywell)	Becton Dickinson
NY	Eastman Kodak Co. Keck Water Quality Laboratory	Rensselaer Polytechnic Institute
OH	Proctor & Gamble Co.	
PA	U.S. Filter Co. (Memtec America Corp.)	
TX	Aramco Services Co. Bruce Foods, Inc. Sulzer Carbomedics, Inc.	
VA	Albemarle Corp.	
WI	S.C. Johnson & Son	
International		
Canada	ZENON Municipal Systems	
France	Lyonnaise des Eaux North American Vivendi Water Co.	Recherche et Développement
Israel	Ben Gurion University of the Negev	Israeli Desalination Association
Japan	Mitsubishi Rayon Corp.	
Mexico	Instituto Tecnologico	
Netherlands	Akzo Nobel Central Research	Unilever Research
Sweden	SCARAB HVR	
UK	BP-Amoco Corp.	



Science and Technology Program

Vision statement:
To develop new information and technologies that respond to and anticipate mission-related needs and provide for innovative management, development, and protection of water and related resources and associated values.

For more information about
Reclamation's Desalination Program, contact:

Kevin Price, Manager
Water Treatment Engineering and Research
Technical Service Center, D-8230
P.O. Box 25007
Denver, CO 80215-0007

email: WaTER@do.usbr.gov

http://www.usbr.gov/water/water.html