WateReuse

Water Research Foundation
advancing the science of water

Desalination Concentrate Management Policy Analysis for the Arid West

WateReuse Research Foundation

Desalination Concentrate Management Policy Analysis for the Arid West

About the WateReuse Research Foundation

The mission of the WateReuse Research Foundation is to conduct and promote applied research on the reclamation, recycling, reuse, and desalination of water. The Foundation's research advances the science of water reuse and supports communities across the United States and abroad in their efforts to create new sources of high quality water for various uses through reclamation, recycling, reuse, and desalination while protecting public health and the environment.

The Foundation sponsors research on all aspects of water reuse, including emerging chemical contaminants, microbiological agents, treatment technologies, reduction of energy requirements, concentrate management and desalination, public perception and acceptance, economics, and marketing. The Foundation's research informs the public of the safety of reclaimed water and provides water professionals with the tools and knowledge to meet their commitment of providing a reliable, safe product for its intended use.

The Foundation's funding partners include the supporters of the California Direct Potable Reuse Initiative, Water Services Association of Australia, Pentair Foundation, and Bureau of Reclamation. Funding is also provided by the Foundation's Subscribers, water and wastewater agencies, and other interested organizations.

Desalination Concentrate Management Policy Analysis for the Arid West

Edmund G. Archuleta, Principal Investigator
Michael Fahy, Scott Reinert, Hector Gonzalez
El Paso Water Utilities

Robert S. Raucher, PhD, Janet Clements, Jeffrey Oxenford
Stratus Consulting Inc.

Michael Mickley
Mickley and Associates

William Dugat
Bickerstaff Heath, LLP

Malynda Cappelle, Thomas Davis
University of Texas El Paso, Center for Inland Desalination Systems

Anthony Tarquin
University of Texas El Paso, Civil Engineering Department

William Hargrove
University of Texas El Paso, Center for Environmental Resources Management

Ari Michelsen, Zhuping Sheng, Ron Lacewell
Texas A&M Agrilife Research Center at El Paso

Alexander Fernald
New Mexico State University, Water Resources Research Institute

Cosponsors
El Paso Water Utilities
Water Environment Research Foundation
Water Research Foundation
San Antonio Water System
Consortium for Hi-Technology Investigations in Water and Wastewater (CHIWAWA)
(Members of CHIWAWA include El Paso Water Utilities, Texas Water Development Board, New Mexico State University, Texas A&M Agrilife Research Center at El Paso, University of Texas at El Paso, and the City of Alamogordo, NM)

WateReuse Research Foundation
Alexandria, VA

Disclaimer

This report was sponsored by the WateReuse Research Foundation and cosponsored by the Water Research Foundation, Water Environment Research Foundation, El Paso Water Utilities, San Antonio Water System, and the Consortium for Hi-Technology Investigations in Water and Wastewater. The Foundation, its Board Members, and the project cosponsors assume no responsibility for the content of this publication or for the opinions or statements of facts expressed in the report. The mention of trade names of commercial products does not represent or imply the approval or endorsement of the WateReuse Research Foundation, its Board Members, or the cosponsors. This report is published solely for informational purposes.

For more information, contact:

WateReuse Research Foundation
1199 North Fairfax Street, Suite 410
Alexandria, VA 22314
703-548-0880
703-548-5085 (fax)
www.WateReuse.org/Foundation

WateReuse Research Foundation Project Number: WRRF-11-09
WateReuse Research Foundation Product Number: 11-09-1

ISBN: 978-1-941242-22-3

Contents

Figures

Tables

Abbreviations and Acronyms

AE	aquifer exemption
AMTA	American Membrane Technology Association
ARPA-E	Advanced Research Projects Agency—Energy
AWWA	American Water Works Association
BC	brine concentrator
BGNDRF	Brackish Groundwater National Desalination Research Facility
BLM	Bureau of Land Management
BPUB	Brownsville Public Utilities Board
BWRO	brackish water reverse osmosis
CDPHE	Colorado Department of Public Health and Environment
CHIWAWA	Consortium for Hi-Technology Investigations in Water and Wastewater
CIDS	Center for Inland Desalination Systems
CM	concentrate management
CO_2	carbon dioxide
CWA	Clean Water Act
desal	desalination
D–J Basin	Denver–Julesburg Basin
DWI	deep well injection
DWTR	drinking water treatment residual
EA	environmental assessment
ECCV	East Cherry Creek Valley Water and Sanitation District
EDR	electrodialysis reversal
EIS	environmental impact statement
EOR	enhanced oil recovery
EPA	U.S. Environmental Protection Agency
EPRI	Electric Power Research Institute
EPWU	El Paso Water Utilities
FDEP	Florida Department of Environmental Protection
FRP	fiberglass-reinforced plastic
GS	geologic sequestration
GWPC	Groundwater Protection Council
HDPE	high density polyethylene
HR	high recovery
IP	intellectual property
KBH	Kay Bailey Hutchison
MCL	maximum contaminant level
MF	microfiltration

MOA	Memorandum of Agreement
NF	nanofiltration
NGVD	National Geodetic Vertical Datum of 1929
NMAC	New Mexico Administrative Code
NMED	New Mexico Environment Department
NMOSE	New Mexico Office of the State Engineer
NOI	Notice of Intent
NPDES	National Pollutant Discharge Elimination System
NRC	National Resource Council
O&M	operations and maintenance
PE	professional engineer
RCRA	Resource Conservation and Recovery Act
Reclamation	U.S. Bureau of Reclamation
RFI	Request for Information
RO	reverse osmosis
ROD	Record of Decision
ROW	right of way
SAWS	San Antonio Water System
SDWA	Safe Drinking Water Act
SJRWMD	St. John’s River Water Management District
SRT	step rate test
SRWA	Southmost Regional Water Authority
SWRO	seawater reverse osmosis
TCEQ	Texas Commission on Environmental Quality
TDS	total dissolved solids
TLAP	Texas Land Application Permit
TMDL	total maximum daily load
TN	total nitrogen
TP	total phosphorus
TRRC	Texas Railroad Commission
TSS	total suspended solids
TWDB	Texas Water Development Board
UIC	underground injection control
USDW	underground source of drinking water
USGS	U.S. Geological Survey
UTEP	University of Texas at El Paso
VSEP	vibratory shear enhanced process
WaterRF	Water Research Foundation
WERF	Water Environment Research Foundation
WRF	water reclamation facility
WRRF	WateReuse Research Foundation

WWTP	wastewater treatment plant
ZDD	zero discharge desalination
ZLD	zero liquid discharge

Foreword

The WateReuse Research Foundation, a nonprofit corporation, sponsors research that advances the science of water reclamation, recycling, reuse, and desalination. The Foundation funds projects that meet the water reuse and desalination research needs of water and wastewater agencies and the public. The goal of the Foundation's research is to ensure that water reuse and desalination projects provide sustainable sources of high-quality water, protect public health, and improve the environment.

An Operating Plan guides the Foundation's research program. Under the plan, a research agenda of high-priority topics is maintained. The agenda is developed in cooperation with the water reuse and desalination communities including water professionals, academics, and Foundation subscribers. The Foundation's research focuses on a broad range of water reuse and desalination research topics including:

- Defining and addressing emerging contaminants, including chemicals and pathogens
- Determining effective and efficient treatment technologies to create 'fit for purpose' water
- Understanding public perceptions and increasing acceptance of water reuse
- Enhancing management practices related to direct and indirect potable reuse
- Managing concentrate resulting from desalination and potable reuse operations
- Demonstrating the feasibility and safety of direct potable reuse

The Operating Plan outlines the role of the Foundation's Research Advisory Committee (RAC), Project Advisory Committees (PACs), and Foundation staff. The RAC sets priorities, recommends projects for funding, and provides advice and recommendations on the Foundation's research agenda and other related efforts. PACs are convened for each project to provide technical review and oversight. The Foundation's RAC and PACs consist of experts in their fields and provide the Foundation with an independent review, which ensures the credibility of the Foundation's research results. The Foundation's Project Managers facilitate the efforts of the RAC and PACs and provide overall management of projects.

This project explores key barriers (and potential solutions) associated with concentrate management (CM) for community water systems considering inland desalination (desal) as a source of municipal water supply. Specifically, this research focuses on CM options available in the arid Southwest region of the United States, where the need for desalination is increasing because of increased water scarcity. Potential policy solutions that protect both public health and the environment while enabling broader development of brackish water desal in the United States are identified. This research included the development of a series of issue papers documenting barriers to implementation for various CM options (largely based on the expertise of the research team), extensive case studies of utilities and municipalities that have implemented alternative CM options, and an expert workshop that helped to further explore potential policy solutions.

Douglas Owen
Chair
WateReuse Research Foundation

Melissa Meeker
Executive Director
WateReuse Research Foundation

Acknowledgments

This project was funded by the WateReuse Research Foundation (WRRF) in cooperation with the Water Research Foundation, El Paso Water Utilities (EPWU), San Antonio Water System, the Water Environment Research Foundation, New Mexico State University (NMSU), Texas A&M Agrilife Research Center at El Paso (TX-Agrilife), and the University of Texas at El Paso (UTEP). In-kind labor and other support were also provided by EPWU, NMSU, UTEP, TX-Agrilife, and others.

The project team thanks the PAC, the WRRF Project Manager (Deana Bollaci), and all the workshop participants.

Principal Investigator

Edmund G. Archuleta
El Paso Water Utilities

Project Team

Michael Fahy
Scott Reinert
Hector Gonzalez
El Paso Water Utilities

Robert S. Raucher, PhD
Janet Clements
Jeffrey Oxenford
Stratus Consulting Inc.

Michael Mickley
Mickley and Associates

William Dugat
Bickerstaff Heath, LLP

Malynda Cappelle
Thomas Davis
University of Texas El Paso, Center for Inland Desalination Systems

Anthony Tarquin
University of Texas El Paso, Civil Engineering Department

William Hargrove
University of Texas El Paso, Center for Environmental Resources Management

Ari Michelsen, Zhuping Sheng, Ron Lacewell
Texas A&M Agrilife Research Center at El Paso

Alexander Fernald
New Mexico State University, Water Resources Research Institute

Project Advisory Committee

Jeffrey Moeller, *Water Environment Research Foundation*
Jennifer Warner, *Water Research Foundation*
Jonathan Gledhill, *Policy Navigation Group*
Sean Lieske, *City of Aurora*
Andrew Shea, *HDR Engineering*

Executive Summary

This document provides an overview and summary of key findings from the WateReuse Research Foundation (WRRF) project Desalination Concentrate Management Policy Analysis for the Arid West. This research was led by El Paso Water Utilities (EPWU) in coordination with Stratus Consulting, Mickley and Associates, Bickerstaff Heath LLP, the University of Texas at El Paso (UTEP), Texas A&M Agrilife Research, New Mexico State University, and other members of Consortium for Hi-Technology Investigations in Water and Wastewater.

The objectives of this research include the following:

- Identify key concentrate management (CM) barriers for community water systems considering inland desalination (desal) as a source of municipal water supply, with a focus on CM options available in the arid Southwest region of the United States.
- Recommend potential policy solutions that protect both public health and the environment while enabling broader development of brackish water desal in the United States, particularly in the arid Southwest.

To meet these objectives, the research team developed a series of issue papers documenting barriers to implementation for various CM options (largely based on the expertise of the research team), conducted extensive case studies of utilities and municipalities that have implemented alternative CM options, and held an expert workshop to identify potential policy solutions.

The following sections provide an overview of the CM options available for use in the arid Southwest region of the United States, including the barriers associated with each. Key findings from the case studies and the expert workshop are also presented.

Background

Brackish water desal is becoming increasingly important in many regions of the United States because traditional freshwater supply options are highly limited and, in many instances, have already been tapped at or beyond their sustainable capacity. Inland desalting offers a viable and climate-insensitive supply option in many areas in need of additional water, especially in the arid Southwest region of the United States.

The level of municipal inland desal has increased appreciably in the United States since 1990 because of improvements in membrane technology and the increasing need for new water supplies. There has been a notable increase in the number and typical size of desal facilities.

Despite the potential benefits of desal, a suite of issues—both technical and institutional—create uncertainties, delays, cost escalations, and other complexities that have inhibited brackish water desal implementation. The key barriers to inland desalting for community water systems are (1) the overall cost (compared to traditional water supply options drawn from freshwater), (2) relatively high energy demands, and (3) limited options for managing the brine concentrates that are the treatment residual of the membrane process.

The relative cost and energy demands associated with inland desalting are becoming less of a barrier as lower-cost traditional water supply options are often unavailable to meet additional needs and the energy efficiency of membrane processes has improved considerably. CM remains the largest impediment to the greater use of inland brackish water desalting in the United States, largely as a result of regulatory barriers and the associated costs and permitting uncertainties.

Overview of CM Options and Barriers

Several options for CM have been applied in the United States; however, the most straightforward and economically viable CM options (i.e., discharge to surface waters, discharge to wastewater treatment plants [WWTPs], and land application) are not feasible in many inland locations, such as the arid Southwest. They are also infeasible for inland desal facilities of any appreciable size.

Discharge to surface waters or sanitary sewers and WWTPs is only viable where there is sufficient instream freshwater flow to facilitate compliance with applicable receiving surface water quality standards and associated National Pollutant Discharge Elimination System permits. Only extremely small desal facilities (i.e., serving less than 40 households) or those in locations with large freshwater receiving stream flows or in near proximity to the ocean can use these CM options. Land application is typically infeasible given the elevated concentrations of salts found in desal residuals.

Given these limitations, in the arid Southwest and many other areas (including Florida) the only viable CM options are (1) deep well injection (DWI), (2) evaporation ponds, and (3) high recovery (HR) processes. HR processes are not disposal options per se but instead reduce the volume (which increases the concentration) of the residuals.

There are numerous barriers to using the three viable CM options available in the arid Southwest, including costs, land area requirements, regulations, and many other factors. Foremost amongst these barriers—especially for DWI—are regulatory requirements and their associated costs and uncertainties.

Despite the challenges associated with implementation, DWI holds the most promise for increased implementation. DWI is suitable for large-volume flow and requires very little land. Data indicate an increasing focus and reliance on DWI over time as desal facilities get larger. Thus, DWI is an important area on which to focus the search for solutions to the CM challenge.

The following sections provide additional detail on the three viable CM options available in the Southwest United States, including DWI, evaporation ponds, and HR processing.

Overview of DWI and the Underground Injection Control Program

DWI is regulated under the federal Underground Injection Control (UIC) Program, established under the federal Safe Drinking Water Act (SDWA). Currently, there are six classes defined under the UIC Program, and desal concentrates and other drinking water treatment residuals (DWTRs) are officially placed under Class I. Class I includes hazardous and nonhazardous industrial wastes and municipal waste. Its requirements are stringent because of the hazardous nature of some wastes in this category, and there are relatively few (<600) Class I wells permitted across the United States.

Under suitable circumstances, desal concentrates also may be discharged under enhanced recovery operations at oil and gas wells, which are regulated under Class II of the UIC Program. In some cases, desal concentrate may also be managed under Class V (a miscellaneous category covering a range of nonhazardous substances, including household septic wastes). These alternatives are not generally viable for municipal water utilities using desal, although the EPWU's groundwater desal facility operates under a Class V permit that includes operational conditions, but its discharge wells are built to the more stringent Class I standards.

A key feature of the UIC Program is the definition of an underground source of drinking water (USDW), which is intended to indicate groundwaters that currently—or might conceivably in the future—serve as a source of drinking water. USDWs are currently defined as any groundwater with total dissolved solid (TDS) levels of 10,000 mg/L or less. Injection above or into an USDW is prohibited under Class I, and most other classes in the UIC Program, regardless of (1) the overall quality of the groundwater found in the USDW zone (i.e., concentration of contaminants/constituents other than TDS), (2) the likelihood (or lack thereof) of there being a future need to use the aquifer as a drinking water supply, or (3) the ability to effectively remove relevant injectate constituents from the receiving groundwater if the aquifer needs to be tapped for drinking water purposes in the future.

An Aquifer Exemption (AE) is required from state primacy agencies and the U.S. Environmental Protection Agency (EPA) for discharging into or above an USDW any concentrate that exceeds a primary drinking water standard (i.e., a maximum contaminant level [MCL]). This issue applies to El Paso's operations under Class V (for the arsenic MCL). This also applies throughout Arizona, where all Class I wells are precluded by the state's designation of all of its groundwater as USDWs.

Recently, Class VI was added to the UIC Program for geologic sequestration of carbon dioxide as part of a national strategy to reduce greenhouse gas emissions. The creation of a new class under the UIC Program was difficult and took many years, despite high level backing by two federal administrations and private energy firms. Nonetheless, the Class VI precedent suggests the possibility (albeit remote) of creating a new Class VII for municipal desalting concentrates. Creating a new Class VII specifically for a residuals stream that is already specifically included under Class I might be very difficult, however, especially given the very limited resources available to EPA and its UIC Program.

DWI: Barriers and Potential Solutions

In the arid Southwest, DWI often is the only viable approach to CM for public water supply desal on any community-size scale; however, there is a wide range of barriers to DWI, including regulatory, hydrogeologic, economic, and numerous other factors. Regulatory and related permitting issues often are the most significant obstacles. General regulatory barriers and those associated with a specific well class are presented in Table ES.1.

Table ES.1. Regulatory Barriers Affecting Implementation of DWI for Inland Desal CM

Barrier	General Explanation of Category
General	factors that limit permitting process efficiency, create uncertainties and delays, and inhibit possibilities for change
Multiple agencies involved	
Lack of UIC Program funding	
Limited experience in some states	
Different mentalities for Class I and II regulations	
Resistance to making changes	
Regulations not specific for desal concentrate	
Specific Well Class	factors limiting use of individual well classes, increasing costs, resource loss, and availability of DWI as a viable CM option
Definition of USDW (Class I)	
Non-use (or prohibition) of Class I in some states	
Primary standards requirement for Class V (linked to USDW definition)	
Only Class II option is enhanced oil recovery	

Notes: CM=concentrate monitoring; DWI=deep well injection; UIC=underground injection control; USDW=underground source of drinking water

Reports developed in 2006 and 2007 by the Groundwater Protection Council (GWPC) and the federal UIC National Technical Workgroup—organizations that represent UIC regulators and regulatory agencies—express a clear recognition that

- Some UIC regulations are unnecessarily burdensome and have no environmental benefits and, as a result, place impediments on beneficial new technologies that provide new sources of safe water supplies (e.g., desal and associated concentrate disposal; GWPC, 2007b).
- "Existing regulations contain unnecessary administrative, construction, operation, and monitoring requirements" because they do not address the specific nature of desal concentrates or similar DWTRs. Recommendations are offered to allow for greater "flexibility and additional cost-saving opportunities" (U.S. EPA, 2006, p. 3).

The Texas Water Development Board met with EPA to explore changes in Class II regulations to broaden the ability to use oil and gas wells for concentrate disposal. EPA instead suggested that Texas develop a General Permit for desal concentrate under Class I. Texas has since developed and issued a General Permit under Class I, and initial use of this approach by the San Antonio Water System (SAWS) suggests that the General Permit approach may effectively streamline the permitting process. This suggests a promising route for other states to explore and perhaps for the federal EPA as well (i.e., to apply in states where EPA retains Class I primacy).

Future efforts to address UIC-related regulatory hurdles to CM need to address both the procedural and technical requirements associated with the permit process (the Texas General Permit accomplishes both). Future efforts also should recognize that desal concentrate is very different from industrial wastes in that it is not significantly impacted by process-added chemicals and, given that it instead reflects the characteristics of the source waters, the composition of desal concentrate is often very site-specific.

Evaporation Ponds

Evaporation ponds are a relatively low technology, low cost, and easy to permit CM option for desal facilities that are very small (i.e., very low discharge volumes) and located in arid areas (i.e., high evaporation rates) with relatively flat terrain and inexpensive land costs.

Costs for evaporation ponds can escalate quickly as the size of the facility and volume of concentrate magnify land area requirements. Costs and regulatory requirements also increase in areas with high quality groundwater beneath the site as dual liner, monitoring, and related regulatory requirements become more likely, and those prone to large precipitation events, which increase the likelihood of flooding and overtopping.

In addition, solids and near solids from evaporation ponds may contain constituents at concentrations that render them hazardous (and in some cases radioactive), which would require them to be removed and transported to suitable landfills or other waste management facilities. This can significantly increase costs and regulatory issues. In some locations, netting and other management practices are also required to minimize potential impacts to wildlife.

Evaporation ponds are not likely to be a viable CM option for community water system desal facilities that are of any appreciable size (i.e., greater than 1 mgd). Researchers are investigating approaches to enhance net evaporation through methods such as spraying concentrate water into the air and evaporating water from porous vertical surfaces. These methods will likely significantly reduce evaporation pond area requirements, potentially increasing the feasibility of evaporation ponds for larger facilities.

High Recovery Processing

Although HR approaches are not a CM option per se, they do impact the volume and characteristics of the concentrate and thereby impact the costs and viability of CM options. The benefits of HR processing include more efficient use of the water resource (i.e., to increase usable water yields). In addition, HR processes allow for increased product water where increased facility capacity is not viable.

Although reducing the volume of concentrate can be useful, the increased concentration of constituents extracted from the source waters may create additional challenges for managing the concentrate. For example, processing all the way to solids requiring disposal brings a new disposal option to municipal desal facilities—that of landfilling solids. Landfill costs can be high for disposal of solids or near solids, including costs for hauling, possible solidification, and final disposal. In some cases (likely limited), highly concentrated brines or mixed solids can be hazardous, which can significantly increase disposal costs.

HR processes can increase disposal costs and technical challenges associated with conventional disposal options. For example, higher salinity brine may result in higher precipitation potential within the well and injection aquifer for DWI. For evaporation ponds, the higher salinity leads to lower evaporation rates and reduced time until the pond fills with solids. This in turn leads to increased costs associated with pond clean-out or construction of new ponds.

The bulk of the research has demonstrated that HR processing is technically feasible, but it remains costly in all its present forms. The high capital costs result from the additional processing equipment required. The high energy costs are associated with the use of thermal evaporative equipment. These energy costs can be lessened by membrane volume reduction steps, but these in turn impose high chemical costs and increase the amount of solids requiring costly disposal. As a result, HR processing used in many other industries is not usually cost-effective within the municipal water supply setting at the present time.

Overview of CM Case Studies

The project team developed a series of water utility case studies to gain a greater understanding of the options and challenges faced by water suppliers in developing inland desal operations. The case studies are focused on challenges associated with CM in inland settings for the following utilities:

- EPWU
- SAWS
- Alamogordo, NM
- East Cherry Creek Valley Water and Sanitation District
- Vero Beach, FL

Each case study details the CM options considered and selected by the utility, the basis for the selected CM approach, and the associated cost and permitting issues.

All of the case study entities found that discharge to surface water or sewer was not a sustainable option for CM because of the relatively large volume of concentrate they would be producing. Discharge to surface water or sewer is generally only feasible for desal facilities operating at a very small scale (e.g., 0.03 mgd, which is roughly enough water for less than 40 households).

Although evaporation ponds were found to be a technically feasible alternative for CM in some locations, the combination of sizing, associated land requirements, and other expenses (including double lining) made this option economically prohibitive for the case study entities that considered it.

Ultimately, all of the case study entities implemented or plan to implement DWI as their primary means of concentrate disposal. Alamogordo plans to implement evaporation ponds at its desal facility in order to manage concentrate from initial small-scale operations. The city will likely switch to DWI as production at its desal facility ramps up to 2.9 mgd.

Although the case study entities found DWI to be the most viable option for CM, UIC permit requirements created significant challenges in terms of time and expense required to obtain full approvals, uncertainty about whether permits will be issued, and challenges associated with operating under permit conditions. The new General Permit provision in Texas under Class I of the UIC Program may serve as a model for a more streamlined approach to DWI permitting.

Key Workshop Findings: Potential Policy Solutions

The research team conducted a 2-day interactive workshop to identify solutions and practical paths forward for addressing the challenges of CM for inland municipal water desalting. The workshop included more than 50 representatives from water utilities, state and federal regulatory and water management agencies, research organizations, technical consultants, and research universities. The workshop was held at the EPWU TecH_2O Center learning facility in El Paso.

The workshop relied extensively on breakout group brainstorming and deliberations. The first set of breakout group activities focused on describing the barriers to CM from inland water utility desalting, with each of the five groups examining different aspects and CM options. In the second set of breakout sessions, these same breakout groups explored possible solutions to help address key barriers identified in the previous session. The solution options developed by each group were presented and discussed in a plenary, and then attendees voted to select the top priority solution options across all groups.

The top priority solutions were the following:

1. Address challenges under Class V of the UIC Program by defining a new subcategory specifically for desal CM wells. This would include improving how USDWs are defined under this subcategory by using approaches such as examining and expanding how the key term “endangerment” is defined so that it can include a treatability component. This suggested solution was the top vote-getter from workgroup participants. Part of this proposed solution pathway includes recharacterizing concentrate as a resource (rather than as a waste) in conjunction with the inclusion of a treatability criterion.
2. Develop a compilation and guidance of best practices and permitting processes to help utilities and state and federal regulators develop better capacity and approaches to issuing and operating under Class I permits. This solution ranked as the second highest solution option among workshop participants. The guidance and associated tool kit should include components that support collection and dissemination of suitable hydrogeologic features and address public perceptions and concerns.
3. Develop a general permit under Class I using the Texas model for other states with primacy and federal programs (EPA regions) where states do not have UIC Class I primacy. This solution ranked as the third highest solution option. Some key features of the general permit are its ability to streamline the process by its use of specific public notification requirements while precluding a protracted public hearing process and enabling sign off by registered professional engineers (PEs) rather than requiring a state regulator to sign off.
4. Provide primacy to the states for the AE process. This option received the fourth highest vote. This would avoid a second-level review by EPA headquarters after a state review had already been completed. A federal review might be limited to administrative procedures only and not include technical matters.
5. Develop a competition for technological advances to enable beneficial use and higher recovery and facilitate CM. This option ranked fifth overall. This approach might include one competition for conceptual design (to stimulate more creative ideas and include entrants with limited resources) and a second competition for successful pilot demonstration.

On the second day of the workshop, the top five priority solutions were further discussed in the plenary. The breakout groups then convened to develop a practical path forward to describe how to help implement the top solution item developed by their group. The five highest ranked solution options and associated suggested pathways forward are summarized in Tables ES.2 and ES.3.

In addition to the key themes and solutions described above, several useful insights were developed and articulated. Some of these key workshop findings and insights include (not necessarily in order of priority):

- Under the UIC Program, it would be valuable to develop a category for water utility desalting concentrate that separates it from the industrial category under Class I. This is justifiable because of the unique nature of desal concentrate as contrasted to industrial and other wastes and the special needs and circumstances faced by inland water suppliers. The desal concentrate category could be in Class I, or Class V, or a new Class VII. The ability to separate desal concentrate from other waste streams would help with public perception and facilitate more suitable regulatory and permitting requirements without creating concern among regulators about setting precedents for other wastes and residual-generating activities (e.g., mining).
- The challenges faced by utilities with CM extend beyond inland desalting. Similar challenges arise wherever water or wastewater utilities rely on membrane processes (e.g., to produce recycled water or for source water treatment to meet regulatory standards for potable water) or need to inject water into groundwater systems (e.g., for aquifer storage and retrieval). Approaches that facilitate permitting for desal CM will also help facilitate these other practices and would be beneficial for salt management practices in general.
- Solutions to the CM challenge need to be considered across two timeframes. Many of the more meaningful opportunities require a long-term perspective; changes to federal statutes (e.g., SDWA) or regulations (e.g., under the UIC Program) typically take at least 5 years and often require several additional years to move into implementation (e.g., state primacy and associated permit requirements). Therefore, some short-term solutions are also required to address more immediate needs. The use of UIC Class V permits, coupled with AEs, is one such short-term approach; however, even this strategy is likely to be time- and resource-consuming and may not be suitable in many locations.
- Many site-specific hydrogeologic features and other factors mean there is rarely a one size fits all solution to facilitating desal CM.
- There is a lack of necessary hydrogeologic information about the subsurface environment and groundwater resources. This impacts inland desalting in two ways. First, there is a need for better characterization of brackish groundwater resources to indicate where there are available opportunities to tap saline groundwater as a source of potable supply. Second, there is a need to better understand potential storage or disposal sites for DWI of concentrate. A more systematic characterization of saline groundwater resources—such as by the U.S. Geological Survey (USGS) or its state counterparts—would facilitate desal implementation and CM.

Table ES.2. Top Five Ranked Solutions for Addressing Barriers to CM

Proposed Solution	Key Components	Barriers Addressed	Potential Partners
Create new subcategory under UIC Class V for desal CM wells.	Permitting process would include a treatability component that would evaluate the impact of the concentrate on the costs of future treatment if the groundwater was ever withdrawn for potable use. Establish construction and operation standards for municipal desal concentrate wells.	Limited experience or prohibition of Class I in some states Primary drinking water standards requirement for Class V injectate Current regulations do not allow for site-specific nature of concentrate, treatment potential, or local water resource needs. Current regulations are not specific to desal concentrate.	Utilities, primacy states, GWPC, AWWA, WRRF, National Groundwater Association, National Rural Water Association GWPC would likely provide the strongest influence in moving this effort forward.
Develop toolkit of best practices and permitting processes to support regulatory agencies, water utilities, stakeholders, and policymakers.	Regulatory best practices Technical information and guidance for design and construction Application guides for utilities Information for policymakers and the general public	Lack of coordination among permitting and other regulatory agencies Limited experience in some states with Class I wells High costs and uncertainty associated with permitting Public perception issues Resistance to change at regulatory level	Major research organizations (GWPC should be a major participant) Content needs to be reviewed or ratified by EPA's UIC Program, National Research Council, or representatives of state organizations. Applicable state agencies

Proposed Solution	Key Components	Barriers Addressed	Potential Partners
Develop General Class I Permit.	Implemented at state level for states with Class I well primacy and at federal level for non-primacy states Modeled after Texas General Permit Ability to streamline process through use of specific public notification requirements, more reliance on registered PEs rather than state regulators, change in requirements to reflect nature of desal concentrate, and less frequent mechanical integrity tests and permit review	High costs, long timelines, and uncertainty associated with permitting Current regulations are not specific to desal concentrate. Limited experience with Class I in some states (general permit would facilitate permitting process in these states)	Utility representatives, regulatory agency representatives, environmental groups Advocacy groups: GWPC, AWWA, Water Environment Federation, Association of State Drinking Water Administrators, Association of Clean Water Administrators
Provide primacy to states for the AE process.	This would avoid a second-level AE review by EPA headquarters after a state review has already been completed; alternatively, a federal review might be limited to administrative procedures only and not include technical matters.	High costs, long timelines, and uncertainty associated with permitting	State agencies with UIC primacy EPA Research foundations/others to coordinate effort
Hold competition for developing technological advances to enable beneficial use and higher recovery and facilitate CM.	Salt Prize for best technology innovation way to reduce the cost of desal by identifying innovative, low cost CM strategies that are environmentally sound Two-round process: Round 1: Design contest with smaller award. Goal is to provide seed money for the next phase of demonstration. Round 2: Demonstrations occur to prove concepts chosen from Round 1. Winners would receive a substantially larger award.	Lack of cost-effective HR and beneficial reuse options available for municipal desal CM high costs associated with CM	AMTA, AWWA, WRRF, WERF, WaterRF, EPRI, Bureau of Reclamation, National Science Foundation, EPA, ARPA-E, the military, Multistate Salinity Coalition, applicable state and local agencies, vendors, engineering firms, industry users

Notes: AE=aquifer exemption; AMTA=American Membrane Technology Association; ARPA-E=Advanced Research Projects Agency—Energy; AWWA=American Water Works Association; CM=concentrate management; EPA=U.S. Environmental Protection Agency; EPRI=Electric Power Research Institute; GWPC=Groundwater Protection Council; HR=high recovery; PE=professional engineer; UIC=underground injection control; WaterRF=Water Research Foundation; WERF=Water Environment Research Foundation; WRRF=WateReuse Research Foundation

Table ES.3. Proposed Path Forward for Top Five Ranked Solutions for Addressing Barriers to CM

Proposed Solution	Short-term Actions	Long-term Actions
Create new subcategory under UIC Class V for desal CM wells.	Develop case studies to demonstrate treatability analysis. Assess number of utilities that would benefit from development of new subcategory. Conduct benefit–cost analysis for new rule. Identify/evaluate unintended consequences. Conduct public outreach and education efforts.	Lobby EPA to return to the 2002 determination that Class V needs to include a subclass for concentrate and drinking water residual. Pressure states to develop minimum protective standards for concentrate disposal. Encourage states to support the regulatory modification and be no more stringent than the federal rule.
Develop toolkit of best practices and permitting processes to support regulatory agencies, water utilities, stakeholders, and policymakers.	Perform literature review of existing state programs. Identify and synthesize permit components. Address challenges with permits. Document site-specific challenges. Identify innovative regulatory approaches. Prepare a permit template example. Develop a process for review or ratification by states or EPA.	Expand the toolkit to support utilities and the general public. Conduct advocacy work at the state and local levels to promote the use and acceptance of suitable DWI. Conduct pilot study by assisting the implementation of a Class I DWI well in one state.
Develop General Class I Permit.	Convince regulatory groups of the need and benefit of a general permit. Develop guidance document for state and federal implementation based on review of current permitting processes, best practices, and potential legal barriers. Define key participants, advocacy groups, and stakeholders. Develop white paper on potential benefits of general permit for other regions/states. Develop position paper detailing pros and cons. Develop strategy for interacting effectively with state and federal regulatory groups.	NA

Proposed Solution	Short-term Actions	Long-term Actions
Provide primacy to states for the AE process.	Build coalition to measure interest, garner support, and proceed with petitioning EPA for a rule amendment. Develop case studies to illustrate cost and time involved in obtaining AEs and where improvements can be made. Prepare public information flyer explaining AE process inefficiencies. Identify proponents and opponents. Approach state agencies with UIC primacy to get initial buy-in.	Work with state agencies to determine the timing and approach for EPA and relevant state and federal committees. If support is obtained with UIC-delegated states, the EPA rulemaking should proceed; this is a multiyear process requiring meetings with EPA and stakeholders, public notice, and comment.
Hold competition for developing technological advances to enable beneficial use and higher recovery and facilitate CM.	Identify funding and advertise program. Implement Rounds 1 and 2. Final award presentation to be made at a national conference, involving keynote presentation.	NA

Notes: AE=aquifer exemption; CM=concentrate management; DWI=deep well injection; EPA=U.S. Environmental Protection Agency; NA=not applicable; UIC=underground injection control

- Many of the permitting challenges associated with desal CM reflect a lack of regulatory capacity at the relevant state and federal agencies. Capacity building is needed to address the limited resources available at these agencies (e.g., increase available staff and supporting budgets) given the competing authorities and priorities facing these organizations.
- To facilitate the possible use of evaporation ponds in arid regions such as the southwestern United States, it may be suitable to establish arid area exemptions from the double-liner requirements.
- It was noted by several breakout groups that a broad coalition of interested stakeholders would be necessary to effectively work toward the proposed solutions. Depending on the initiative, potential partners include interested water utilities (potentially brought together through coordinated efforts by utility foundations such as the American Water Works Association [AWWA] and the WateReuse Association), WRRF, Water Research Foundation, GWPC, National Groundwater Association, Rural Water Association, National Science Foundation, and state and federal regulatory agencies. Coordinating efforts with existing desal research groups (e.g., UTEP Desalination Research Center, New Mexico State University, U.S. Bureau of Reclamation) will also be important.

Recommendations for Next Steps

As noted in the previous section, there are numerous constructive activities that could be pursued to address the challenge of CM for inland municipal water suppliers. The challenge will be to organize the relevant groups and stakeholders so that a concerted, well-coordinated set of next steps can be agreed upon and implemented effectively.

One possible option to help orchestrate a coordinated and broadly participatory movement in that direction would be to host a workshop with key stakeholders, including regulatory agencies or associations (e.g., EPA, Association of Clean Water Administrators, Association of State Drinking Water Administrators), water sector professional associations (e.g., AWWA, National Association of Clean Water Agencies, WateReuse Association, Water Environment Federation, Association of Metropolitan Water Agencies), water-oriented research organizations (e.g., WERF, WaterRF, WRRF), and utilities.

In such a workshop setting (or possibly absent a workshop), the participants could develop key talking points to support the various solution pathways and the associated next steps toward implementation. The solution elements can be drawn from the recommendations and observations noted previously. Key focal points would likely include articulating the need for and value of the following:

- Inland brackish water desalting as a way to effectively tap into an underutilized resource to help address critical water supply limitations in the arid Southwest and many other parts of the United States
- A new classification under the UIC Program for drinking water treatment and desal residuals
- Key talking points to support the need for states or EPA to create the possibility of a general permit for desal facilities and possibly other inland uses of membrane technologies when utilizing DWI as a disposal option

- A more systematic characterization of saline groundwater resources—such as by the USGS or its state counterparts—to facilitate desal implementation and CM
- Separating desal concentrate from other waste streams in the UIC regulatory scheme to help with public perception and facilitate more suitable regulatory and permitting requirements without creating concern among regulators about setting precedents for other wastes and residual-generating activities (e.g., mining)
- Near-term solutions (i.e., to help with ongoing challenges) as well as longer-term, more meaningful changes to the statutory and regulatory approaches to inland desal CM.

Chapter 1

Introduction

This document presents the findings from WateReuse Research Foundation (WRRF) project Desalination Concentrate Management Policy Analysis for the Arid West. This research was led by El Paso Water Utilities (EPWU) in coordination with Stratus Consulting, Mickley and Associates, Bickerstaff Heath LLP, the University of Texas at El Paso (UTEP), and members of the Consortium for Hi-Technology Investigations in Water and Wastewater (CHIWAWA).

1.1 Background

Brackish water desalination (desal) is becoming increasingly important in many regions of the United States because traditional freshwater supply options are highly limited and in many instances have already been tapped at or beyond their sustainable capacity. Inland desalting offers a viable and reliable (e.g., climate-insensitive) supply option in many areas in need of additional water, especially in the arid Southwest region of the United States.

Brackish water resources are an important future source of water supply. Developing these resources in inland areas requires advanced water treatment and concentrate management (CM), the disposition of the salts that are taken out of the brackish water. Brackish water desal is increasingly being utilized in the United States because of its potential advantages, especially in inland regions where mid-sized and larger-scale applications would be suitable for water supply utilities. There has been a notable increase in the number and average size of desal facilities.

Despite the potential benefits of desal, a suite of issues—both technical and institutional—create uncertainties, delays, cost escalations, and other complexities that have inhibited brackish water desal implementation. The key barriers to inland desalting are (1) the overall cost compared to traditional water supply options drawn from freshwater, (2) relatively high energy demands, and (3) limited options for managing the brine concentrates that are the treatment residual of the membrane process.

The relative cost and energy demands associated with inland desalting are becoming less of a barrier as lower-cost traditional water supply options are often unavailable to meet additional needs and the energy efficiency of membrane processes has improved considerably. CM remains the largest impediment to the use of inland brackish water desalting in the United States, largely because of regulatory barriers and the associated costs and permitting uncertainties.

1.2 Objectives

To further explore the regulatory and policy barriers associated with inland desal CM, EPWU—in coordination with CHIWAWA, Stratus Consulting, Mike Mickley, Bill Dugat, and other researchers—developed a tailored collaborative research effort funded in part by the WRRF, the Water Environment Research Foundation (WERF), and WaterRF. The objectives of this research include the following:

- Identify key CM barriers for community water systems considering inland desal as a source of municipal water supply, with a focus on CM options available in the arid Southwest region of the United States.

- Recommend potential policy solutions that protect both public health and the environment while enabling broader development of brackish water desal in the United States, particularly in the arid Southwest.

This research generally focuses on the use of deep well injection (DWI) as the primary method for inland desal CM, as it has been identified through the course of this research as the CM option that has the most promise for increased implementation. DWI is suitable for large-volume flow and requires very little land area. Data indicate an increasing focus and reliance on DWI over time and as desal facilities get larger; therefore, it is an important area on which to focus the search for solutions to the CM challenge.

1.3 General Approach

To meet these objectives, the research team developed a series of issue papers documenting barriers to implementation for various CM options (largely based on the expertise of the research team), conducted extensive case studies of utilities and municipalities that have implemented alternative CM options, and held an expert workshop to identify potential policy solutions. Our general approach is summarized below.

- A multidisciplinary approach was used to review and analyze regulatory and policy barriers to CM involving several sources of technical, legal, economic, and policy expertise. Policies and regulations currently in effect were examined for several western states as well as Florida (i.e., inland states and coastal states with access to major brackish aquifers). Findings from these efforts were developed into a series of white papers highlighting key issues. These white papers have been incorporated into this report as Chapters 2 through 8.
- Case studies of desal facilities and CM practices in the United States were conducted to identify policies and regulations that inhibit or facilitate the development and use of brackish water desal in practice. Information from various U.S. utilities with regard to permitting processes was compiled and investigated to compare environmental issues, consistency, relative/approximate costs, sustainability, and timelines for development, noting differences and appropriateness of policies and regulations pertaining to CM impacts and environmental safety. The case studies have been incorporated into this report as Chapters 9 through 16.
- A workshop of more than 50 experts was held in October 2012 to identify potential solutions and recommendations related to inland CM policies and regulations. The findings from this workshop are incorporated into this report as Chapters 17 through 22.

1.4 Report Organization

The remainder of this report is organized as follows:

- Chapters 2 through 7 provide technical background on CM issues and policies. Chapters 2 and 3 outline the barriers and potential solutions associated with desal in general and the various CM options typically available in the arid Southwest. Chapters 4 and 5 focus on DWI policies, barriers, and solutions, and Chapters 6 and 7 focus on opportunities and challenges associated with evaporation ponds (Chapter 6) and high recovery (HR) processing of desal concentrate (Chapter 7).
- Chapter 8 summarizes findings from the case studies conducted as part of this research. Chapters 9 through 16 provide the detailed case studies as follows:
  - Chapter 9: EPWU's Kay Bailey Hutchison (KBH) Desalination Plant, TX
  - Chapter 10: East Cherry Creek Valley Water and Sanitation District (ECCV), CO
  - Chapter 11: Vero Beach, FL
  - Chapter 12: Alamogordo, NM
  - Chapter 13: San Antonio Water System (SAWS) Brackish Water Desalination Plant, TX
  - Chapter 14: Brownsville, TX
  - Chapter 15: Sterling, CO
  - Chapter 16: North Miami Beach Norwood–Oeffler Water Treatment Plant, FL
- Chapters 17 through 22 provide an overview of key findings from the expert workshop held in October 2012 at EPWU's KBH Desalination Plant in El Paso. Chapter 17 summarizes the workshop and outlines the key solutions identified by participants related to CM policies and regulations. Subsequent chapters focus on the top five solutions identified at the workshop, including:
  - Chapter 18, Solution 1: Defining a new subcategory specifically for desal CM wells under Class V of the UIC Program.
  - Chapter 19, Solution 2: Develop a compilation and guidance of best practices and permitting processes to help utilities and state and federal regulators develop better capacity and approaches to issuing and operating under Class I permits.
  - Chapter 20, Solution 3: Develop a general permit under Class I using the Texas model for other states with primacy and federal programs (U.S. Environmental Protection Agency [EPA] regions) where states do not have UIC Class I primacy.
  - Chapter 21, Solution 4: Provide primacy to the states for the aquifer exemption (AE) process. This would avoid a second-level review by EPA headquarters after a state review had already been completed; a federal review might be limited to administrative procedures only and not include technical matters.
  - Chapter 22, Solution 5: Develop a competition for creating technological advances to enable beneficial use and higher recovery of desal concentrate and facilitate CM.

Chapter 2

U.S. Inland Municipal Membrane Desalination: Background and General Barriers

2.1 Introduction

Access to fresh water resources is becoming an increasingly critical issue in the arid West and many other portions of the United States. Over the past several decades, a tremendous growth in population and industry has increased the demand for water in this region (Hightower, undated). In addition, many surface and groundwater supplies in the arid West have been tapped to their maximum or perhaps even tapped at levels now recognized as unsustainable. Accordingly, many communities find themselves facing limits on their abilities to extract additional waters from the array of supply options that have been available to them in the past.

Water scarcity in this region will be further impacted by climate change, which has a likely potential for increasing demands for municipal water as well as competing water use sectors (e.g., agriculture, energy production). Hotter temperatures, especially in summer, coupled with projected changes in seasonal precipitation patterns (e.g., drier summers), are expected to increase water demands related to outdoor use.

To meet these challenges, communities will need to better balance water demands with available water resources in a sustainable manner. In addition to conservation and water reuse, desal of brackish groundwater resources is becoming an increasingly important option for augmenting water supplies. In the arid West (and many other areas), desal is a logical candidate because it is based on proven technologies, is used extensively around the world, has capital costs that are decreasing, and is becoming more competitive with other new water supply alternatives. In addition, desal provides communities enhanced reliability as a drought-resistant supply, which is a benefit that does not accrue under most other water supply options (e.g., drawing from surface water sources).

As shown in Figure 2.1, much of the United States, including much of the arid West, contains extensive brackish groundwater resources (Krieger et al., 1957). Because much of this supply underlies more easily accessible and higher quality fresh water resources, it has remained primarily untapped (Hightower, undated). The U.S. Geological Survey (USGS) reports that in 2005, only 4% of total groundwater withdrawals in the United States were saline (saline groundwater suitable for desal is generally defined as having total dissolved solid [TDS] levels between 1000 and 10,000 mg/L). This amounts to 3020 mgd of the 82,620 mgd total of groundwater withdrawals; however, as freshwater supplies become more limited, desal of these brackish water resources will become more common.[1]

1. It is also feasible to desalinate groundwaters with TDS concentrations considerably greater than 10,000 mg/L, as evident from the widespread global desal of seawaters with TDS levels exceeding 30,000 mg/L. This suggests that the potentially available quantity of usable saline groundwater could be much greater than that indicated by USGS.

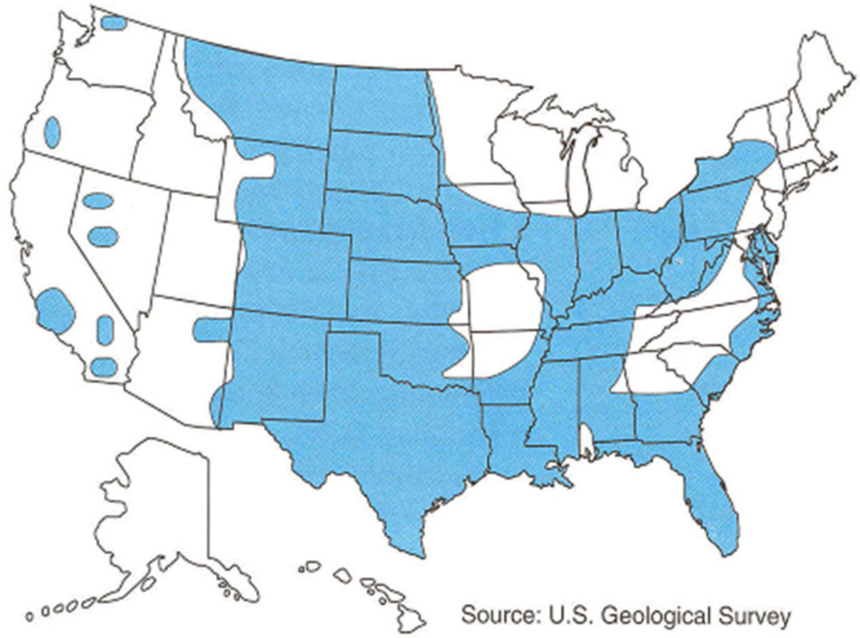

Figure 2.1. Availability of brackish groundwater resources in the United States

Despite the potential benefits of desal, a suite of issues—both technical and institutional—create uncertainties, delays, cost escalations, and other complexities that have inhibited brackish water desal implementation. In particular, the challenges associated with CM have made brackish water desal implementation a very complex, uncertain, time consuming, and often frustrating endeavor for utilities in Texas, New Mexico, and other arid, water-limited regions of the United States.

This chapter describes the practice of inland municipal desal in the United States and the general barriers limiting its implementation, with a focus on challenges associated with CM in the arid southwestern region of the United States.

2.2 Status of U.S. Municipal Desal

A series of surveys conducted over the last 20 years provides a detailed representation of U.S. municipal desal (Mickley et al., 2012). The surveys are estimated to include greater than 90% of all such facilities built. An estimated 324 desal facilities capable of generating 25,000 gpd or more (typically large enough to supply roughly 40 or more households per year) were built through 2010. All are membrane plants, with about 94% producing drinking water and 6% associated with processing wastewater treatment plant (WWTP) effluent for water reuse. Only 4% of the drinking water plants are seawater facilities. Figure 2.2 shows the cumulative number of plants over time, and Figure 2.3 shows an estimate of the cumulative capacity of the plants over time. The greater slope of the capacity curve reflects the increasing average plant size over time.

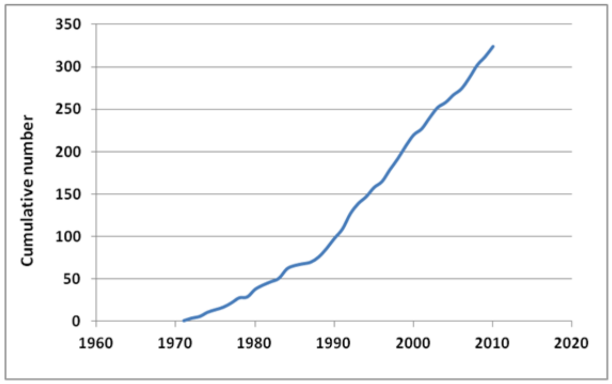

Figure 2.2. Cumulative number of U.S. municipal desal plants over time
Source: Mickley et al. (2012)

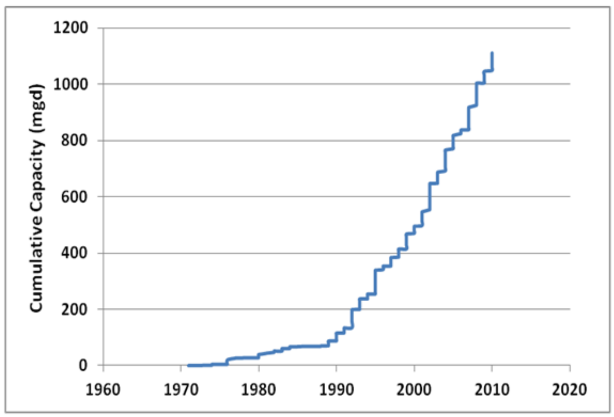

Figure 2.3. Cumulative capacity of U.S. municipal desal plants over time
Source: Mickley et al. (2012)

Figure 2.4 shows the number of different types of membrane plants built in three time periods. There are presently no municipal thermal (i.e., evaporation/distillation) desal plants in the United States. The membrane processes used are brackish water reverse osmosis (BWRO), nanofiltration (NF), seawater reverse osmosis (SWRO), and electrodialysis reversal (EDR). Also represented in Figure 2.4 are processes that include microfiltration (MF) prior to reverse osmosis (RO) and NF. Table 2.1 shows the percentage use of the different membrane processes.

Table 2.2 lists the number of municipal desal plants in various states as of 2010. The plants are located in 32 states (up from 14 in 1993 and 26 in 2003). Florida has 45% of the plants, followed by California and Texas with 14% and 9%, respectively. Together, these states account for 68% of the U.S. municipal desal plants. The remaining 32% of the plants are spread over the 29 other states. From 2003 through 2010, 39% of the plants were built in states other than Florida, California, and Texas, up from 19% for plants built prior to 2003.

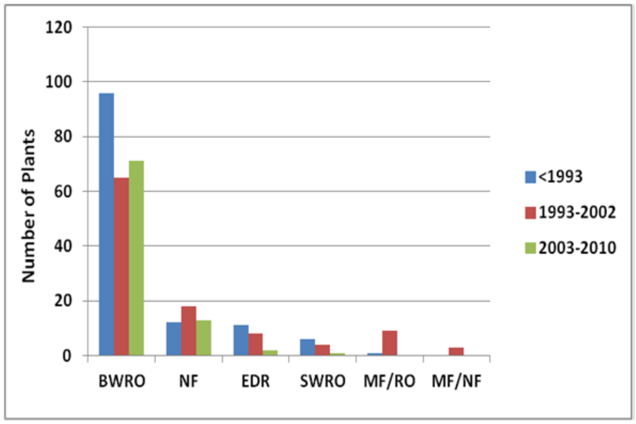

Figure 2.4. Number of plants by type and time period
Source: Mickley et al. (2012)

Table 2.1. Percentage Use of U.S. Municipal Membrane Desal Processes

Membrane Process	Percent of Total
BWRO	78
NF	13
EDR	5
SWRO	4

Source: Mickley et al. (2012)
Notes: BWRO=brackish water reverse osmosis; EDR=electrodialysis reversal; NF=nanofiltration; SWRO=seawater reverse osmosis

Figure 2.5 shows the number of plants built in Florida, California, Texas, and other states in three time periods. In 1993, over 62% of the plants were in Florida. Although more plants were built in Florida in each time period than in any other state, the total percentage of plants in Florida has declined to the 2010 percentage of 45%. The large number of plants in Florida is due to the state's growing population in areas where more traditional supplies are not as readily available (i.e., the flat terrain does not allow for the easy capture and storage of rain water). Average plant size for all inland desal plants (BWRO, NF, EDR) has increased over time from approximately 1.6 mgd in 1993 to 3.5 mgd in 2003 and 5.5 mgd in 2010.

2.3 General Barriers to Desal

The major limitations to the increased implementation of municipal desal plants are the following:

- High costs relative to more traditional freshwater supply options (e.g., fresh surface or groundwater)
- High energy requirements
- Limited options for disposing of desal concentrate in inland settings

Table 2.2. Number of U.S. Municipal Desal Plants by State

State	Number of Plants	State	Number of Plants
Florida	148	Minnesota	2
California	45	Missouri	2
Texas	30	Nebraska	2
North Carolina	12	Nevada	2
Illinois	11	New York	2
Arizona	10	Oklahoma	2
Iowa	10	Pennsylvania	2
Colorado	7	Utah	2
South Carolina	6	Alabama	1
Virginia	6	Mississippi	1
Ohio	5	New Jersey	1
North Dakota	4	South Dakota	1
Kansas	3	Washington	1
Montana	3	Wisconsin	1
Alaska	2	West Virginia	1
Massachusetts	2	Wyoming	1

Source: Mickley et al. (2012)

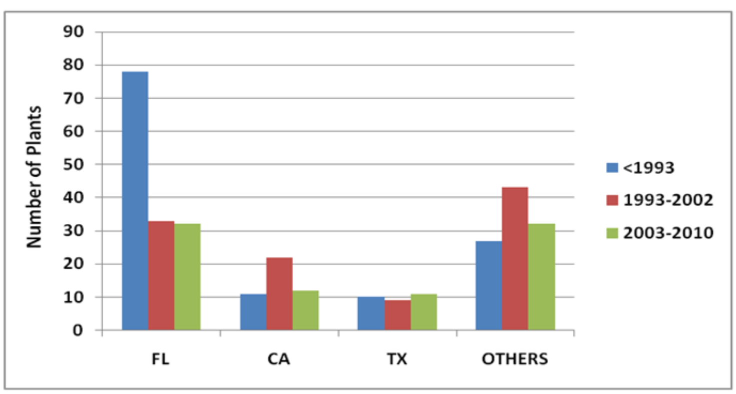

Figure 2.5. Number of plants by state and time period
Source: Mickley et al. (2012)

Desal production costs have decreased significantly over the past 20 years because of several factors, including the following:

- More efficient membranes (requiring lower operating pressure and having higher fluxes)
- Use of energy recovery devices
- Increased production of membranes and greater competition among equipment manufacturers

All three of these factors reduce equipment and operating costs. Cost, however, remains a factor in consideration of desal plants as it remains significantly greater than that of conventional water treatment processes. As traditional water sources become fully utilized, however, desal is becoming cost-competitive relative to other options available for meeting growing demands. For example, recent case studies reveal that groundwater desal is less expensive than importing water from distant areas and provides a more reliable yield.

Energy requirements are primarily based on pumping needs, and the aforementioned improvements in membrane efficiency and pressure recovery have reduced the energy requirements somewhat. As with production costs, however, relatively high energy requirements still remain a factor in making decisions about supply options. The high energy requirements of desal may conflict with other utility goals to reduce energy consumption and lower greenhouse gas emissions.

New desal technologies (including forward osmosis and membrane distillation) may play a role in reducing both equipment and energy costs, but both present and future desal technologies produce concentrate/brine that requires disposal. It is the barriers associated with the disposal of concentrate that are increasingly dictating the general feasibility of municipal desal, particularly at inland settings (as compared to coastal and near-coastal desal facilities, which have ocean outfalls as a viable and relatively inexpensive alternative for CM).

A recent study of desal by the National Resource Council (NRC; 2008) stated that “Few, if any, cost-effective environmentally sustainable CM options have been developed for inland desalination facilities” (p. 107).

Although desal production costs have decreased, costs associated with concentrate disposal have not and include:

- Determining disposal option feasibility
- Permitting
- Pumping, transportation, and other capital costs associated with the various concentrate disposal options

As a result, the costs of concentrate disposal are becoming an increasing proportion of the total desal costs (production + concentrate disposal).

Recognizing the importance of the challenges associated with all of the barriers to inland desal implementation (as outlined previously), this project focuses on the challenges associated with CM. The following sections describe the general barriers to CM, and Chapters 3 through 7 provide additional details on specific barriers.

2.4 Barriers to CM

The focus of this project is on CM barriers, which may fall into several categories:

- regulations/permitting
- hydrogeology
- water quality
- water quantity
- economic (i.e., cost)
- environment
- technology
- public/political

These barriers are included in Chapter 3, which discusses CM options in greater detail.

2.5 Arid Southwest

Whereas the previously quoted statement by NRC applied to municipal desal throughout the United States, the concerns are particularly urgent in the arid Southwest, which is also an area of project focus. The project team has arbitrarily defined this area as including the following states:

- Arizona
- California
- Colorado
- Nevada
- New Mexico
- Texas
- Utah

In general, these are areas where low freshwater resources are highly stressed. The region has only limited precipitation, and desal is increasingly being considered to support population growth. The low level of freshwater resources also results in limited flows in potential receiving waters (e.g., rivers and streams) for concentrate discharge. Generally, concentrate disposal options for all but extremely small desal plants are more limited in this region than in other parts of the United States. As will be discussed in Chapter 3, the CM options that hold the most promise for application in the arid Southwest are DWI, evaporation ponds (for smaller facilities), and HR processing (which produces a smaller volume of concentrate/brine or solids for disposal).

Chapter 3

Overview of Concentrate Management Options and Barriers

3.1 Introduction

Desal is of growing importance and application in meeting increased demands for water resources and improving the quality of drinking water and reuse water. The net result is more concentrate to manage. The CM dilemma is that it is increasingly difficult to manage concentrate in a way that is cost-effective, expeditious to permit, and environmentally prudent.

The challenge of managing concentrate is a function of its volume and composition. It contains greater amounts of all constituents found in the feed water concentrated to different degrees by the membrane process.

Historically, CM has amounted to disposal, but the most widely used disposal options can impact source waters. The same environmental and health concerns that have led to the demand for higher quality potable water treatment and the increased use of desal have also led to increased protection of source waters. As a result, it has become more difficult to find a long-term sustainable concentrate disposal option, and in some cases desal plants have not been built because of the seemingly insurmountable challenges associated with CM issues.

Over 96% of the municipal desal facilities in the United States are inland. CM has become a major factor in determining the feasibility of building a desal plant. Moreover, it has become an increasingly significant cost factor. A recent study of desal by NRC (2008) stated that "few, if any, cost-effective environmentally sustainable CM options have been developed for inland desal facilities" (p. 107).

3.2 CM Options

As of 2010, five conventional concentrate disposal options have been used by more than 98% of the estimated 324 municipal desal plants built in the United States (Mickley et al., 2012). The five conventional disposal options include:

- surface water discharge
- discharge to sewer
- DWI
- evaporation pond
- land application

These general categories have several subcategories (see Table 3.1). The application of each option is a function of plant size (i.e., concentrate volume), water quality, location, regulatory policy, and cost.

Table 3.1. CM Options[a, b]

1. Five conventional CM options (for concentrate of any salinity)
   - Surface water discharge
     - Direct ocean outfall (includes brine lines both when direct to ocean and via WWTP on way to ocean)
     - Shore outfall
     - Co-located outfall (with power plant cooling water or WWTP effluent discharges)
     - Discharge to river, canal, lake
   - Discharge to sewer
     - Sewer line
     - Direct line to WWTP
   - Injection wells
     - DWI
     - Shallow well (beach well)
   - Evaporation pond
     - Conventional pond
     - Enhanced evaporation ponds/schemes
   - Land application
     - Percolation pond/rapid infiltration basin
     - Irrigation
2. Beneficial use (other than irrigation)
   - Several potential uses (for concentrate or solids)
3. Landfill (for solids)
   - Dedicated monofill
   - Landfill accepting industrial waste

Source: Mickley et al. (2012)

Notes: CM=concentrate management; DWI=deep well injection; WWTP=wastewater treatment plant;
[a]the options apply to concentrate of any salinity, thus concentrate from HR, including zero liquid discharge (ZLD)/brine minimization processes as well as conventional recovery processes, are included;
[b]the options also apply to desal processing involving salt recovery.

In addition to the conventional disposal options, the beneficial use of concentrate has also been explored. Although several possible beneficial uses of concentrate have been identified (besides irrigation), none are widely applicable, most are unproven, and most do not result in the disposal of concentrate. There are very few viable uses of concentrate thus far demonstrated, although some—such as treatment wetlands—may contribute to improved water quality through the removal of specific problematic constituents such as selenium or nitrate, making some form of blending and discharge more viable (Jordahl, 2006; Mickley et al., 2012). However, given the challenges of CM, it is prudent to explore any and all beneficial use options early in project planning as the options are site-specific, and a feasible option may present itself. A combination of methods such as linking more conventional options with beneficial uses may provide redundancy, reliability, and potentially some ancillary benefits. Together, these options recognize the possibility of managing concentrate in a more beneficial way and reflect that concentrate might be considered a resource.

In the last decade, largely because of various challenges associated with CM (discussed in a following section), increasing attention has been given to HR processing. This has been referred to under different names, such as concentrate minimization and volume reduction (of concentrate). In special cases where no liquid crosses the facility boundary, HR processing amounts to what is known as zero liquid discharge (ZLD).

Other drivers for consideration of HR processing include:

- Increased concern for concentrate as a lost water resource.
- The realization of a longer term need to develop sustainable technologies/solutions. Although CM options remain costly, the recovery of salts and other constituents in concentrate may be an approach toward more sustainable practices. Wastes in other industries also have limited disposal options available, and the beneficial recovery of values from waste is proving to be a cost-effective and important step toward more sustainable business practices.

The final wastes from HR processing are either concentrate/brine or solids. In theory, concentrate/brine from HR processing may be disposed of by any of the five conventional disposal options. Landfills (for solids) are added to the list to account for solids produced by the HR processing, where solids result from either accumulation in evaporation ponds or a final evaporation step to produce mixed solids. At WWTP sites utilizing desal for water reuse, the low salinity concentrate may be recycled to the front of the WWTP.

The solids bring a new disposal option into consideration: disposal to landfills. A subcategory of HR processing recovers one or more products (e.g., salts, trace metals, or other constituents) as part of the processing scheme. As of 2010, there was one municipal ZLD facility in Tracy, CA. Presently, there is at least one other HR RO plant being built, along with a few HR NF membrane plants. The higher salinity concentrate/brine and the solids produced introduce new disposal challenges to municipal desal and are the topic of Chapter 7, which addresses HR processing.

3.3 CM Practices

Table 3.2 shows the percentage of use of the five conventional disposal options for desal plants within the United States as well as the number of states having municipal desal plants utilizing each option. As shown, few states have plants that use DWI, land application, or evaporation ponds as a method of disposal. For these options, the states and the number of sites using the option in each state are given. Thirty-two states presently have municipal desal plants. Table 3.2 demonstrates that

- seventy-one percent of the plants discharge concentrate to surface water or the sewer, although these are largely in states where surface waters have relatively high volume flows or the desal facilities are very small).
- DWI and land application are used in only 5 of the 32 states.
- evaporation ponds are used in only 3 of the 32 states.
- 100% of the plants in 26 states discharge either to surface water or the sewer.
- roughly 95% of the DWI sites are in Florida.
- twenty of the 23 land application sites are in Florida.
- Florida is the only state utilizing all five conventional disposal options.

Figure 3.1 shows the percentage of plants built in three time periods using different disposal options. Surface water discharge and discharge to sewer are used at relatively high levels regardless of the time period, but there are distinctive trends for three of the other four disposal options. DWI use has increased with time, whereas disposal to land and evaporation ponds have decreased with time.

Figure 3.2 provides additional information on how the disposal options are used as a function of size of the municipal desal plant. The combinations represented (such as surface water discharge for BWRO/EDR plants) eliminate the bias introduced when SWRO plants and NF plants are included in the data. Although discharge to surface water is used at a consistently high level regardless of plant size, discharge to sewer is used less as the plant size increases, use of DWI is increasingly used with larger plants, and use of evaporation ponds and land applications are restricted to small-sized plants.

Although the representations of Figures 3.1 and 3.2 are accurate, they are somewhat misleading in that they may imply that all disposal options are available regardless of location. As reflected in Table 3.2, this is not the case. To account for this, Figures 3.3 through 3.6 represent the percentage use of the disposal options by time period for Texas, Florida, California, and all other states, respectively.

Table 3.2. Number of States Using Disposal Options for Municipal Desal Concentrate as of 2010

Disposal Option	Percentage of Facilities	Number of States	States (number of sites) Using Option
Surface water discharge	47[a]	25	Many
Discharge to sewer	24	22	Many
DWI	17	4[b]	FL (53), CA (1), KS (1), TX (1)
Evaporation pond	4	3	TX (7), AZ (3), FL (3)
Land application	7	4	FL (20), AZ (1), CA (1), TX (1)
Recycle	1	3	CA (2), AZ (1), PA (1)

Notes: DWI=deep well injection; [a]Includes plants in California that discharge to brine lines that eventually discharge to the ocean. The number may represent approximately 20% of all surface water discharges. [b]Colorado has since permitted DWI for two municipal desal plants, Texas for one, and Florida for more than three.

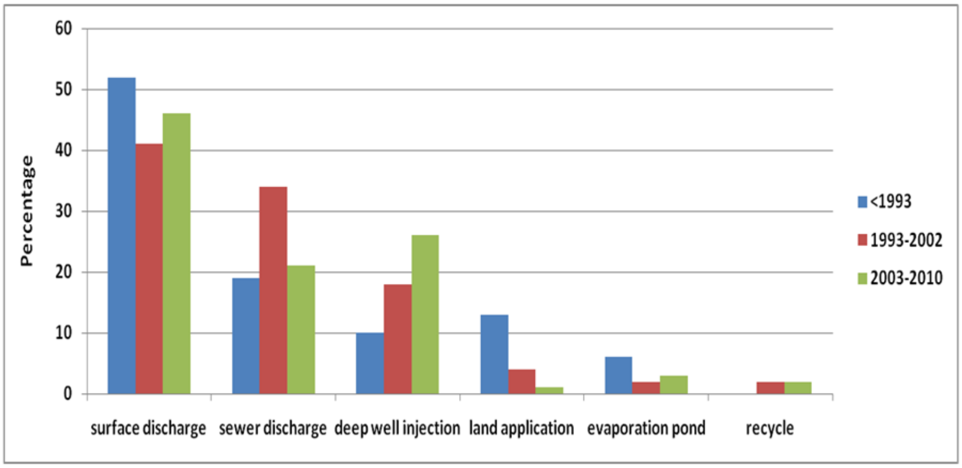

Figure 3.1. Use of disposal option by time period.

Source: Mickley et al. (2012)

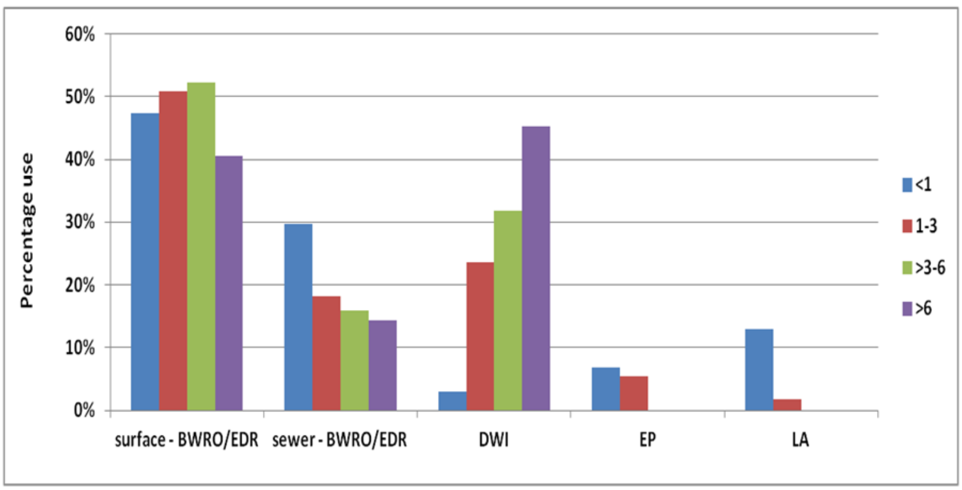

Figure 3.2. Disposal option use by plant size (mgd).

Notes: DWI=deep well injection; EP=evaporation pond; LA=land application

Source: Mickley et al. (2012)

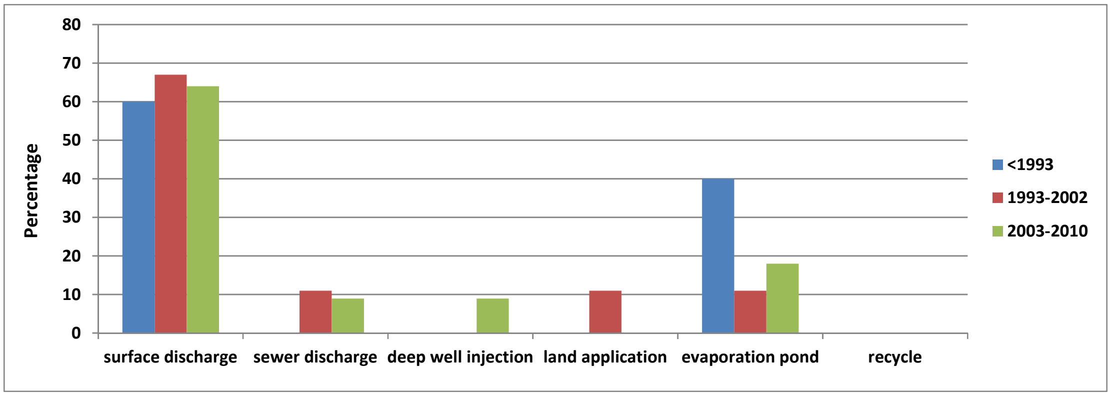

Figure 3.3. Use of disposal option by time period: Texas.

Source: Mickley et al. (2012)

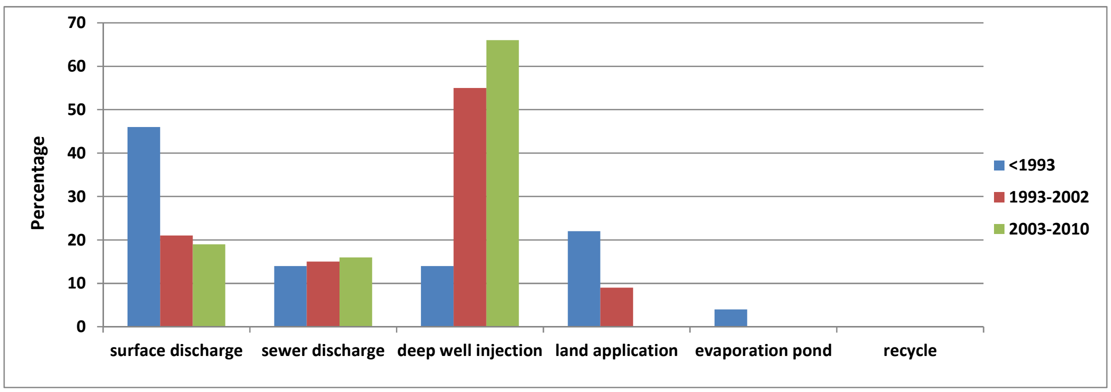

Figure 3.4. Use of disposal option by time period: Florida.

Source: Mickley et al. (2012)

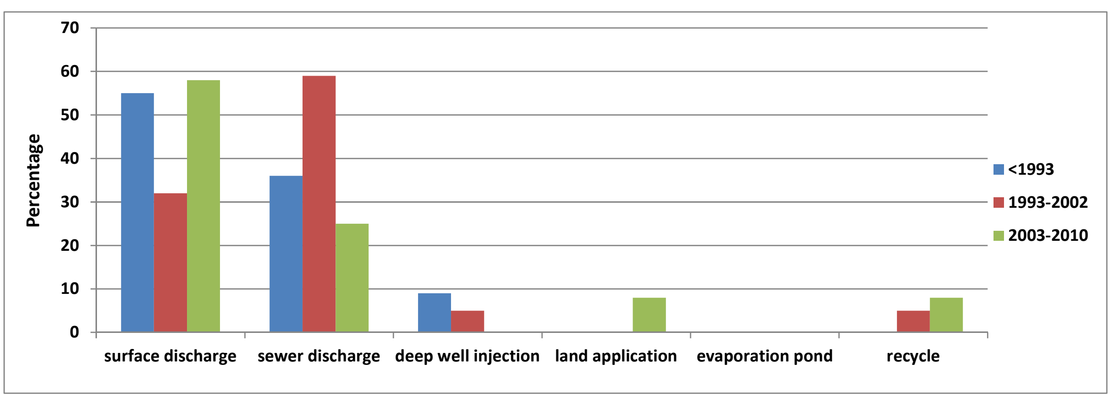

Figure 3.5. Use of disposal option by time period: California.

Source: Mickley et al. (2012)

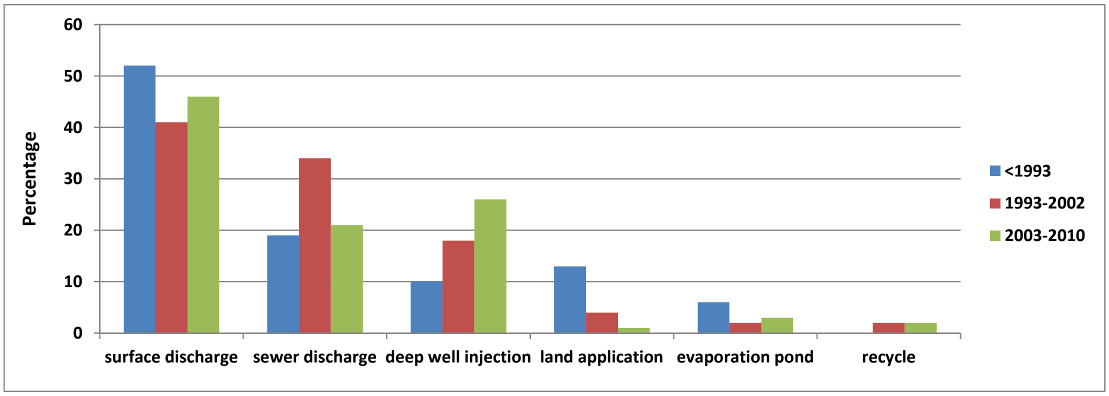

Figure 3.6. Use of disposal option by time period: All other states.
Source: Mickley et al. (2012)

Although the details are masked by the small size of the figures, it is the general distribution of the data that stands out. Most notably:

- Texas has a higher percentage of evaporation ponds than the other areas; most of the ponds are from smaller and older facilities.
- Florida has the largest use of DWI and a strong trend toward increasing use of this disposal method.
- California is similar to the fourth group representing all other states in that discharge to surface water and sewer account for most of the disposal.

3.4 Summary of CM Practices

A recent survey (Mickley et al., 2012) to determine desal plant characteristics and CM practices for plants built through 2010 coupled with past surveys allows comparison of data and identification of trends. Findings from the survey of municipal desal plants include:

- More than 94% of the municipal desal plants are at water treatment plants, with the remaining 6% at WWTPs and recharge facilities.
- Of the identified 324 plants, 45% are located in Florida, 14% in California, and 9% in Texas.
- Florida, California, and Texas account for 68% of the municipal desal plants; the other 32% are scattered over 29 states.
- A greater percentage of plants are being built outside of the three states where most desal plants and overall capacity currently are found (Florida, California, and Texas).
  – In 2003, only 19% of plants were built in other states.
  – Between 2003 and 2010, 39% of the plants built were in other states.
- The pattern of use of concentrate disposal options varies greatly in the four regions represented by Florida, California, Texas, and the other states.
- The operating capacity of desal plants has been increasing (from 1.57 mgd for plants built prior to 1993 to 5.53 mgd for plants built between 2003 and 2010).

- There has been an increased use of DWI and a declining use of evaporation ponds and land application.
- The past several years have resulted in the increased consideration and investigation of DWI in states other than Florida and enhanced evaporation in all the states reported. Few plants in states other than Florida, however, have implemented these options.
- An increased number of plants are treating source water for removal of contaminants in addition to salinity.
- An increased number of plants have concentrate-containing contaminants that restrict the application of CM options or require treatment to remove the contaminants prior to disposal.
- Increasing CM challenges have led to planning-phase consideration of plants with HR processing of concentrate. To date, one ZLD plant has been built (Mickley et al., 2012), and one is under construction. A few HR NF plants are also being built.

3.5 CM Challenges

As with most industrial waste disposal situations, few options exist for managing concentrate from desal plants. Monies available for achieving more effective processing and recovery of wastes are limited in the municipal water treatment industry because of the undervaluing (and underpricing) of water. As a result, technologies and approaches that are cost-effective in many other industries are not cost-effective in the municipal setting.

As reflected in Table 3.2, a major concentrate disposal challenge is the limited local availability of options. Rarely are more than one or two conventional CM options considered potentially feasible after an initial screening evaluation. Although surface water discharge and discharge to sewer will continue to play an important role in many parts of the United States where sufficient flows enable adequate dilutions, salt loading of receiving waters is a growing environmental concern. In other locations, and particularly in the arid Southwest, most conventional disposal options are not possible or cost-effective for anything but very small desal plants.

Other concerns and challenges associated with CM include:

- ***Increasing size of plants:*** Desal plant size has been increasing, and the increased volume of concentrate represents an increased impact on receiving waters and less likelihood of discharge to sewer, land application, or evaporation pond, the use of which has historically decreased with increasing concentrate volume.
- ***Increasing number of plants in a region:*** An increasing number of plants in a given region increases the risk of cumulative impacts.
- ***Increasing regulation of discharge:*** Source water quality has declined in many areas because of human activities, and drinking water standards have become more stringent. As a result, a strong case can be made for increased application of desal; however, the same environmental and health concerns that have led to tighter drinking water standards have also resulted in the increased protection of water sources. This presents a challenge to CM as 80% of the municipal desal plants discharge concentrate via options that can affect source waters (e.g., surface water discharge, discharge to sewer, and land application).

- ***Lack of public understanding:*** Part of the challenge in getting a desal plant implemented in a timely manner is resolving public concerns. Frequently, the public has a limited understanding of issues involved and often has misconceptions about the nature of the desal process and the actual risk of concentrate effects on the environment. The public may be unaware of the benefits of desal technology relative to conventional water treatment technologies and supply options.
- ***Increasing CM costs:*** The treatment cost of desal has decreased considerably because of more efficient, longer lasting, and less expensive membranes; use of energy recovery devices; and increased competition among equipment manufacturers and system suppliers. CM costs, however, have not decreased. Capital costs associated with conventional disposal options have not decreased (the exception is enhanced evaporation ponds), and operating costs have increased because of more detailed monitoring requirements. As a result, CM costs have become an increasing percentage of total desal plant costs and, in some cases, the most significant factor in determining the feasibility of building a new desal plant.
- ***Increasing occurrence of contaminants in concentrate:*** A recent survey (Mickley et al., 2012) found a handful of concentrates with spikes of contaminants (e.g., nitrate, perchlorate, selenium, arsenic) that required removal before discharge. This occurrence is associated with plants built within the past decade and appears to represent a growing trend.
- ***The regulatory interactions*** can be complex, time-consuming, and uncertain. Permitting is complicated by the lack of desal concentrate–specific federal and state regulations and limited experience of the regulation community with desal concentrate disposal permitting.

3.6 General Barriers Associated with CM Options

Tables 3.3 and 3.4 summarize the challenges and issues that limit the use of the options. Both tables list various potentially limiting issues for the disposal options and HR processing. Table 3.3 lists different factors that can limit the feasibility of concentrate disposal options. Table 3.4 was adapted from a table published in 2008 (NRC, 2008). Although Table 3.3 is more specific as to why a given factor may be limiting for a disposal option, Table 3.4 ranks different factors as to the level of challenge they typically present to a disposal option. Together, they provide a more detailed and accurate summary than either table alone.

Figure 3.7 brings into consideration an additional perspective, that of the relative capital costs (not including conveyance costs) of the disposal options. It also shows that both evaporation ponds and land application may be cost-effective for small volume concentrates—something that the capital cost column of Table 3.4 does not imply. It also reflects the high costs of DWI for small concentrate flow caused by high front-end feasibility study costs associated with drilling test wells and hydrogeological studies.

Table 3.3. Requirements, Characteristics, and Barriers for Inland CM Options

	Discharge to Sewer	Discharge to Surface Water	Evaporation Ponds	Land Application	Underground Injection	HR Processing (including ZLD)
Regulatory requirements	Permit not required, but responsibility falls on wastewater facility to meet NPDES permit requirement May be subjected to pretreatment requirements	Requires an NPDES permit	State permit—regulations vary by state In most cases, lining and monitoring are required.	State permit—regulations vary by state May be regulated by land-use criteria or groundwater protection requirements	UIC permit—regulations vary by state; multiple agencies may be involved Limited experience in many states Practice may not be allowed in some states.	Permit required for disposal of final waste—regulations vary by the type of final waste produced (brine or solid).
Cost factors	Conveyance to collection system May be a connection or discharge fee Cost is typically not a barrier	Conveyance to outfall Outfall design and construction Cost is typically not a barrier.	Major costs are pond lining, leak monitoring system, and land Little or no economy of scale	Conveyance to distribution system Little or no economy of scale	Conveyance to injection wells Large costs associated with permitting and determination of injection feasibility Well construction costs	High capital, energy, and chemical costs associated with additional processes Final waste disposal costs
Concentrate water quality influence	Effect of concentrate salinity and constituents on wastewater effluent conditions and treatment	Effect on permit discharge conditions (limits)	Effect on evaporation rate and solids accumulation rate	Effect on soil, vegetation, and groundwater	Effect on precipitation potential in well and aquifer; corrosion, and disposal well class feasibility	Effect on level of recovery and final brine or solids nature

	Discharge to Sewer	Discharge to Surface Water	Evaporation Ponds	Land Application	Underground Injection	HR Processing (including ZLD)
Environmental concerns	Impact on flora and fauna as part of the WWTP discharge	Impact on flora and fauna of receiving water WWTP discharge	Control of wildlife access to the ponds Requires a large amount of land Concern for drift from winds	Impact on soil, vegetation, and groundwater	Potential migration from the target aquifer Potential for well failure Potential to cause earthquakes Impact on other aquifers through migration and leakage	Impact from waste disposal
Technical issues	Can impact wastewater processes and inhibit microbial growth, corrosion, and changing settling characteristics	Suitability for year-round operation Challenges associated with outfall design and construction Time-limited antiscalant effect in preventing precipitation of sparingly soluble salts/silica	Must ensure that evaporation exceeds precipitation Higher salt concentrations decrease evaporation. Ensure that there are no leaks from the liner Suitability for year-round operation	Understanding the maximum loading acceptable Suitability for year-round operation	Potential for precipitation prior to injection Potential for down hole precipitation/plugging Unknowns regarding high salinity downhole effects Nearby aquifer and geology may not be suitable for injection.	Need to understand what to do with the waste Technical improvements needed to reduce capital costs, energy, and chemical requirements
Public perception factor	In some areas, public concern with potential impact on freshwater flow to bays and estuaries	Environmental concerns associated with potential impacts on receiving waters	Potential adverse response from the public regarding drift, odor	Environmental concerns from land discharges (impact on soil, vegetation, groundwater)	Association of DWI with fracking concerns Concern over injection of an industrial waste Concerns over earthquake potential	Generally considered a beneficial option by the public May be some concern over disposal of final waste

	Discharge to Sewer	Discharge to Surface Water	Evaporation Ponds	Land Application	Underground Injection	HR Processing (including ZLD)
Other	Must have an effective relationship with the WWTP				Experience in drilling deep wells is only found in the oil and gas industry Contractors are often unfamiliar with the requirements of municipalities or regulatory agencies other than those serving oil and gas	
Water quantity effect	Effect on WWTP capacity	Effect on permit discharge conditions (limits)	Land requirement (and cost) can be excessive.	Land and dilution water requirements can be excessive.	Effect on aquifer capacity and number of injection wells	Impacts processing costs

Notes: NPDES=National Pollutant Discharge Elimination System; UIC=underground injection control; WWTP=wastewater treatment plant; ZLD=zero liquid discharge

General barriers applying across the board:

- Risk adverse—The water industry is generally risk adverse and looks for technologies and approaches that minimize it. More expensive approaches/technologies may be applied that reduce risk but lead to increased costs.
- Tightening environmental regulations—Environmental regulations in general are becoming more stringent. For example, new total maximum daily loads that impact NPDES permits will limit surface water discharges. This may also impact discharge to water treatment or land application.
- Public perception can impact all the disposal options. They all have some impact and may touch different stakeholder groups.
- Continuous vs. intermittent—It is typically preferred to operate a desal facility on a continuous basis, which in turn would produce a steady stream of brine. Some disposal options may be impacted by seasonal low flows or intermittent (.e.g., enhanced oil recovery wells). Matching these two approaches presents a barrier to certain technologies.
- Long approval time—Review and approvals of applications may take a long time because there is not sufficient history and experience with CM. Regulators take a very conservative approach in the absence of history and experience.
- Market size—The opportunities for inland desal industry are relatively small. There is little incentive for manufacturers and other vendors to tackle the large obstacles associated with municipal projects, approval times, and uncertain regulatory environment for such a small market.

Table 3.4. Inland Concentrate Disposal Barriers

Issue Type:	Technical				
Method	**Land Area Required**	**Applicability for Large Conc. Flows**	**Pretreatment Needed**	**Climate Limitation**	**Special Geological Requirements**
Surface water discharge	–	yes	medium	maybe[a]	no
Sewer discharge	–	no	low	no	no
DWI	low	maybe	low	no	yes
Evaporation pond	high	no	low	yes	yes
Land application	high	no	low	yes	yes
Thermal evaporation to solids	low	no/maybe?	low	no	no

Issue Type:	Cost				Environment/Regulatory		Public
Method	**Unit Capital Costs ($/mgd)**	**Unit[b] O&M Costs ($/kgal)**	**Labor Needs and Skill Level (for operation)**	**Energy Use**	**Permitting Complexity**	**Potential Environmental Impact**	**Public Perception Concerns**
Surface water discharge	low[c]	low[c]	low	low[d]	medium/high	medium	high
Sewer discharge	low[c]	low[c]	low	low[d]	medium	medium	low
DWI	high[c]	medium[c]	low/medium	medium[d]	high/medium[e]	low	low/medium
Evaporation pond	high[c]	low[c]	low	low[d]	medium	medium	low/medium
Land application	low/medium[c]	low[c]	low	low[d]	medium	medium/high	high
Thermal evaporation to solids	high[c]	high[c]	high	high[d]	low[a]	low[a]	low

Notes: DWI=deep well injection; O&M=operations and maintenance; --=not applicable: water quality of the concentrate and composition of landfill solids can eliminate feasibility of each of the disposal options by presence of toxins, precipitation of solids upon blending, or presence of hazardous levels of contaminants. [a]Climate can affect amount of rainfall and surface water available for dilution; [b]Unit O&M costs increase with the amount of monitoring and analytical lab support required; [c]Costs are highly site-specific; general trends in relative costs are indicated; capital cost for all options can be higher if distance from the desal facility to the disposal site is large, necessitating long pipelines and possibly pumping stations or hauling; [d]Energy use for each option can be higher because of distance from desal plant to option site, large land application area, and if a distribution system is required; [e]Deep wells are not permitted in some states.

Sources: Adapted from NRC (2008) and Mickley et al. (2012)

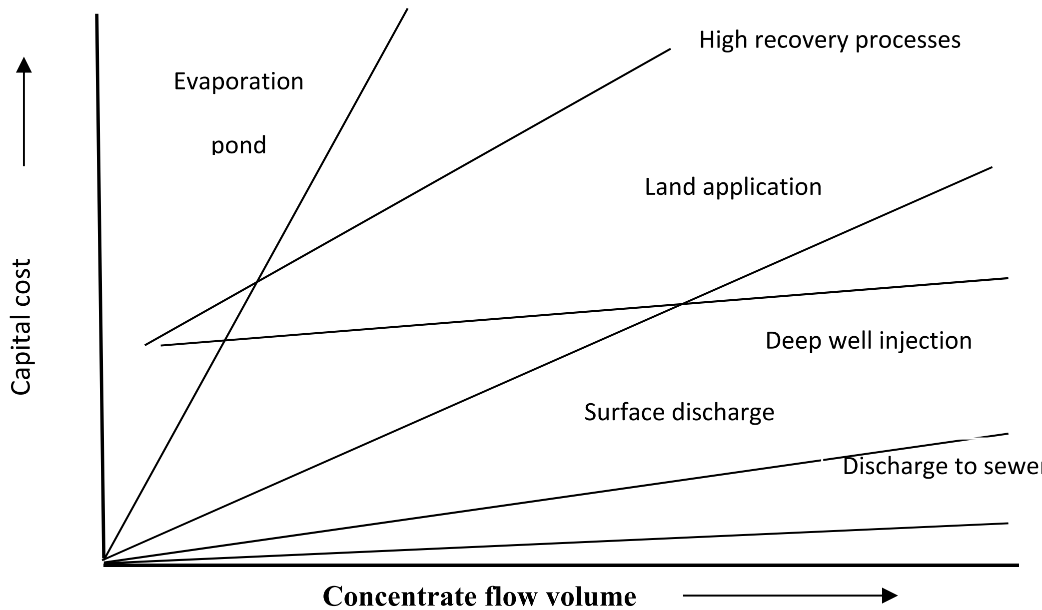

Figure 3.7. Relative capital costs of CM options (not considering conveyance).

Not considering the distance of conveyance from the desal plant to the disposal site, the major barriers associated with the different disposal options and HR processing include:

- ***Surface water discharge:*** As discharge regulations become increasingly stringent, concentrate disposal via surface water discharge may ultimately become an unsustainable practice.
- ***Discharge to sewer:*** High salt concentrations can have a negative effect on WWTP operations and may impact the ability to meet discharge permit requirements. Key challenges to DWI include restrictive regulatory policy and related permitting requirements, unknown hydrogeological conditions in many locations, and high costs associated with determining feasibility and implementation.
- ***Evaporation ponds:*** Land requirements are suitable for only small volumes of concentrate. In addition, there are high capital costs associated with this option and low economies of scale.
- ***Land application:*** This option requires dilution water to limit impacts on soil, vegetation, and groundwater.
- ***HR processing:*** These processes have high capital costs associated with additional processing equipment. In addition, there are questions concerning the impact of high salinity brine on disposal options.

3.7 CM Options for the Arid Southwest

Because beneficial use options are rare and site-specific, they were not chosen for further consideration. This leaves the following options:

- surface water discharge
- discharge to sewer
- land application
- DWI
- evaporation pond
- HR processing

As previously discussed, the first five bullet items are conventional disposal options, and the final one is a CM option that produces concentrate/brine or solids for disposal.

Of the remaining CM options, the first three are considered unsuitable for implementation in the arid Southwest.

- The arid Southwest is characterized by limited waters available for surface water discharge, which restricts its consideration to only small volumes of concentrate. Further long-term discharge to inland surface waters is not a sustainable practice.
- Discharge to sewer is limited to WWTPs where the impact of concentrate on their operations and discharge permits would be minimal: where the concentrate salt load is relatively small. Although this situation may be found, the option is further restricted by the growing use of WWTP effluent for water reuse.
- Land application of concentrate generally requires low TDS dilution water (scarce in the arid Southwest) to meet soil, vegetation, and groundwater restrictions. The option is restricted to low volumes of concentrate.

This leaves the following three CM options as potentially viable for desalting at inland locations in the arid Southwest:

- Evaporation ponds are suitable for low volumes of concentrate because of both large land requirements (a net evaporation rate of 3 gpm/acre is a high value) and low economies of scale. The arid Southwest has high net evaporation rates and more available land, and in some cases this can be the only approved disposal option. Technical innovations (enhanced evaporation systems) that have the potential to decrease costs need to be considered. The use of evaporation ponds will still be restricted to low concentrate volumes. Evaporation ponds are considered further in Chapter 6.
- Of the five conventional disposal options, DWI holds the most promise for increased implementation. The specific barriers to increased application are the subject of Chapter 5. Chapter 4 provides the background to the regulation of DWI.
- As explained previously, the increasing challenges of concentrate disposal make HR processing a subject of considerable attention. Although it does not necessarily solve the disposal problem, it does bring into consideration possible alternatives and benefits, which include:
    - landfill of solids

- possible recovery of values from concentrate
- more efficient use of the water resource

In addition to these options, Chapter 7 discusses the use of HR processing.

Chapter 4

Overview of Deep Well Injection and the Underground Injection Control Program

4.1 Subsurface Injection for Desal Concentrate

DWI is a disposal option in which liquid wastes are injected into porous subsurface rock formations. The aquifer/rock formation receiving the waste must possess the natural ability to contain and isolate it.

Paramount in the design and operation of an injection well is the ability to prevent movement of wastes into underground sources of drinking water (USDWs). Injection wells may be considered a storage method rather than a disposal method; the wastes remain there indefinitely if the injection program has been properly planned and carried out.

Subsurface injection can also be done in shallow wells (such as beach wells used for seawater desal concentrate). DWI is needed for the isolation of injected liquid wastes and inland municipal desal concentrate disposal.

As of 2010, about 16% of the roughly 320 municipal desal plants in the United States processing more than 25,000 gpd—roughly large enough to serve 40 households or more—disposed concentrate to deep wells (Mickley, 2006; Mickley et al, 2012). Although other states are increasingly exploring the use of DWI for municipal desal concentrate, only Florida, California, Texas, Colorado, and Kansas had such wells as of 2010. Florida, with approximately 50 wells, was the only state having more than one well for municipal desal concentrate disposal.

The high number of wells in Florida is due to the state's large and growing population and the exhausted availability of fresh groundwater and resulting proliferation of inland brackish water municipal desal plants (approximately 46% of all U.S. municipal desal plants are in Florida). In addition, there are limited disposal options in many locations yet near ideal hydrogeological conditions for DWI in parts of Florida. Further, several concentrates in Southwest Florida have high levels of naturally occurring radioactive materials, making the concentrate unsuitable for surface water discharge and leaving DWI as the only viable disposal option.

Because of significant front-end feasibility determination costs associated with test wells and hydrogeological studies, DWI has not usually been cost-effective for small municipal plants. For larger desal plants, DWI is often the only feasible CM option. As a result, DWI use increases significantly with desal plant size. The high cost of deep wells is also due to the regulatory classification—Class I of the UIC Program of the federal Safe Drinking Water Act (SDWA)—of municipal desal concentrate as an industrial waste. Class I is the same classification that applies to injection of other industrial and hazardous waste. Class I wells have stringent construction requirements.

4.2 Regulation of DWI

Under the SDWA, EPA sets standards for drinking water quality and protection of source water and oversees the states, localities, and water suppliers that implement those standards. The law requires many actions to protect drinking water and its sources: rivers, lakes, reservoirs, springs, and groundwater wells. Prior to the SDWA in 1974, there were few national enforceable requirements for drinking water. The oil and gas industry had been injecting saltwater into deep rock formations to increase oil recovery for more than a quarter of a century. The SDWA established the requirements and provisions for the UIC Program, and 40 CFR §144 provides the minimum requirements for the UIC Program promulgated from the SDWA. It took nearly a decade after passage of the SDWA for EPA to implement a standardized UIC Program governing underground injection. Part of the challenge of defining a regulatory approach for protecting possible drinking water sources was resolved by defining USDW as any aquifer water with TDS levels of 10,000 mg/L or less. Injection into or above USDW zones is restricted depending on the type of injection fluid regardless of the water quality of the USDW zone. (As noted later, this criterion of 10,000 mg/L TDS for defining a USDW may now be overly limiting for managing drinking water and underground injection.)

The purpose of the UIC Program is to ensure that underground injection of fluids is managed so as to protect USDWs. This goal is accomplished by setting the physical and operational standards that apply to the practice (Groundwater Protection Council [GWPC], 2007a).

EPA developed the Statement of Basis and Purpose for the UIC Program to support regulations. These documents (U.S. EPA, 1979, 1980) identified the technical reasons for developing the UIC Program regulations. In the 1980s, federal UIC regulations were passed that define five classes of injection wells and set minimum standards that state programs must meet to receive primary enforcement responsibility (primacy) of the UIC Program.

Since inception of the UIC Program, additions have been made to it. Congress amended the SDWA to allow existing oil and gas programs to regulate, provided they are effective in preventing endangerment of USDW and include traditional UIC Program components such as oversight, reporting, and enforcement. Congress also passed the Hazardous and Solid Waste Amendments to the Resource Conservation and Recovery Act (RCRA), requiring additional UIC regulations for deep wells injecting hazardous waste. More recently, the UIC Program has had he following challenges from new uses of injection wells:

- Managing treatment residuals from drinking water treatment plants
- Increasing drinking water storage options through aquifer storage and recovery wells
- Limiting carbon dioxide (CO_2) emissions through geologic sequestration (GS)
- Evaluating the impact to USDW by hydraulic fracturing of unconventional gas sources

In 2010, EPA finalized regulations for the GS of CO_2 using the existing UIC Program regulatory framework modified with criteria and standards specific to GS, thus creating a new class of wells: Class VI. With proper site selection and management, this new class could play a role in reducing emissions of CO_2.

The UIC regulations establish specific performance criteria for each well class to assure that drinking water sources, actual and potential, are not rendered unfit for such use by underground injection of the fluids common to that particular category. The UIC Program is responsible for regulating the construction, testing, operation, permitting, and closure of injection wells that place fluids underground for storage or disposal (U.S. EPA, 2012c).

4.3 Classes of Injection Wells

In simplified descriptions, deep injection well classes are defined under the UIC Program as follows:

Class I wells: Technologically sophisticated wells that inject wastes into deep, isolated rock formations below the lowermost USDW. Class I wells may inject hazardous waste, nonhazardous industrial waste, or municipal waste. Desalting wastes (i.e., concentrated brines) fall under Class I.

Class II wells: Wells that inject brines and other fluids associated with oil and gas production or storage of hydrocarbons. Class II well types include salt water disposal wells, enhanced recovery wells, and hydrocarbon storage wells.

Class III wells: Wells that inject fluids associated with solution mining of minerals. Mining practices that use Class III wells include salt solution mining, in situ leaching of uranium, and sulfur mining using the Frasch process.

Class IV wells: Wells that inject hazardous or radioactive wastes into or above a USDW. These wells are banned unless authorized under a federal or state groundwater remediation project.

Class V wells: Wells not included in Classes I to IV and Class VI. Wells inject nonhazardous fluids into or above a USDW and are typically shallow, on-site disposal systems (e.g., septic systems); however, this class also includes some deeper injection operations. There are approximately 20 subtypes of Class V wells.

Class VI wells: Wells that inject CO_2 for the purposes of long-term storage, also known as CO_2 GS.

The vast majority of injection wells existing prior to the UIC Program were associated with oil and gas production (and became Class II wells) and a wide range of other wells (that became Class V). Most Class V wells are shallow disposal systems that depend on gravity to drain fluids directly into the ground. There are over 20 well subtypes that fall into the Class V category; these wells are used by individuals and businesses to inject a variety of nonhazardous fluids underground. Class V wells include stormwater drainage wells, cesspools, and septic system leach fields; however, the Class V well category also includes more complex wells that are typically deeper and often used at commercial or industrial facilities.

A national UIC database project was launched in 2008 and is not complete. Some EPA regions have databases that can be obtained by request through the Freedom of Information Act. There is a 2011 EPA Injection well inventory (U.S. EPA, 2012b), the statistics of which are summarized in Table 4.1. A database of Class I wells was published in 2007 by GWPC (2007a).

Table 4.1. 2011 EPA Injection Well Inventory

Category	Number
Class I hazardous wells	117
Class I nonhazardous and municipal wells	561
Class II wells	168,089
Class V wells	468,543
Number of states having no Class I wells	33

Source: U.S. EPA (2012b)

Of note is the much greater use of Class II and V wells compared to Class I wells. Several states and territories (36 at this time) do not have or do not allow Class I wells. In some cases, no application for Class I wells has been submitted because suitable hydrogeological conditions have not been found.

The classes have different construction requirements. Class I wells require a confining layer between the injection zone and the lowermost USDW. Class I federal construction requirements are found in 40 CFR §146.12 and dictate that all Class I wells have to be "cased and cemented to prevent movement of fluids into or between USDWs." Further requirements are that all Class I wells except municipal wells injecting noncorrosive fluids shall inject fluids through tubing and packer set immediately above the injection zone or tubing with an approved fluid seal as an alternative.

Class II wells that inject into an oil- or gas-bearing formation (typically sandstone) have a confining layer that defines the zone. This zone is typically below the lowermost USDW but may be above it. As with Class I wells, all Class II wells must be "cased and cemented to prevent movement of fluid into or between USDWs." There is no requirement for tubing and packer, but most EPA regions require them. Some states allow no surface casing; some allow no tubing or no packer (U.S. EPA, 2012a).

Figure 4.1 shows a schematic for a Class I well. The design includes concrete covering of all well casing down to the injection zone as well as a tubing and packer arrangement to monitor for well leaks from the injection tubing. The packer is the means of isolating the annular fluid from injection fluid at the bottom of the casing string. An annular space between the innermost casing and the injection tubing is filled with fluid the conductivity of which is monitored for indications of leakage from the injection tubing. Well and aquifer leakage is also monitored through required monitoring wells.

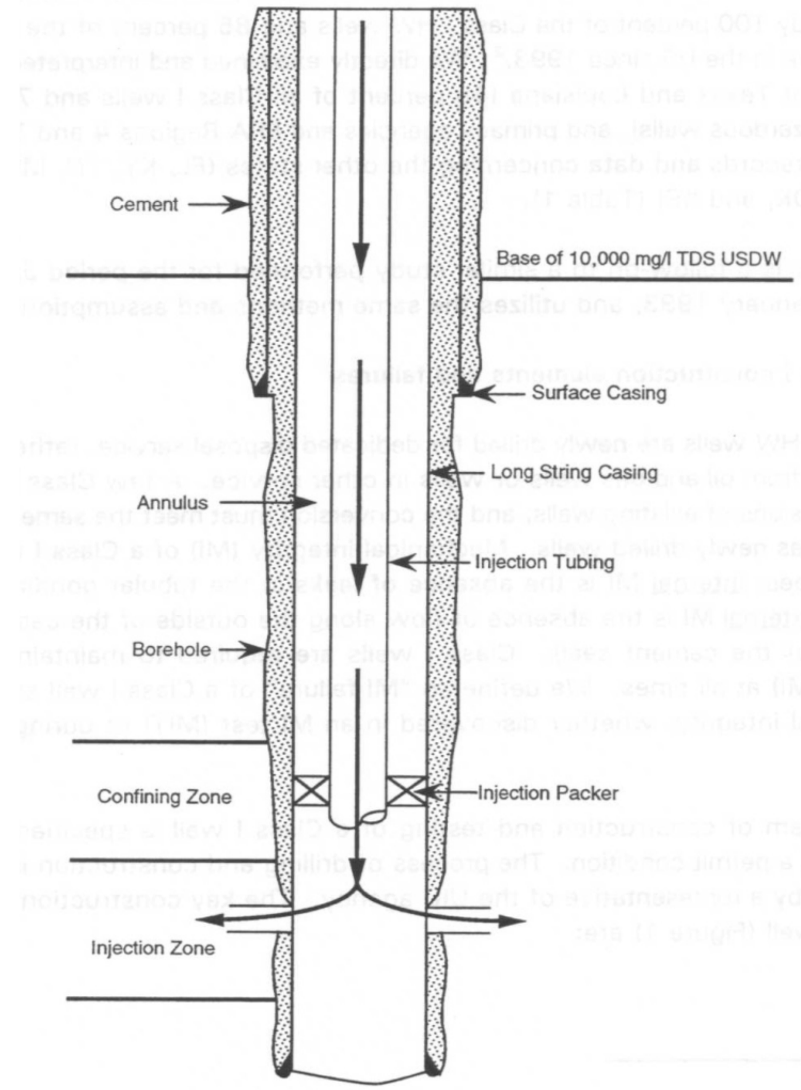

Figure 4.1. Schematic of Class I well.

4.4 Primacy

Primacy or primary enforcement authority is the authority to implement the UIC Program. To receive primacy, a state, territory, or tribe must demonstrate to EPA that its UIC Program is at least as stringent as the federal standards. The state, territory, or tribal UIC requirements may be more stringent than the federal requirements.

States can apply for primacy in the following ways:

- To gain authority over all classes of wells or Classes I, III, IV, V, and VI, state programs must be at least as stringent as the federal program and show that their regulations contain effective minimum requirements. State regulations may be more stringent. Such states are authorized under Section 1422 of the SDWA.

- To gain authority over Class II wells only, states with existing oil and gas programs may demonstrate that their program is effective in protecting USDW. Such states are authorized under Section 1425 of the SDWA.

- To gain authority over Class VI wells only, states may apply for Class VI primacy under Section 1422 of the SDWA for managing UIC GS projects under the Class VI Program. EPA will publish guidance for obtaining primacy for Class VI after the Final Geologic Sequestration Rulemaking (U.S. EPA, 2012c).

EPA has delegated primacy for all well classes to 33 states and 3 territories. It shares responsibility with seven states. If a state does not obtain primacy for all or some of the well classes, EPA implements the program directly through one of its regional offices. Currently, EPA implements the program for all well classes in 10 states.

Table 4.2 describes the UIC regulatory responsibilities as well as Class I well statistics for states of interest in this report. This includes states in the arid Southwest and Florida (included because of the large-scale use of DWI). Note the following:

- The primacy status of states for the well classes varies considerably.
- Class II oversight is frequently separated from that of the other well classes.
- There is a wide divergence of experience with Class I wells.
- In 2007, only Florida had injection wells for concentrate disposal, but in 2012 both Texas and Colorado also had permitted desal concentrate injection wells.

4.5 Minimum Federal Requirements

The UIC regulations establish specific performance criteria for each well class to assure that drinking water sources, actual and potential, are not rendered unfit for such use by underground injection of the fluids common to that particular category. The requirements are called “minimum” requirements that must be met in all oversight situations. States having primacy may institute more stringent requirements beyond the minimum ones. Areas of minimum requirements include:

- permit life
- area of review
- mechanical integrity testing
- other well testing
- monitoring
- construction
- logging
- operation
- reporting
- abandonment

Table 4.2. UIC Regulatory Responsibilities for States of Interest and Class I Well Statistics

State	EPA Region	State Regulatory Agencies Involved	Class I, III, IV, V Oversight Agency	Class II Oversight Agency	Prohibited Wells	# UIC Class I Wells[a]	# Municipal Desal Plant Class I Wells, 2007[b]	# Municipal Desal Plant Class I Wells, 2012[b]
Texas	6	TCEQ TRRC	TCEQ[c]	TRRC		98	0	2 permits; El Paso; 1 in progress (general permit for SAWS)[f]
New Mexico	6	NMED OCD of the New Mexico Energy, Minerals and Natural Resources Department	NMED and OCD[d]	OCD	I for hazardous waste	5	0	0; 1 application (Sandoval County), later dropped
Colorado	8	COGCC	EPA	COGCC		5	0	2 permits; ECCV, Sterling
Arizona	9		EPA	EPA	[e]	0	0	1 historical application for injection into a salt dome
	9	DOGGR	EPA	DOGGR		13	0	0
Nevada	9	NDEP	NDEP	NDEP	I, II	0	0	0
Florida	4	FDEP	FDEP	EPA	I for hazardous waste	168	36	50

Notes; COGCC=Colorado Oil & Gas Conservation Commission; DOGGR=Department of Conservation, Division of Oil, Gas, and Geothermal Resources; FDEP=Florida Department of Environmental Protection; NDEP=Nevada Division of Environmental Protection; NMED=New Mexico Environment Department; OCD=Oil Conservation Division; TCEQ=Texas Commission on Environmental Quality; TRRC=Texas Railroad Commission; [a]Wells from all industries, based on GWPC (2007a) report; [b]Based on Mickley et al. (2012); [c]Shared oversight with TRRC; [d]Mix of oversight; [e]All aquifers are considered drinking water aquifers—Class I injection is possible but would require aquifer reclassification, which has never been done and which would likely be an involved and unmapped process; [f]El Paso Kay Bailey Hutchison plant operates under a Class V authorization, although well is constructed to Class I standards.

Class I, II, and III permitted wells have two major technical requirements that are similar: (1) a mechanical integrity testing requirement established to assure that leaks do not result in significant movement of fluids into a USDW, and (2) an area of review requirement established for new wells to assure that existing, improperly completed, and abandoned wells or transmissive faults or fractures within the area of endangering influence do not provide avenues for vertical migration into USDW. Although the technical requirements for Class I, II, and III wells are similar, there are differences warranted by the nature of the waste, well design, and operational characteristics. The specific regulations that address each well class are found in 40 CFR §§146, 147, and 148.

4.6 Potential Use of Other Well Classes

On the basis of well class definitions, disposal of municipal desal concentrate may, under certain conditions, be possible in Classes I, II, V, and perhaps a future new class specifically for concentrate. These possibilities are examined further in the following section:

Class I: As an industrial waste, municipal desal concentrate has a designated category for disposal of Class I. Current DWI of membrane concentrate is through Class I wells. The injection zone must be below the lowermost USDW, and there are stringent construction requirements (tubing and packer, casing, cementing, for example) surpassed only by Class I—Hazardous requirements. Concentrate is rarely hazardous and different from most other industrial effluents because it has very few process-added chemicals; it is essentially concentrated raw groundwater.

Class II: Injection of concentrate into a Class II well has the advantage of disposing of municipal desal concentrate into a well that is already constructed. In Texas, for instance, nonhazardous concentrate may be used for enhanced recovery of oil and gas without getting a permit, although an approval is required from the Texas Railroad Commission, the regulatory group overseeing Class II wells. Most Class II wells are below the USDW, and the well design in many cases is as stringent as Class I wells. Matching the volume of concentrate to the capacity of Class II wells may result in the need for more than a single well as many Class II wells are of limited size. A concern is that a desal plant may have a much longer lifetime than the Class II wells used for enhanced recovery, which may make the option temporary. Presently, concentrate cannot be injected into Class II disposal wells.

Class V: Injection of concentrate into a Class V well has the advantage of a shallower, less costly well. The concentrate may need to be diluted with low TDS water to meet the TDS restriction of less than 10,000 mg/L, and the concentrate must meet primary (and in some states secondary) drinking water standards. This is typically not possible without dilution and sometimes would require removal of isolated contaminants. A large concern and challenge in Florida is meeting the gross alpha primary standard, and as a result many concentrates cannot meet Class V standards just on this parameter. The option is not practical with HR (high salinity) brine as it would require too much dilution water to meet TDS and other standards. The injection aquifer, which by definition is a USDW aquifer, may be exempted if the aquifer is not currently being used and will not be used in the future as a drinking water source, or if it is not reasonably expected to supply the public water system because of a high TDS content. An AE, if issued by the primary agency and approved by EPA, would not require dilution of the concentrate. If permitted the way Class V wells are currently permitted, there would not be the same casing and tubing and packer requirements as for Class I wells, resulting in lower costs.

To date, only one inland facility (the KBH Desalination Facility in El Paso) has sought and received a Class V permit for injection of municipal desal concentrate. The well is constructed to Class I specifications, however, to minimize risks. For the operating conditions of the plant, meeting the Class V standards requires diluting the concentrate with fresh water. The facility has obtained an AE, which would not require dilution of the concentrate to meet the drinking water standard (maximum contaminant level [MCL]) for arsenic.

Class VII (hypothetical new class): The potential advantage would be a class based on concentrate characteristics, which might mean in some cases (it would likely be case by case) fewer design and operating constraints and thus lower costs. The special class might also represent important policy changes reflecting the urgency of finding CM solutions for municipal desal concentrate using an efficient permitting process.

The effort involved to accomplish a new class will likely require much money, effort, and time. The new classification for CO_2 sequestration Class VI, took several years and a considerable lobbying effort by powerful entities, including the U.S. Department of Energy, two Presidential administrations, and the private energy sector.

These possible options have the potential to address the cost aspects of constructing and operating a concentrate disposal well. Other well permit issues, such as elapsed time and uncertainties regarding the final disposition from permit application to final well operation, also need attention.

Chapter 5

Deep Well Injection: Barriers and Potential Solutions

5.1 Case To Be Made for Focusing on DWI

The focus on DWI was explained in Chapter 3. To recap, concentrate disposal (as opposed to beneficial use) occurs at nearly all municipal desal facilities and is a limiting factor in the implementation of municipal desal plants. This is particularly true in the arid Southwest, where concentrate disposal options most frequently used elsewhere are not widely available. Of the five conventional concentrate disposal options (surface water discharge, discharge to sewer, evaporation pond, land application, and DWI), DWI has the greatest potential for increased application; however, there are several barriers that presently limit its implementation. This chapter discusses these barriers and possible means of addressing them.

5.2 General Barriers to DWI Implementation

As detailed in Table 5.1, there are several regulatory and permitting barriers that prevent DWI from being more widely available for disposing of municipal desal concentrate where hydrogeologic conditions are suitable. Most notably, many UIC regulations are not appropriate for municipal desal concentrate, which is generally nonhazardous. As exemplified in the EPWU case study described in Chapter 9, the definition and regulations surrounding USDWs also present a challenge for widespread implementation of DWI. In addition, regulators in many states are not familiar with the UIC process for Class I wells; there are often multiple agencies involved in the permitting process; and some states (e.g., Nevada) do not allow Class I wells. Changes to the regulatory and permitting process surrounding DWI should address these issues, with the goal of making permitting less burdensome, time-consuming, uncertain, and costly. At the same time, changes should recognize and address all scientifically based environmental concerns surrounding DWI.

Although regulatory issues appear to represent the most limiting barriers to DWI, obstacles go beyond regulatory concerns and include impediments in the areas of:

- hydrogeology
- water quality
- water quantity
- cost
- environment
- technology
- public/political issues

Table 5.1 summarizes presently identified barriers. The entries are not necessarily independent or complete. They are listed by category with a short description included.

5.3 Framing Events for Regulatory Barriers and Possible Changes

Three events have occurred in the past 5 years that help to characterize DWI regulatory challenges and suggest changes that might address the regulatory barriers. These events include the publication of a GWPC report on groundwater issues in 2006, the 2006 UIC National Technical Workgroup Report, and the development of a General Permit for desal concentrate disposal in Texas. Each of these events is described below.

5.3.1 2006 GWPC Report

In 2006, the GWPC developed the Ground Water Report to the Nation…A Call to Action (GWPC, 2007b).[2] This report describes, among other groundwater issues, the challenges in implementing DWI and the problems associated with the UIC Program in general. The report identifies the main UIC problems as follows:

- Some UIC regulations are unnecessarily burdensome and have no environmental benefits and, as a result, place impediments on beneficial new technologies that provide new sources of safe water supplies (e.g., desal and associated concentrate disposal) and the ability to capture and sequester CO_2. The GWPC message was for EPA to revise the classification scheme, which was subsequently done for CO_2, creating a new Class VI for sequestering carbon.

- Severe shortfalls of UIC Program resources have limited the implementation of standardized programs and program revisions. The GWPC message was for Congress to increase annual funding for the UIC Program.

Class V wells represent a higher risk area than generally perceived. Class V regulation has historically been and continues to be an area with a lack of clarity, which is somewhat understandable given the large number of wells and several types (20 subcategories) of wells and injectates. The GWPC message was that from an environmental impact perspective, Class V wells can carry more risk than Class I and II wells and should receive more study and regulation.

2. GWPC is a nonprofit 501(c)(6) organization consisting of state groundwater regulatory agencies that come together within the GWPC organization to mutually work toward the protection of the nation's groundwater supplies. The purpose of the GWPC is to promote and ensure best management practices and fair but effective laws regarding comprehensive groundwater protection.

Table 5.1. Barriers Affecting Implementation of DWI for Inland Desal CM

Barrier	General Explanation of Category
Regulatory—General 1. Multiple agencies involved 2. Lack of UIC Program funding 3. Limited experience in some states 4. Different mentalities for Class I and II regulations 5. Resistance to making changes 6. Regulations are not specific for desal concentrate	Factors that limit permitting process efficiency, create uncertainties and delays, and inhibit possibilities for change
Regulatory—Specific to Well Class 7. Definition of USDW (Class I) 8. Non-use (or prohibition) of Class I in some states 9. Primary standards requirement for Class V (linked to USDW definition) 10. Class II's only option is EOR.	Factors limiting use of individual well classes, or increasing costs, resource loss, and unavailability of DWI as a viable CM option
Cost 11. Feasibility study—cost of USDW 12. Feasibility study—general costs (identification and assessment of aquifer hydrogeology and other characteristics) 13. Class I compliance costs 14. Capital cost of final well system 15. Operating cost of final well system	High costs associated with determination of DWI feasibility (test well, testing, hydrogeological studies) and capital costs of the well system
Hydrogeology 16. Feasibility of injection aquifers not assured 17. Site properties (aquifer confinement, porosity, permeability, capacity) may dictate process changes. 18. Distance of suitable aquifers from facility 19. Seismic concerns	Factors that can limit implementation of DWI system

Barrier	General Explanation of Category
Water Quality 20. Potential for precipitation prior to injection 21. Potential for downhole precipitation/plugging 22. Unknowns associated with high salinity brines	Factors that require study and could complicate implementation of DWI system
Water Quantity 23. Aquifer capacity may limit concentrate volume or injection life.	Volume limitation
Environmental risk 24. Migration from injection aquifer to other aquifers 25. Leaks from well 26. Potential earthquakes	Barriers addressed by regulatory requirements (not necessarily suitable for concentrate)
Public Perception 27. Industrial classification 28. Association of DWI with hydraulic fracturing, or "fracking" concerns	Most permits require public review/comment periods; public perceptions affect public approval, and public hearings can significantly delay the process.
Lack of Technical Knowledge 29. Guidelines for evaluating downhole injectate–aquifer compatibility 30. Unknowns regarding high salinity downhole effects	Technical areas that could benefit from research study

Notes: CM=concentrate management; DWI=deep well injection; EOR=enhanced oil recovery; UIC=underground injection control; USDW=underground source of drinking water

5.3.2 2006 UIC National Technical Workgroup Report

The UIC National Technical Workgroup is composed of experts from across EPA's UIC Program. It periodically investigates specific issues and generates reports. In December 2006, the workgroup issued a report entitled Drinking Water Treatment Residual Injection Wells: Technical Recommendations as part of an ongoing effort to develop an agency position on drinking water treatment residual (DWTR) disposal (U.S. EPA, 2006). The definition of DWTR includes, but is not limited to, desal concentrate. The study group identified 104 currently permitted or authorized injection wells classified as Class I nonhazardous or Class V wells and their permit requirements. The requirements were stated to be generally similar to federal Class I requirements. The report makes the statement:

> The resulting recommendations address the concern that the existing regulations contain unnecessary administrative, construction, operation, and monitoring requirements because they are not specific to DWTR injection. Another benefit of using this (recommended) approach is that it allowed for flexibility and additional cost saving opportunities. (U.S. EPA, 2006, p. 3)

The terms "appropriate" and "flexible" are used throughout the report, suggesting that permit requirements could be improved if made on a case-by-case basis that reflected the nature of desal concentrates and other DWTR.

5.3.3 General Permit (Texas)

In the early 2000s, representatives from the Texas Water Development Board (TWDB) met with EPA to explore potential changes to UIC Class II regulations to facilitate injection of municipal desal concentrate under the oil and gas UIC category. EPA indicated that it did not have the resources, nor was the agency inclined to make rule changes to facilitate CM through the Class II program. EPA suggested that Texas should instead consider relaxing its Class I regulations (but keep them equivalent to or more stringent than the federal regulations) for municipal concentrate that could be shown to meet appropriate standards. They suggested a general permit for Class I nonhazardous wastes for municipal drinking water desal concentrate.

In 2007, Texas began developing a General Permit for Class I desal concentrate and other drinking water residuals. The permit, issued in 2009, offers several changes relative to the existing Class I requirements, including:

- a 0.25 mile radius for review and public comment (as opposed to the 2.5 mile radius previously required for detailed characterization and study)
- no requirement for concrete on all casing in all casing strings if it can be shown that the design is adequate for the risks
- less frequent mechanical integrity tests (every 5 years as opposed to annually)
- permit review every 10 years (as opposed to every 5 years)

The major advantage is that the General Permit is more reliant on professional geologists interpreting the data and applying their professional engineer (PE) seals rather than requiring internal agency review. The end result is the intent to get permits approved in 90 days rather than the typical 1 year minimum. The importance of the General Permit approach taken by Texas is that it is a path to making meaningful changes at the state level and still meeting the requirements of the federal regulations.

Together, the GWPC and UIC National Technical Workgroup reports and the Texas General Permit approach offer the following:

- Confirmation of the real regulatory challenges associated with the injection of municipal desal concentrate
- Examples of how regulations and permitting might feasibly change for the better
- A concrete example of one apparently successful approach to making useful changes. SAWS is the first water agency in Texas to apply for and obtain a Class I permit under the new General Permit approach, and initial indications are that this has made the DWI permitting process much quicker and simpler.

5.4 Possible Regulatory Requirement Changes

This section describes several possible regulatory changes (identified prior to the project workshop) that would facilitate more widespread application of DWI in the arid Southwest. These changes aim to address environmental concerns and make permitting less burdensome, thereby reducing capital and other up-front costs.

5.4.1 General Regulatory Requirements

Changes to procedural and technical requirements. Changes and improvements to regulatory requirements should consider the value and burden of both procedural and technical requirements. Procedural requirements are typically represented in a process flow chart or roadmap that describes the required steps involved in navigating the permitting process. This type of roadmap also includes the timing and scheduling of the steps, such as the time limit for agency application review, the frequency for permit renewal, and the need for public comment on every permit. Detailed technical requirements include specific testing, construction, and monitoring.

Changes that reflect the general nature of concentrate. Concentrate is different from most industrial wastewaters in that the water quality is not strongly defined or determined by process-added chemicals. Concentrate is, to a large degree, concentrated raw water. This suggests that different regulations may be more applicable to concentrate (i.e., regulations that differ from those for other industrial wastes).

Changes that consider the site-specific nature of concentr**ate.** Because the characteristics of raw water are site-specific, the concentrates generated by the membrane process are therefore also highly site-specific. The specific composition of concentrate (e.g., the constituents and their concentrations) as well as the salinity can vary. The site-specific nature of concentrate indicates a need for flexible regulations.

The recommendations of the UIC National Technical Workgroup stress the terms “flexible” and “appropriate” and apply these to the technical type of regulatory requirements. One interpretation of flexible and appropriate is that permit conditions be defined more on a case-by-case basis than is presently done. The Texas General Permit includes improvements to both procedural and technical requirements, but it appears to provide a set of requirements applicable to concentrate but without consideration for a case-by-case flexibility.

5.4.2 Regulatory Changes Specific to Class

- Change the definition of USDW for municipal concentrate (Class I). As described in previous chapters, an aquifer is considered to be an USDW if it has TDS levels less than 10,000 mg/L. This definition holds despite other water quality constituents that might be present (and how much it would cost to remove these constituents if the aquifer was to be used as a source of drinking water) and the likelihood that the aquifer would ever be used as a source of drinking water given its depth, geologic formation, or location. Given these factors, it seems the site-specific nature of the aquifer and adding a treatability component that takes into account the existing water quality of the aquifer are relevant factors that should be taken into consideration and integrated into the definition of a USDW.
- Remove/change the requirement of meeting primary drinking water standards for injection under Class V. This change also ties into the issues of how USDW is defined and the AE process. One approach would be to make non-degradation of the aquifer water the applicable requirement or base the permitting process on the ability of existing treatment technologies to render the receiving aquifer water potable, if or when needed.
- Allow injection of desal concentrate in Class II disposal wells (in addition to the allowance for enhanced oil recovery).

5.4.3 Other Changes

Level of Change

In states that have primacy over the UIC Program, changes must be made at the state level. Changes at the state level will likely be much easier to make than changes at the federal level (e.g., a federal general permit under Class I to apply in states where EPA retains primacy).

Public and Stakeholder Outreach

Effective change will require public and stakeholder outreach and education efforts. For example, in Colorado, ECCV and Sterling were confronted with concerns by stakeholders that DWI would have the same impacts as hydraulic fracturing. These concerns need to be addressed through education and outreach efforts in order to gain public support.

Interagency Cooperation

In order for effective change to occur, the sharing of information and coordination across local, state, and federal agencies will be necessary.

Recommended Research

To facilitate changes in the permitting process, several research needs should be addressed, including the following:

- Effects of injection of high salinity concentrate
- Effects of downhole compatibility issues and means of determining effects

- Effect of organic level on antiscalant
- Effects of aquifer media on adsorption phenomena
- Updated cost models
- Characterization of Class II aquifer (capacity, well size, depth with respect to USDW)

Path for State Reconsideration

States that currently do not allow Class I should allow some avenue for municipal desal concentrate injection (e.g., a viable process for reclassifying some groundwaters in Arizona as not USDW).

Chapter 6

Evaporation Ponds

Evaporation ponds are a relatively low technology approach to CM in which the concentrate is pumped into a shallow, lined pond and allowed to evaporate naturally using solar energy. Evaporation ponds can be a viable option for disposing of low volume concentrate flows in regions with relatively warm, dry climates, high evaporation rates, level terrain, and low land costs (Mickley, 2006).

This chapter describes the opportunities and challenges associated with the use of evaporation ponds for concentrate disposal, including key cost considerations and permitting requirements and processes.

6.1 Opportunities and Challenges

Evaporation ponds are relatively easy and straightforward to construct. Properly constructed ponds generally require little maintenance (except for pumps to convey the desal concentrate to the pond, no mechanical equipment is required). For smaller volume flows, evaporation ponds are frequently the least costly means of disposal, especially in areas with high evaporation rates and low land costs. Under suitable climatic conditions, evaporation ponds can enable the operation of desal plants under ZLD conditions: no liquid waste leaves the plant boundary (NRC, 2008).

Despite these advantages, there are a number of factors that often preclude the use of evaporation ponds as a means of CM (Mickley, 2006; NRC, 2008):

- The most significant issue associated with evaporation ponds is the substantial land requirement. Land requirements are a direct function of evaporation rates and concentrate volume.
- Seepage from poorly constructed evaporation ponds can contaminate underlying potable water aquifers.
- Most states require the use of impervious liners of clay or synthetic membranes to prevent the saline concentrate from percolating into the water table. Monitoring requirements also may be applicable. These requirements substantially increase the costs of disposal to evaporation ponds.
- Because of the extensive land requirements and costly liners, ponds are generally only feasible for small volume concentrates.
- If the ponds accumulate solids at a high rate, they may need to be dredged and disposed of in a landfill or replaced during the life of the desal plant. This can be a significant added cost.
- Despite preventative berms at the pond edge, there is a potential for wind to blow mist into work areas and onto adjacent land. This may be an environmental and human health concern, particularly if the concentrate contains hazardous materials (e.g., concentrated levels of arsenic or other constituents found in the source waters).

Evaporation ponds can have the potential to provide wildlife habitat; however, elevated levels of salinity and trace elements in the discharge water may have negative impacts on breeding and migrating birds, as was seen with the effects of selenium at the Kesterson National Wildlife Reserve (NRC, 1989; Hannam et al., 2003; NRC, 2008 from Hoffman et al., 1988).

Whereas maintenance needs can be relatively minor, the need for active erosion control and wildlife management should be considered in all cases (NRC, 2008). Other factors that affect environmental water quality include sufficient basin storage volume to prevent overflow in case of major precipitation events and location of sites topographically above long-term flood reoccurrence intervals of nearby water sources (NRC, 2008).

Finally, researchers have been investigating approaches to enhance net evaporation through methods such as spraying water into the air and evaporating water from porous vertical surfaces. Some of the methods will likely reduce evaporation pond area requirements and reduce capital costs significantly. Operating costs are typically increased with the use of these methods, but the net result is a decrease in total annualized costs.

6.2 Cost Factors

The costs associated with construction of the evaporation ponds are highly site-specific. For some applications, an evaporation pond can be a cost-effective disposal alternative; in other locations, costs can be prohibitive (Mickley, 2006). Mickley identifies the major factors contributing to the cost of an evaporation pond as follows:

- land costs
- earthwork
- lining
- miscellaneous costs

The cost of land can vary greatly from site to site. Costs vary not only from city to city but also in the vicinity of a particular municipality itself. Earthwork costs include expenses for activities associated with land clearing and dike construction. The major variable in dike design/cost is the required height of the pond. The pond depth is set by the volume required to accumulate sludge and the height required to prevent overflows (Mickley, 2006).

Miscellaneous costs can potentially include expenses associated with leak detection, disposal of concentrated salts, and contaminated ground/groundwater clean-up. Seepage monitoring or leak detection may be required depending on the pond construction and proximity and quality of nearby aquifers.

In addition, the solids collected in the pond may require periodic disposal if the pond is not large enough to hold the total solids volume produced during the life of the plant. Costs associated with solids disposal include dredging the solids from the pond (if feasible), transporting them, and landfill disposal costs. In isolated cases, the solids may require stabilization if hazardous materials (e.g., heavy metals) are present. A land-intensive alternative is to cover and retire the pond and construct a new one.

Finally, the earth surrounding the evaporation pond may become contaminated by seepage or pond overflows. Clean-up of contaminated soils can be a significant cost factor (Mickley, 2006).

As reported in the Alamogordo, NM case study developed as part of this research (see Chapter 12), the U.S. Bureau of Reclamation (Reclamation) operates three evaporation ponds at its Brackish Groundwater National Desalination Research Facility (BGNDRF) in Alamogordo. Two of the ponds have a capacity of 341,000 gallons (without freeboard), and the third pond has a capacity of 721,000 gallons (without freeboard). Each pond is constructed with two layers of high density polyethylene (HDPE) with a leakage detector system between the layers. The first layer is 80 mils thick, and the secondary liner is 40 mils thick. A 200 mil HDPE geonet acts as a spacer between the primary and secondary liners. The installed cost for these ponds, which were built in 2007, was about $562,700, excluding land costs (only about $0.40 per gallon of capacity for a 1 mgd facility). Reclamation estimates annual repairs and maintenance to be around $1000 per year for simple repairs to the evaporation ponds. Reclamation costs are relatively inexpensive compared to other costs reported in the literature, in part because land costs are not included in this estimate.

6.3 Permitting

Permits for evaporation ponds are not specifically required under either the National Pollutant Discharge Elimination System (NPDES) or UIC Program; however, individual state requirements and permits apply. In most states, the permit process seems to be relatively straightforward, although permit applications can require extensive technical information, especially related to the assurance that the ponds will not contaminate nearby groundwater.

Because the potential for groundwater contamination exists with any evaporation pond, most states require impervious liners of clay or synthetic membrane. Where the waste discharged to the pond can be verified as nonhazardous and the groundwater in the area is of poor quality or substantially distant from the pond, a single liner may be acceptable. If the water has the potential to contain even trace amounts of hazardous substances, or high quality groundwater exists in shallow aquifers, double-lined ponds with leak detection systems are typically required (Mickley, 2006).

Some states also require measures to prevent adverse effects to wildlife. For example, to comply with New Mexico Environment Department (NMED) permit requirements, Alamogordo will include netting around its planned evaporation ponds to prevent birds from entering. In Texas, however, no special measures for wildlife protection are required.

A Permitting Example: Texas Land Application Permit

In order to construct and operate an evaporation pond for concentrate disposal in Texas, desal facility operators must obtain a Texas Land Application Permit (TLAP) from the Texas Commission on Environmental Quality (TCEQ), which reports that permits are typically issued within 6 to 9 months from the date the permit application is submitted (TCEQ technically has 330 days to issue a permit). This timeframe includes a public comment period.

TCEQ reports that the technical portion of the permit application is quite extensive and most often completed by consultants. Several studies are typically necessary, including soil surveys and information on groundwater and wells within a certain area of the proposed pond site. Throughout the permitting process, there is typically a lot of back and forth between TCEQ and the applicant. Once the application is submitted, TCEQ conducts an administrative review and sends out a notice for public comment. In certain circumstances, a hearing may be required.

Following the administrative review, the permit application is reviewed for technical information and adequacy. During the technical review, TCEQ determines or confirms the proposed size of the pond(s) and whether liners and leak detection will be necessary. TCEQ's main concern is that the water stays in the pond (i.e., it is cautious of infiltration and overflow). Ponds can be lined with compacted soils in some cases or a synthetic liner. Storage capacity is calculated based on the average rainfall and evaporation rate for the area, and ponds are built to meet worst-case scenarios. TCEQ requirements assume that the daily average flow is at capacity every day, there is no accumulation from year to year, and that there must be 2 ft of freeboard. Once the technical review is completed, TCEQ and the applicant have 2 weeks to negotiate final requirements.

TLAP is often the only permit needed for concentrate disposal via evaporation ponds. If solid waste is being kept on-site, the desal facility will also likely need to obtain a solid waste permit.

It is interesting to note that because desal concentrate is considered an industrial waste in Texas, the TLAP application and requirements for evaporation ponds are different for a desal facility than they are for a municipal water treatment plant (which falls in the municipal waste category). There are actually fewer requirements associated with TLAPs for desal concentrate evaporation ponds because there are fewer requirements related to the treatment process/design chain.

Chapter 7

High Recovery Processing

7.1 Introduction

One approach to increasing the potable water yield from desalting, which also reduces the volume of concentrate, can be accomplished using what are referred to as HR processes. Although the use of HR processes is not a CM option per se, it does alter the volume and nature of the residuals generated by the desalting process and, therefore, ultimately impacts the management of the remaining concentrate.

The volume of first-pass concentrate in municipal desalting systems can be quite large, amounting to 15 to 35% of the input volume. Although HR processes may be implemented at the time of the initial plant construction, within the municipal desal industry HR processing is most often considered as additional processing of concentrate from an existing facility. This has been referred to in different ways, including concentrate minimization and volume reduction.

In circumstances where no liquid crosses the plant boundary, according to strict definition HR processing is referred to as ZLD processing. There is a lack of consistency in the literature: ZLD is sometimes used to denote processing all the way to solids, and when this is not the case, HR is referred to as near-ZLD processing.

The first-pass concentrate is most typically generated by a BWRO step but may result from processing by an EDR or NF step. In a limited number of cases and depending on the feed water quality, HR (i.e., recovery rates >90%) may also result from the initial membrane step.

HR processing is widely and increasingly used in other industries and is now more frequently being considered for municipal desal settings. The reasons for this are listed here:

- There are significant and increasing challenges in managing first-pass concentrate via the five conventional concentrate disposal options (e.g., surface water discharge, discharge to sewer, DWI, evaporation ponds, land application). HR (including ZLD) processing is another way to address CM beyond the five conventional disposal options and beneficial use of concentrate.
- It is helpful to make more efficient use of the water resource (i.e., to increase usable water yields).
- It can be an option to provide increased product water when increased facility capacity is not viable.
- It satisfies the perception (albeit not always correct) that it will be simpler to dispose of a lower volume of concentrate than a higher one.

Although HR processing offers an option for managing concentrate, there are barriers to its implementation in the municipal setting. Higher salinity brine may pose additional management challenges for conventional disposal options. Processing all the way to solids requiring disposal brings a new disposal option to municipal desal facilities—that of landfilling solids, which can be costly.

7.2 HR Processing Options

HR processing arguably began with the development of ZLD systems in the 1970s, which were designed to limit discharges from power plants into the Colorado River. The initial systems treated cooling tower blowdown and consisted of thermal evaporators known as brine concentrators (BCs). Brine effluent from the BC went to either an evaporation pond or another thermal evaporator known as a crystallizer that produced mixed solids. In terms of concentrate/brine flow, this may be represented as either:

- Blowdown → BC → evaporation pond
- Blowdown → BC → crystallizer (thermal evaporator producing solids)

Because of the high capital costs and energy requirements associated with the evaporator steps, a next generation of systems used BWRO to reduce the volume of concentrate going to the thermal process steps. These systems included:

- Blowdown → BWRO → BC → evaporation pond
- Blowdown → BWRO → BC → crystallizer

Some systems included only an HR membrane step:

- Blowdown → HR–BWRO → evaporation pond

This is within the context of ZLD processing of cooling water blowdown originating from concentration of surface water. In most municipal desal situations, the concentrate from an initial BWRO system results from concentration of brackish groundwater. Relative to the cooling water situation, it frequently has higher concentrations of sparingly soluble salts.

Further volume reduction by a second membrane system prior to thermal evaporation steps may require reduction of sparingly soluble salts prior to the second membrane step:

- BWRO concentrate → coagulation → BWRO/SWRO → BC → evaporation pond
- BWRO concentrate → coagulation → BWRO/SWRO → BC → crystallizer

Where:

coagulation = some form of chemical coagulation to reduce the level of sparingly soluble salts and silica, which limited the BWRO recovery

HR processing of desal concentrate has been the subject of extensive research, and today several other processing options have been considered, some of which have patents and are commercially available.

The bulk of the research has demonstrated that HR processing is technically feasible, but it remains costly in all its present forms. The high capital costs result from the additional processing equipment required. The high energy costs are associated with the use of thermal evaporative equipment. These energy costs can be lessened by membrane volume reduction steps, but these in turn impose high chemical costs and increased solids requiring costly disposal. As a result, HR processing used in many other industries is not usually cost-effective within the municipal water supply setting.

7.3 HR Costs

HR processing of concentrate requires additional treatment equipment with unit capital ($/gpd) and, in most cases, operating costs ($/gpd and $/kgal) greater than those of first-pass RO, EDR, or NF equipment. Consequently, the cost per volume of additional product water recovered by the HR processing steps can be considerably higher than the cost per volume of the first-pass recovered water.

Table 7.1 shows representative capital equipment costs and energy requirements for a first-pass BWRO system and various HR processing steps. The fourth column gives the unit capital cost where those of the BC, crystallizer, and evaporation ponds are shown to be greater than those for the BWRO equipment. Similarly, with the exception of evaporation ponds, the energy requirement is also greater.

The HR processing steps are treating smaller volumes than the initial BWRO step, so the impact of the cost differences of the processing steps is less than that suggested by Table 7.1. In a 2008 study (Mickley, 2008), the capital and operating costs of five commercial ZLD processing schemes were estimated for eight different concentrate compositions of the same brackish salinity. The initial BWRO processing step was assumed to have a recovery of 75%. The HR processing steps treated the concentrate, which represented 25% of the original feed volume. The total capital cost of the HR steps ranged from 60 to 130% of the original BWRO step. Total operating costs ranged from 45 to 190% of the original BWRO step. A main finding of the referenced report was the significant effect of salinity and composition on individual HR step performance and costs, and consequently on total HR system costs.

Table 7.1. Process Equipment Capital and Unit Capital Costs and Energy Requirements

Process Step	Size in mgd (gpm)	Capital Cost (M$)	Unit Capital Cost (M$/mgd or $/gpd)	Energy Requirement (kWh/kgal)
BWRO	1 (694)	2.5	2.5	3
BC	1 (694)	10	10	75–95
Crystallizer	0.036 (25)	2.5	70	200–250
Evaporation pond[a]	0.036 (25)	2.0	55	Low

Notes: BC=brine concentrator; BWRO=brackish water reverse osmosis; [a]Assumes net evaporation rate of 2.5 gpm/acre and a per acre cost of $200,000.

7.4 HR Technologies

The Mickley (2008) study considered commercially available ZLD processing schemes that were in substantial use at the time of the study. These schemes correspond to the processing options discussed in Section 7.2.

A key to achieving HR is in how to address precipitation/scaling potential in the concentrate feed to the volume reduction (second desal) step treating concentrate. Various approaches include the following:

- Precipitates are inhibited from happening within the desal equipment.
- Precipitates are allowed to happen within the desal equipment.
- Precipitating species are removed before desal steps.
- Unique processing sequences are used that allow HR by other means.

In addition to the general technologies discussed in Section 7.2, several other HR technologies that utilize these approaches have been developed or are undergoing research.

Additional reports contain more detailed discussion of HR processing technologies and performance considerations (e.g., Mickley, 2008; Drewes, 2009; Brandhuber and Burbano, 2013).

7.5 Status of HR Processing at U.S. Municipal Desal Plants

In the last decade, HR processing has been considered in several initial feasibility studies for municipal desal; however, it typically does not make it past the initial screening of processing options. To date there are only a limited number of HR municipal desal facilities: the first in Tracy, CA, and others being implemented in Florida. Two examples include:

- A system at the Deuel Vocational Institute in Tracy, CA is touted as the world's first BC system as a key component of an RO drinking water plant at a ZLD facility. It treats 250 gpm of groundwater RO concentrate using a seeded slurry BC to reduce the concentrate volume by 97%. The remaining 3% goes to evaporation ponds. The system was commissioned in 2009.
- Palm Coast, FL, Water Treatment Plant #2 is a 6.4 mgd NF facility currently discharging concentrate to a canal. Permit renewal was denied in 2006 because a mixing zone was no

longer allowed. The facility was given a 48 month administrative order to allow continued operation. After studying several alternatives, a pilot lime softening/MF/RO system to treat the NF concentrate was successfully operated. Over 80% of the concentrate was recovered to give an overall recovery rate of 98%. The final concentrate was mixed with lime process sludge that was further mixed with sludge from WWTP #1 and used for road base stabilization. This approach avoids concerns with surface water discharge, including upcoming numerical nutrient criteria.

7.6 Barriers to Implementation of HR Processing at Municipal Sites

There are several barriers to the broader use of HR processes at municipal water utilities, including:

- Cost
  - High capital and operating costs make HR approaches cost-ineffective for most municipal water suppliers.
- Regulatory
  - As described in Chapter 3, the regulatory barriers are similar to those for lower salinity concentrate, with some differences. For example, with DWI, high salinity concentrate is less likely to be suitable for Class V injection.
- Possible increased disposal costs or technical challenges
  - For DWI, the higher salinity brine may result in higher precipitation potential within the well and injection aquifer.
  - For evaporation ponds, the higher salinity leads to lower evaporation rates, which requires more pond area per volume of concentrate/brine. This results in higher cost. Typically, in spite of the lower evaporation rates, the higher salinity reduces the time until the pond fills with solids. This in turn leads to increased costs associated with additional pond clean-outs or the construction of new ponds.
  - For landfills, the solids from the pretreatment steps and possibly from final crystallization or evaporation ponds require disposal at a suitable landfill. Landfill costs can be high for disposal of solids or near-solids, including costs for hauling, possible solidification, and final disposal. In some cases (likely limited), highly concentrated brines or mixed solids can be hazardous, which can significantly increase disposal costs.
  - For surface or sewer discharge, the options are somewhat less suitable; discharged solids load may be the same as for lower recovery concentrate but with less accompanying water, such that greater levels of dilution may be required.
  - Experience is limited; there may be other effects of higher salinity brine on DWI and evaporation ponds.

- Technology
  - Some vertical BCs do not comply with California height limits.
- Water quantity
  - Higher salinity brine has a greater impact for a given volume than lower salinity concentrate.
- Water and environmental quality
  - Higher levels of concentration from HR processing lead to higher levels of contaminants, which may render the concentrate/brine hazardous.
  - There are possible greater impacts of the higher salinity/higher constituent concentrations; as previously mentioned, these impacts are countered somewhat by a reduced volume, which results in a similar salt load.
- Public perception
  - This is perhaps better than for conventional recovery concentrate, as the smaller volume may be perceived as having less environmental impacts.
  - More efficient use of water resources may be positively perceived.

7.7 Changes Sought (Specific for HR Processing)

- Lower costs
  - for both capital and operating costs, through continued research and innovation
- Clarity on research issues
  - effects of high salinity brine on DWI feasibility and performance
  - effects of high salinity brine on evaporation pond feasibility and performance
  - likelihood of brine and solids from various HR operations being hazardous

7.8 Possible Outcomes (for Reducing Barriers)

- Clarity gained from research
- Change in regulations (similar to that for conventional concentrate)
- Impact of new technologies on costs

Chapter 8

Overview of Concentrate Management Case Studies

A series of water utility case studies has been developed as a means to gain a greater understanding of the options and challenges faced by water suppliers in developing inland desal operations, with a focus on the CM options considered and selected, the basis for the selected CM approach, and the cost and permitting issues associated with those CM options. Each case study is provided in the chapters that follow. In this chapter, an overview of the case studies' key issues and findings is provided in summary form. Most of the relevant information is provided in Table 8.1.

In selecting the case studies, the project team aimed to obtain a mix of geographic locations within the arid Southwest. Examples from Florida were also selected because DWI has been implemented on a wide scale throughout the state. In addition to geographic variation, the project team also aimed to obtain a cross-section of CM permitting issues and lessons learned. Although we tried to include case studies of different disposal methods, most of the entities that have implemented desal in the arid Southwest have used DWI as their primary method for managing concentrate. This is reflected in the case study examples.

The case studies included in our analysis consist of the following utilities:[1]

- EPWU, which faces severe limits on its allocation of fresh groundwater and surface water, operates the largest inland brackish groundwater desal facility in the United States. The 27.5 mgd facility began operation in 2007. The largest single challenge facing the utility was getting an approved CM approach, which involves DWI under the UIC regulatory program delegated to TCEQ, in accordance with the federal SDWA. This took several years and a considerable sum of money for various studies to obtain the permit and begin operations. Other CM options considered included evaporation ponds, which were economically prohibitive (see Table 8.1); other options (e.g., discharge to surface waters or sewers) were not feasible.

  CM challenges still exist for EPWU, primarily related to the need to have the injectate meet federal drinking water standards (MCLs) even though the existing quality of the receiving groundwater makes it very unlikely to be considered as a potential drinking water source and would require extensive treatment if ever tapped for water supply purposes regardless of the concentrate. This MCL requirement is associated with the Class V UIC permit under which EPWU operates and has necessitated diluting the concentrate (and other operational adjustments) in order to make the injectate comply with the MCL for arsenic. This is expensive and wastes scarce water resources that could

1. Additional abbreviated inland desal case studies have been examined for Brownsville, TX, Sterling, CO, and the North Miami Beach Norwood-Oeffler Water Treatment Plant, FL. These cases were used to gather information to supplement the main case studies summarized here. These supplemental sites will be included in the full project report and are not included in this chapter because it is intended to be concise, and the additional insights provided by the supplemental sites are limited.

otherwise be used to meet the region's water supply needs. EPWU has requested and obtained an AE under Texas UIC regulations, which would be the first step prior to requesting TCEQ's elimination of the requirement that concentrate meet MCLs. AE approvals have been obtained from state and federal regulators.

- SAWS is establishing a groundwater desalting facility to help meet growing demands in a highly water-limited setting where freshwater extraction from the Edwards Aquifer has been strongly regulated in response to adverse impacts from prior overexploitation of the aquifer. The range of CM options was evaluated, and DWI was selected as the most suitable (the only other viable alternative was discharge to the San Antonio River, which, while feasible under current standards, would likely have undesirable impacts). SAWS is the first utility to use the new Texas General Permit for desal concentrate under the state's Class I UIC Program, and the General Permit approach appears to have streamlined the regulatory process for DWI considerably (e.g., from over 390 days to about 90 days). The General Permit approach under Class I of the Texas-run UIC Program may be a viable model to address CM challenges in other states.

- Alamogordo, NM is pursuing groundwater desalting to meet its projected large and growing water supply shortfall. The city has faced several challenges in developing its desal facility, including securing water rights and rights of way (ROW), in addition to the CM issue. The city is considering both conventional and HR desal processes to maximize water yields and reduce concentrate volumes. The city had initially considered the use of evaporation ponds as its CM strategy (similar ponds are already permitted and in use at a nearby Reclamation desal research facility), but there is inadequate land available at the proposed city facility site to accommodate all the brine volume. The city is currently evaluating an accelerated schedule for implementing desal, which will include the construction of a temporary small-scale desal plant. The temporary operations will include an evaporation pond for CM. The city will later switch to DWI as desal production ramps up toward the targeted production level of 2.9 mgd and a more permanent facility is completed. The city is in the initial stages of exploring regulatory requirements and permitting-related CM issues pertaining to the evaporation ponds, DWI, and disposal of solids (or near-solids) from an HR system.

- ECCV, in the greater Denver metropolitan area, began operating a 10 mgd RO groundwater desal system in early 2012, with plans to expand to 40 mgd to meet growing demands. Initially, surface discharge to an irrigation ditch was considered for concentrate discharge, but this was not a viable CM option because agricultural water needed to dilute the concentrate to acceptable discharge levels is not reliably available. ECCV evaluated a range of other CM alternatives and determined that DWI, coupled with an HR system to reduce concentrate volumes and increase water yields, would be the most cost-effective of the viable options. It has secured a UIC Class I permit from EPA Region 8 (Colorado does not have primacy over the Class I UIC Program) and begun operation of an initial disposal well. An additional injection well is planned to provide redundancy and ensure continuous operation.

Table 8.1. Overview of Brackish Groundwater CM Case Studies

	El Paso, TX	San Antonio, TX	Alamogordo, NM	East Cherry Creek, CO	Vero Beach, FL
Project status and size	Operational since 2007, up to 27.5 mgd.	Under development, 10 mgd by 2016, up to 25 mgd by 2026	Under development since 2001, planned for 3200 AFY(2.9 mgd)	Initial RO at 10 mgd completed in 2012, planned at 40 mgd at build-out	Operational since 1992 at 2 mgd, expanding to 6 mgd
CM option(s)	DWI, 22 mile brine line to DWI site, injection at 3 wells of 3700 to 4000 ft deep	DWI within 2 miles of desal facility via 3 wells (depths of 4200 to 4800 ft)	EP for initial small-scale operation and DWI when production increased. HR processes may also be used.	DWI with HR process added to reduce injectate volume and enhance yield at 10,500 ft depth	DWI at upsized desal facility: 2 wells with depths of 1650 and 3000 ft
CM permit issues	UIC Class V permit with wells built to Class I standards Discharge must meet MCLs (as Class V permit; receiving water <10,000 TDS) unless AE granted (pending, cost close to $1 million)	UIC Class I General Permit (first test of General Permit) Receiving portion of Edwards Aquifer at 90,000 TDS 5 deep injection wells to be developed (for redundancy, to ensure 3 operable)	EIS includes hydrogeologic assessment and considers site suitable for DWI. HR (ZDD) likely to increase yield, reduce concentrate volume, and produce some potentially recoverable salts Solids anticipated to be nontoxic (enabling landfill disposal)	Pressure testing has been costly and caused delays. Utility siting recognizing concern over earthquake potential Regulator concern over pressure of injection	Surface discharge initially used at smaller scale operation; became unviable as water quality criteria changed and discharge volume increased
CM permitting timeline	Close to 4 year permit approval process for authorization to construct up to 5 wells, plus >1 years to work through AE process	90 days for permitting of 5 wells; SAWS will need to file financial assurance 60 days prior to drilling of Wells 2 through 5 (not injecting into a USDW)	Unknown, not yet pursued	2.5 years between the original EPA Statement of Basis and the authorization to inject	4 years between application for test well construction/testing permit and issuance of operating permit

	El Paso, TX	San Antonio, TX	Alamogordo, NM	East Cherry Creek, CO	Vero Beach, FL
CM costs	DWI-related capital costs of $22.5 million for 3 wells, annual O&M costs of $166,000 >$1.6 million for preconstruction studies and permit-related efforts AE effort cost >$1 million	1 completed well cost $4.8 million to construct, plus $640,000 for planning, design, and permitting SAWS expects future wells to cost less.	EP concept design cost $175,000 to $250,000 for 500,000 gallon pond (50'x50'x4') with 2 HDPE liners, netting, and monitoring. DWI well cost estimated at $2.6 million (capital outlay only) BGNDRF capital cost for 3 EPs ~ $563,000 (~ 1.4 million gallon combined capacity)	$38 million capital outlay ($60 million, including capitalized O&M) for 10 mgd RO system, including HR and DWI Initial well cost $3.2 million, plus pumps, pipes, etc. Permit costs ~ $100,000. Planned second well estimated total capital cost of $8.9 million EP total capital cost estimate >$220 million at 10 mgd scale	Total capital cost of $11 million ($4.7 million for well; pipeline is largest cost factor)
Regulatory agencies	TCEQ for UIC permits; EPA and TCEQ for AE	TCEQ for UIC permit. TRRC also must provide a letter stating that injection will not impact known oil and gas reservoirs.	NMED	EPA Region 8 (CO does not have primacy for Class I.)	FDEP
CM options considered	EP (enhanced and passive): both found to be much more expensive than DWI (by factor of 3 to 4, in present value terms)	Surface discharge feasible but not preferred because of concerns for San Antonio River EP, HR, sewer discharge considered, but none found feasible/reliable	EP considered for full-scale but switched to DWI because of site limitations on size of evaporation ponds also considered sewer disposal and effluent water discharge field	Surface discharge not viable because of limited, variable (seasonal) dilution of receiving ditch and uncertain availability of blend water HR and sewer discharge also considered	Surface discharge via 1 mile discharge line used until desal production expanded; issues also arose with tighter surface water nutrient standards No other option but DWI feasible at greater desal production levels

	El Paso, TX	San Antonio, TX	Alamogordo, NM	East Cherry Creek, CO	Vero Beach, FL
Other comments	First large-scale inland desal facility completed in United States Arsenic levels in concentrate challenging to keep below MCL (seek AE) One injectate well unusable because of proximity to NM border	General permit approach (new) appears to streamline process (~ 90 days versus >390 days) and reduce uncertainties.	May be first utility in NM to file for a UIC Class I permit for CM (none issued in state to date)	SRT repeat required by EPA, resulting in snapped cable and loss of pressure transducer to bottom of well; recovery efforts cost $225,000 Consumptive water rights required to offset concentrate Municipal contracting requirements limited the number of potential drilling contractors.	Upsizing of desal operation necessitated switch to DWI from surface discharge. WWTP also using DWI for excess reclaimed water Sewer discharge infeasible (interferes with reclaimed water production)

Notes: AE=aquifer exemption; BGNDRF=Brackish Groundwater National Desalination Research Facility; CM=concentrate management; DWI=deep well injection; EIS=environmental impact statement; EP=evaporation pond; EPA=U.S. Environmental Protection Agency; FDEP=Florida Department of Environmental Protection; HDPE=high density polyethylene; HR=high recovery; MCL=maximum contaminant level; NMED=New Mexico Environment Department; O&M=operations and maintenance; RO=reverse osmosis; SAWS=San Antonio Water System; SRT=step rate test; TCEQ=Texas Commission on Environmental Quality; TDS=total dissolved solids; TRRC=Texas Railroad Commission; UIC=underground injection control; USDW=underground source of drinking water; WWTP=wastewater treatment plant; ZDD=zero discharge desalination

- Vero Beach, FL has been operating a 2 mgd groundwater desal facility since 1992 and is expanding production to 6 mgd to meet growing demands and limited supply options. At initial production levels, the utility was able to discharge its concentrate to a canal, which in turn flowed to a saline lagoon. A combination of factors preclude continued use of surface discharge, including changes in the applicable water quality criteria for the receiving waters and the increased volume of concentrate from the expanded desal facility. DWI has been identified as the only feasible CM option, and wells are being developed under the Class I UIC Program administered by the state.

In addition to the five primary case studies described above, the project team also conducted three shorter case studies, including profiles of desal facilities and CM methods in Brownsville, TX; Sterling, CO; and Miami–Dade, FL. The facility in Brownsville currently discharges concentrate via a drainage ditch that leads to a hypersaline lake and ultimately to the Gulf of Mexico. Both Sterling and Miami–Dade use DWI as their means for concentrate disposal. For the most part, these facilities did not report significant challenges with the permitting process; however, Sterling and Miami–Dade did note that the costs associated with DWI and the extended timeline for permit approval presented some difficulties.

On the basis of the case studies, the following general observations may be made regarding CM:

- In the arid Southwest (and even in coastal Florida), discharge to surface water or sewer is not likely to be a sustainably feasible option unless the system is operating at a very small scale (e.g., 0.03 mgd, which is roughly enough water for less than 40 households).

- Evaporation ponds may be a feasible alternative for CM in some locations, but the combination of sizing and associated land requirements and other expenses (including double-lining) make this option economically prohibitive and often technically infeasible except for very small–scale desalting operations.

- DWI may often be the only viable option for CM, but UIC permit requirements may create significant challenges in terms of time and expense required to obtain full approvals, uncertainty about whether permits will be issued, and challenges associated with operating under permit conditions. The new General Permit provision in Texas under Class I of the UIC Program may serve as a model for a more streamlined approach to DWI permitting.

- Challenges associated with DWI vary significantly by location based on local geology and permitting requirements. For example, EPWU experienced significant challenges in obtaining an AE even though the water in the receiving aquifer did not meet primary drinking water standards. At the same time, SAWS experienced relatively few difficulties and obtained a permit much faster than EPWU because of the recent General Permit established in Texas for municipal desal concentrate.

- Costs also range significantly depending on permit requirements, depth of the well, and other miscellaneous expenses. For example, EPWU reports that the utility spent about $715,000 on permitting-related costs and an additional $1 million on the AE effort. ECCV, on the other hand, estimates that permitting costs amounted to about $100,000 (however, pressure testing associated with the permit cost an additional $225,000). In terms of capital construction, the capital costs associated with construction of one well range from $2.6 million for Alamogordo to $8.9 million for a second well in ECCV.

- Many of the municipalities highlighted reported no significant challenges in obtaining the DWI permit (e.g., SAWS, Vero Beach); however, in most cases costs associated with DWI were reported as significant.

Chapter 9

El Paso Water Utilities' Kay Bailey Hutchison Desalination Plant

EPWU's KBH Desalination Plant is the world's largest inland desal facility. A joint project of EPWU and Fort Bliss (U.S. Army), El Paso's desal plant has the capacity to produce 27.5 mgd of potable water, making it a critical component of the region's water supply portfolio (EPWU, 2012).

Kay Bailey Hutchison Desalination Plant

Concentrate from the plant is currently disposed of through three deep injection wells (with authorization for up to five) located approximately 22 miles northeast of the plant on Fort Bliss land. This chapter focuses on the permitting and planning processes associated with implementing DWI in El Paso, including a detailed account of permitting requirements, challenges, and lessons learned.

9.1 Project Background

El Paso's water supply sources have historically included surface water from the Rio Grande and groundwater from the Hueco and Mesilla Bolsons (aquifers). Over the past several decades, the demand on these freshwater sources has significantly increased because of population growth and other factors.

Water from the Rio Grande is only available during the spring, summer, and early fall months and is further limited in years of drought. In addressing reductions in river water availability, EPWU has traditionally increased groundwater pumping to meet demands. The Hueco and Mesilla Bolsons serve as the source of water not only for El Paso but for several other communities (including Juarez, Mexico; Las Cruces, NM; and several small areas in outlying water districts and colonias), and groundwater pumping has exceeded the recharge rate in these aquifers for many years. In addition, brackish groundwater has intruded into areas of the Hueco Bolson that have historically yielded fresh groundwater.

As a result of concerns regarding the long-term ability of the bolsons to support future demand, EPWU implemented several strategies in the early 1990s to reduce reliance on fresh groundwater. These strategies included a number of water conservation initiatives and an extensive reclaimed water program. Despite the success of these programs, it was clear that additional freshwater sources would be needed. To diversify supplies and meet future demands, EPWU began exploring the idea of desalinating brackish water from the bolsons.

When new technology reduced the cost of the RO process, EPWU began to plan the construction of a desal plant (EPWU, 2012).

EPWU conducted considerable research and numerous studies to ensure the validity of its desal design and better understand the potential environmental effects. In 1997, EPWU and the Ciudad Juárez water utility (Junta Municipal de Aqua y Saneamiento) commissioned USGS to conduct a detailed analysis of the amount of fresh and brackish water remaining in the Hueco Bolson and model flow patterns and the impacts of recharge. EPWU used the results of these efforts to determine where to locate the desal plant and source wells.

In 2002, EPWU drilled and monitored nine test wells to characterize a section of the aquifer selected to provide the blend water. EPWU and its consultants also completed an extensive analysis of existing wells that might be used to supply the desal facility. A pilot plant was constructed to test the chemicals, filters, and membranes used in the RO process and determine which worked best with local water (EPWU, 2012).

A considerable amount of effort (technical, financial, and other) and research went into solving the complex problem of concentrate disposal and management. EPWU tested several different disposal options, including conventional evaporation ponds (i.e., passive evaporation), evaporation ponds with concentrators (i.e., enhanced evaporation), and DWI. Passive evaporation for 3 mgd of concentrate would require a 700 acre, double-lined pond; enhanced evaporation would require a smaller pond and mechanical sprayers to enhance the evaporation rate. An economic analysis of the three alternatives completed in 2002 showed that DWI would be significantly less expensive than either of the evaporation alternatives, provided that a suitable site was identified (Table 9.1).

Based on the lower estimated costs for injection wells, EPWU conducted a detailed investigation of the deep well disposal option from 2002 to 2004. One of the complexities involved with this option was the need to determine whether a specific geologic formation in the area would meet all of the UIC regulatory requirements. For a geologic formation to be suited for DWI, there must be sufficient reservoir capacity to accept injected concentrate, and the formation must demonstrate the ability to contain injected fluids. One of the following must also apply: (1) it cannot be considered a USDW, or (2) it must be designated as an exempt aquifer due to its poor water quality and because it is too deep and remote to be an economical source of water (TCEQ Rules 30 Tex. Admin. Code §§331.5 and 331.13).

Table 9.1. Estimated Costs for Alternative Concentrate Disposal Options, 2002 (millions US$, updated to 2012 values)

Disposal Method	Capital	Annual O&M	Present Value
Passive evaporation	$52.30	$1.28	$90.57
Enhanced evaporation	$29.34	$3.70	$112.25
DWI	$8.93	$1.02	$31.89

Notes: DWI=deep injection well; O&M=operation and maintenance

Source: Adapted from Hutchison (2007), updated via Consumer Price Index

The area that was ultimately selected for DWI had very limited geologic and hydrologic information available at the beginning of the feasibility studies. As part of the permitting approval process, EPWU conducted extensive studies of local geological and hydrological conditions, examined existing data (including seismic analysis and water samples), and performed geologic modeling in partnership with UTEP. The U.S. Army also drilled four wells to test the hydrogeological conditions of the underlying geological formations. Encouraging findings from these studies led to the construction of a pilot test well. The subsequent injection testing of the pilot test well demonstrated that there was sufficient reservoir capacity to accept injected fluids.

Today, there are three injection wells in operation, ranging between 3700 and 4000 ft deep. The wells do not need pumps and are capable of accepting water by gravity at rates approaching 2000 gpm. The injection facilities consist of yard piping, a 300,000 gallon storage tank at each site, overhead electrical power with solar and generator backup, and various instrumentation and controls to manage the injection and collect performance data. Built to Class I UIC standards, the sites confine the concentrate to prevent migration to freshwater, provide storage volume sufficient for 50 years of operation, and meet all the requirements of TCEQ. Table 9.2 summarizes the capital and operations and maintenance (O&M) costs for the injection facilities.

9.2 Permitting Processes and Regulatory Requirements

TCEQ is the permitting agency responsible for the UIC Program in Texas. EPWU's desal project was the largest that TCEQ had ever considered for disposal of drinking water concentrate by DWI, and the agency did not have a permitting option specifically designed for such a project. In addition to that hurdle, at the time that EPWU was seeking an injection well permit, the level of TDS in the injection zone (the Fusselman Formation) was unknown. Upon completion of the pilot well and the testing of a sample collected from the proposed injection zone, it was determined that the TDS was less than 10,000 mg/L, and the Fusselman Formation was considered a potential USDW.

Table 9.2. Capital Costs of Injection Wells and Supporting Infrastructure (US$, updated to 2012 values)

Facility	Capital Cost	Comment
Injection wells	$7,747,000	3 injection wells drilled to depths of 3700 to 4000 ft to Class I standards
Surface injection facilities	$4,936,000	Surface facilities for 3 wells, including tanks, controls, and piping
Concentrate pipeline	$8,290,000	16 in. diameter HDPE pipe from plant to injection wells (22 miles)
Downhole equipment	$1,549,000	Injection facilities for 3 wells within injection well casing (injection tubing, packers, instrumentation, and controls)
Total capital cost	$22,523,000	–
O&M (annual)	$166,000	Electricity for concentrate pump station and propane to operate injection facilities

Notes: HDPE=high density polyethylene; O&M=operation and maintenance

This posed a potential barrier because TCEQ regulations prohibit injection into a USDW, but EPWU and TCEQ ultimately negotiated regulatory oversight in the form of an authorization by rule for Class V disposal wells constructed to Class I standards. As discussed herein, this authorization was based on the condition that the injected concentrate would "not exceed any national or state primary drinking water standards." This authorization by rule did not require a public comment period; however, there was a public comment period for the environmental impact statement (EIS) that was prepared for the desal facilities built on Fort Bliss Military Reservation property. The EIS included discussion of concentrate disposal through either DWI or evaporative ponds.

EPWU worked closely with TCEQ for close to 4 years (November 2001–July 2005) before receiving the authorization to construct and operate up to five Class V injection wells in the Fusselman Dolomite (Silurian Age), Montoya Dolomite (Ordovician Age), and El Paso (also of Ordovician Age) formations. The following specific conditions are included in the authorization:

1. A well completion report must be submitted to TCEQ prior to initiation of injection.
2. An initial formation water analysis must be used for baseline water quality standards. The current Class V injection well authorization prohibits injecting water that does not meet primary drinking water standards, even if the formation water exceeds the primary drinking water standard for that particular parameter. Native Fusselman-Montoya-El Paso Group water samples demonstrate that water quality does not meet national and state primary drinking water standards for arsenic, gross alpha (less radium and uranium), nitrite, and radium. In addition, the formation water is brackish, with TDS over 8000 mg/L. Monthly sampling must be performed and reported quarterly. The injected waste stream shall be sampled at the point of injection and analyzed for the constituents above.

3. The injected waste stream is not to exceed any national or state drinking water standards. If standards are exceeded, injection shall cease until concentrations are brought into compliance.
4. The injection pressure shall not exceed 0 pounds per square inch-gage pressure (psig). Pumping of the concentrate is allowed, provided injection pressures do not exceed authorized injection pressures. At the point of injection at the ground surface, the instantaneous rate of injection is not to exceed 1100 gpm; the average rate of injection for all wells is not to exceed 2100 gpm for all wells combined; the monthly maximum injection is not to exceed 93,744,000; and the annual maximum injection is not to exceed 1,103,760,000 gallons. Pumping of the concentrate is allowed. The pressure in the annulus surrounding the injection tubing must be maintained at 100 psi greater than the injection pressure.
5. Continuous monitoring and digital recording of injection pressure, injection rate, and injection volume shall be reported quarterly.
6. Annual mechanical integrity testing, including the pressure fall-off test, will be performed.
7. The closure will comply with the TCEQ closure rule.
8. Spills and releases will be managed in accordance with TCEQ rules.
9. The well design, construction, operation, and location changes will be reported and approved.

For El Paso, the most challenging requirement associated with the Class V authorization is the stipulation that the injected concentrate must meet primary drinking water standards. This requirement applies even if the formation water exceeds the primary drinking water standard for a particular parameter. The Class V authorization does not require TDS to meet secondary standards.

Native Fusselman-Montoya-El Paso Group water samples show that the groundwater quality does not meet national and state primary drinking water standards for arsenic, gross alpha (less radium and uranium), nitrite, and radium. As noted previously, however, the formation is nevertheless considered a potential USDW because the TDS of the natural formation water is below 10,000 mg/L.

Under operation of the original Class V authorization, the chemical composition of the diluted and nonhazardous desal concentrate has TDS less than 6000 mg/L, which is lower than the levels in the native Fusselman-Montoya-El Paso Group water. The only parameters of the concentrate that do not meet primary drinking water standards are arsenic and gross alpha (less radium and uranium). As noted previously, the native Fusselman-Montoya-El Paso Group formation water contains arsenic and gross alpha that already do not meet primary drinking water standards.

In order to be in compliance with the TCEQ UIC regulations, the concentrate was being diluted to meet the requirements of the authorization (i.e., to reduce arsenic and gross alpha concentrations to below primary drinking water standards). Although the plant is currently generating only 700 gpm of concentrate, EPWU recognizes that, as water demand increases over the years, the volume of concentrate will also increase, raising the questions of how to address the primary drinking water standard issue and continue operations.

The most viable option for dealing with injecting concentrate that does not meet primary drinking water standards for one or more parameters is to obtain an AE. TCEQ can approve an AE by finding that the aquifer does not currently serve as a source of drinking water and is not reasonably expected to supply water to a public water system. After granting an AE, TCEQ must submit it for approval to EPA, and EPA's approval is treated as a revision to the TCEQ UIC Program.

AEs also require TCEQ regulatory approval, including public notice and participation throughout the process. As described below, these requirements were satisfied by EPWU. The approved AE will be the basis for amending the requirement in the Class V authorization that the injected concentrate meet primary drinking water standards. The exemptions are granted by TCEQ with concurrence from EPA, in accordance with 40 CFR§§ 144–146, 30 TAC, and Chapter 331.

The process for acquiring an AE includes submittal of an application package to TCEQ for review. Once TCEQ reviews and approves an AE request, it sends it to EPA for approval as a revision to the UIC Program. Upon EPA approval of the EA, the TCEQ's delegated UIC Program is amended to note the exempt aquifer.

On December 15, 2011, TCEQ granted EPWU's request for an AE. Consistent with federal law, on February 17, 2012, TCEQ submitted a program revision to EPA under 40 CFR §§ 144.7, 146.4, and 145.32 to reflect the AE designation for the Texas UIC Program. On April 19, 2012, EPA requested additional information from TCEQ and EPWU. EPA approved the AE on September 20, 2012. On August 29, 2014, TCEQ amended the original UIC well authorization eliminating the previous requirement to blend the concentrate with other source waters to reduce the concentration of several constituents. The subject amendment also included provisions for mechanical integrity testing of injection wells and continuous monitoring and digital recording of injection pressure, injection rate, and injection volume.

STEP 1. Pre-application Meetings
November 2001–November 2002
In November 2001, EPWU met with TCEQ to discuss permitting the disposal of concentrate through DWI for the proposed desal project. EPWU also met with the New Mexico Groundwater Quality Bureau-UIC Program, and New Mexico determined that EPWU was not required to comply with New Mexico law.

STEP 2. Drilling of Test Wells
March 2003–August 2003
EPWU drilled three test wells to gather water quality data.

STEP 3. Discussion with TCEQ To Determine Well Classification and Construction Standards
August 2003–March 2005
EPWU met with TCEQ on numerous occasions to provide information on the status of the test wells, water quality, design specifications, and determine the type of well (i.e., Class I or V) to be authorized. TCEQ's guidance was for EPWU to seek authorization for a Class V well to be constructed under Class I design specifications.

STEP 4. Authorization for Class V Injection Well
March 2005–July 2005
In March 2005, EPWU applied for authorization to construct five Class V injection wells to dispose of concentrate from the desal plant. On July 13, 2005, TCEQ provided authorization by rule (in lieu of a permit) for construction and operation.

STEP 5. Well Completion
July 2007
EPWU completed three wells and submitted completion reports to TCEQ. Although classified as Class V wells, EPWU constructed the wells to Class I injection well permit standards.

STEP 6. Commence Injection Operations
August 2007–present
EPWU commenced injection. Levels of arsenic exceeded the MCL. EPWU met with TCEQ and reduced arsenic concentrations through dilution.

STEP 7. Pre-application Meeting Concerning AE
December 2007–September 2008
EPWU met with TCEQ, EPA Region VI, and NMED to provide an overview of the proposed AE request by EPWU. EPWU submitted the Texas application in August 2008 and the New Mexico application in September 2008.

STEP 8. Technical Review of Application
September 2008–June 2011
EPWU worked with regulators for 2.5 years to refine its plume modeling and respond to inquiries from both NMED and TCEQ. In July 2009, revised modeling showed no plume into Mexico, and EPWU dropped the request for an AE in New Mexico. A final revised application was transmitted to TCEQ in April 2011. The application sought an exemption on the basis that the aquifer is not currently, nor has it ever been, a source of drinking water for human consumption and that the aquifer is situated at a depth of 1000 to 4000 feet below the surface, which makes recovery of water for drinking water purposes economically or technically impractical.

STEP 9. Public Participation
June 2011–December 2011
The TCEQ process for obtaining an AE provides for a preliminary decision, notice, public meeting, and opportunity for public hearing. TCEQ denies the hearing request opposing the AE and grants the exemption.

STEP 10. TCEQ Request To Revise UIC Program
February 2012–present
In February 2012, TCEQ requested a revision to its UIC Program to reflect the AE designations. In April 2012, EPA sent TCEQ a letter requesting additional information. The letter stopped a 45 day automatic approval process. EPA approved the AE on September 20, 2012, and TCEQ issued the corresponding amendment to the original UIC authorization on August 29, 2014.

Figure 9.1. EPWU permitting process and timeline for DWI authorization and AE.

Figure 9.1 provides an overview of the various steps and timeline involved in obtaining EPWU's Class V authorization and the AE for DWI.

9.3 Permitting Challenges and Opportunities

EPWU reports that the biggest challenge associated with the permitting process has been obtaining the AE. Throughout the approval process, EPWU worked very closely with TCEQ to provide information, collect data, and develop models to demonstrate that the AE would not result in adverse environmental effects. TCEQ regulators were primarily concerned about containment of the concentrate within the aquifer (i.e., regulators wanted to ensure that the concentrate would not contaminate surrounding aquifers), and extensive modeling was required prior to authorization. Because the wellfield is so isolated and located on military land at Fort Bliss), there is no active well literature for the area, and it was difficult to develop a model for this site.

EPWU hired consultants to conduct studies and develop models and held many meetings with TCEQ regulators over the 3.5 year AE approval period to ensure that concentrate disposal via DWI would not result in adverse environmental effects. This was a somewhat challenging exercise because of the unique nature of an AE associated with Class V injection wells used for concentrate disposal, and the project has a high profile. Therefore, the two agencies worked very closely to ensure the project's success.

A public meeting and opportunity for a contested hearing were required by TCEQ to complete the AE application. The public meeting was held in July 2011 in El Paso, nearly 3 years after the application was submitted to TCEQ. It is important to note that the public meeting for approval of the AE went very smoothly, with only minimal public interest. Only one nearby landowner had an objection to the project; this landowner requested a contested public hearing, but it was denied by TCEQ because the landowner did not meet the criteria for a contested hearing.

As noted previously, TCEQ approved the AE in December 2012 and sent it to EPA for approval and revision to the Texas UIC Program. EPA responded with a request for additional information primarily concerning the projected changes in the concentrate over a 50 year period. In response, EPWU developed 50 year projections for the changes in the concentrate quality based on 5 years of operational data. These projections were then used to model the water quality of the AE plume. The results showed that the TDS of the concentrate would double over 50 years, because the TDS of the source wells is expected to increase over time (based on 5 years of plant operation data showing small increases). This would increase the native groundwater TDS by only 0.25% (from 8000 to 8020 mg/L) at the edge of the AE plume.

At present, the technical staff at EPA have recommended approval of the AE and program revision, and the recommendation is awaiting final approval at higher levels. Continued operation of the desal plant ultimately hinges on the approval of the AE by EPA.

Although EPWU has stated that the AE has been the biggest challenge of the permitting process, EPWU representatives note that obtaining the Class V authorization was no easy task. EPWU worked closely with TCEQ for almost 4 years on the Class V authorization to investigate DWI feasibility, develop test wells, submit data, develop models, determine well classification and construction standards, and finally submit the permit application or request. Figure 9.2 provides an example of some of the DWI studies conducted as part of the initial development and permitting phases of the project.

In total, the cost of preconstruction activities amounted to about $1.62 million. EPWU estimates that approximately $715,000 of this was related to studies and other permitting activities. (The cost of the Class V application alone was $198,375.) Costs associated with the AE process have amounted to close to $1 million to date (including staff time, study costs, and other miscellaneous costs). Construction of the test well cost about $1 million.

The Class V permit authorizes EPWU to build up to 5 wells to inject a total of 3 mgd of concentrate. The authorized well sites are all on the Fort Bliss Military Reservation in Texas. EPWU requested five well sites in its permit to allow the drilling of additional injection wells on an as-needed basis. EPWU has now completed injection wells on 3 of the 5 authorized well sites, and they are hydraulically capable of injecting up to 8 mgd of concentrate, although the permit allows for injection of only 3 mgd.

The five permitted well sites were included in the groundwater model simulations required for the AE application. Modeling showed that the injectate plume is directed southward and is contained within Texas. This model was approved by EPA and TCEQ.

Additional considerations for operating the injection wells include (1) avoiding potential mineral precipitation (e.g., calcite, barite, and silica) in the wells and formation, and (2) maintaining the capacity of the injection reservoir. So far, EPWU has been pleased with the performance of the injection wells. None of the wells are exhibiting an upward trend in minimum depth to water during the initial 5 year operational period. This suggests that the injection rate does not exceed the limitations of the injection reservoir.

> Extensive investigations and studies were undertaken to address the potential for loss of injection well efficiency from borehole scaling or formation damage, including:
>
> *Characterization of reservoir water.* Accurate information on reservoir conditions regarding temperature, pressure, and water quality were required as input data for computer simulations of blending.
>
> *Evaluation of potential for minerals to precipitate from solution during pipeline transport, in wells during injection, and in the receiving formation after injection.* The evaluation was done using geochemical modeling software. Based on this analysis, acid pretreatment of the concentrate to prevent calcite formation and exclusion of oxygen to eliminate the potential for ferric hydroxide precipitation were recommended.[a]
>
> *Adsorption tests to determine the fate of antiscalant*. From the results, it was assumed that inhibitor would absorb on the host rock (dolomite) almost immediately and should not be depended on to reduce precipitation potential in the formation.
>
> *Identification and evaluation of analogous DWI sites, including characterization of scaling experiences.* Computer simulations of scaling potential at these sites were shown to correctly predict the scaling results observed.[a]
>
> [a]Based on internal reports prepared for EPWU by Geochemical Technologies Corporation in 2007 and 2006, respectively.

Figure 9.2. EPWU studies to investigate potential for loss of injection well efficiency.

Finally, as part of permit compliance, EPWU routinely provides reports to TCEQ with detailed information on injection volumes and rates and water table levels during injection. This information, as well as input from plant operators, will be helpful to EPWU if any potential well problems arise (e.g., if the well does not accept additional concentrate). If an existing well site were to fail, EPWU would plug that well and drill a new one. The replacement well would have to meet all of the Class I well requirements before it would be put into service.

9.4 Lessons Learned

EPWU believes that the permitting process would be much simpler if more attention were given to the quality of the water in the injection zone. With or without injection by EPWU, the water in the Fusselman Formation would require treatment before use. Using primary standards as a discharge standard for concentrate does not take into account the degree of treatment needed to convert the naturally occurring brackish groundwater into a potable source of drinking water.

As noted previously, TCEQ did not have a permitting option specifically designed for large-scale injection of concentrate from a municipal desal plant; therefore, the permitting process provided a learning opportunity for both EPWU and TCEQ regulators. This process served as TCEQ's initial development of a process for authorizing a Class I well for nonhazardous desal concentrate disposal under a general permit. This regulatory tool is intended to reduce the processing time and the cost of obtaining authorization for Class I permits for desal concentrate disposal. These permits can be also used to authorize injection of nonhazardous DWTRs. The term of the current Texas General Permit is 10 years.

EPWU believes that it may be useful to pursue the development of an expedited regulatory process to allow the use of existing Class II disposal wells for desal concentrate disposal. Class II disposal wells, ubiquitous in Texas, are only permitted for oil and gas mining operations, but a Class II well operator may accept desal concentrate if used for the purpose of oil and gas operations. Allowing the use of existing Class II wells for the permanent disposal of desal concentrate without the restriction of having to be part of an oil and gas operation would save the cost of installing an entirely new well. There may be other issues involved with coupling concentrate disposal to Class II wells that may be limiting (e.g., aquifer capacity, the uncertainty of whether the well will exist for the life of the desal plant). Navigating the regulatory complexities of underground injection wells to enable the dual certification of Class II wells (i.e., allowing Class II wells to accept Class I wastes) would likely require a multistate concerted effort to succeed (Arroyo, 2011).

Chapter 10

East Cherry Creek Valley Water and Sanitation District

10.1 Project Background

ECCV RO Desalination Facility

ECCV is located southeast of the Denver metropolitan area. It serves 57,000 residents and is estimated to be 80% developed. The district has traditionally relied on a non-renewable source of groundwater for its water supply. ECCV has been pursuing a renewable water supply since the 1980s to diversity its water portfolio and has experienced a decline in the yield of the non-renewable wells as the population of the district increased. To keep up with demands, 377 more wells would be needed at a cost of $476 million. This was considered not to be feasible.

To meet future demands, ECCV obtained water rights along the South Platte River. The water would be extracted from wells in a shallow alluvial aquifer. Water quality parameters observed and targets for distribution are provided in Table 10.1.

The ECCV Northern Water Supply Project was developed in two phases to extract and utilize this water. The first phase included development of the groundwater wells and infrastructure. Water produced from these wells would be blended with other sources and used immediately to satisfy current demand. An interconnect was also developed with Denver Water for the short-term purchase of water. Both blending and purchase from Denver Water in Phase 1 allowed ECCV to meet current demands while providing time to plan and construct Phase 2.

The second phase of the project included a RO treatment facility that at full build-out could produce up to 40 mgd and meet 70 to 80% of ECCV's water demand. In 2012, ECCV completed Phase 2A of a treatment facility with a production capacity of 10 mgd.

The final treatment option selected consisted of two process trains, shown in Figure 10.1. Approximately two-thirds of the water passes through the RO treatment train. The other one-third is treated by ultraviolet only. The two trains are then blended together to provide water of the quality desired.

Table 10.1. Raw Water and Target Water Qualities

Parameter	Raw Water Quality (mg/L)	Water Quality Targets (mg/L)
TDS	650–1000	<300
Total hardness	300–330	<100
Total organic carbon	1–2	
Nitrates	1–3	

Note: TDS=total dissolved solids

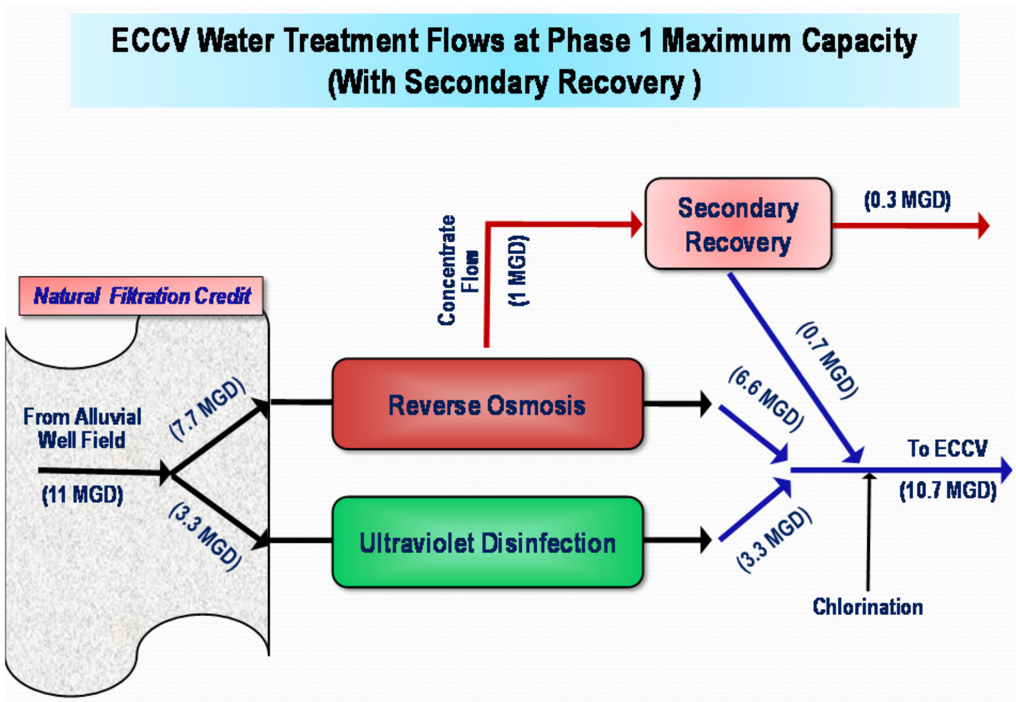

Figure 10.1. ECCV treatment process.

Table 10.2. ECCV Injection Well Specifications

Type of Well	Class I Nonhazardous
Surface casing	9.25 in. casing to 1400 ft in a 12.25 in. hole and cemented to the surface
Production casing	7 in. casing to 10,500 ft in an 8.75 in. hole and cemented in 2 stages
Estimated injection rate	200 to 400 gpm (tested to 1200 gpm)
Maximum pressure	1485 psi (tested to 3120 psi and currently attempting to get this pressure approved)

A variety of options were considered for disposal of the RO brines. These included:

1. Discharge
   a. Surface water discharge through the NPDES permit
   b. Discharge to sanitary sewer system
2. ZLD
   a. Thermal/mechanical evaporation systems
   b. Enhanced evaporation system
   c. Passive evaporation basins
3. DWI with or without brine minimization (requiring an EPA permit under the SDWA UIC Program)
4. Beneficial uses

The first option considered was blending the brine with agricultural ditch water. Preliminary studies indicated that a blend of 7 parts Barr Lake water to 1 part RO concentrate would equal the existing groundwater quality. This option was not used because of concerns that the ditch water did not run consistently throughout the year, and therefore the utility would not be able to discharge during certain times of the year. ECCV maintains a permit to use the surface water discharge as an alternative to DWI.

Underground injection, through a Class I UIC permit, was selected as the most appropriate option. Injection will occur into an underground saline formation at 10,500 ft, over 9000 feet below drinking water aquifers. Care was taken to site the well away from a bedrock formation that had a history of causing earthquakes.[1] This work included detailed fault mapping and characterization. The well injection zones were selected to avoid proximity to faults in both vertical and lateral directions. Details of the well are found in Table 10.2.

ECCV Injection Well

To decrease injection volume going down the well and increase water recovery, ECCV implemented a second pass of RO. Water recovery increased to 85 to 97% (90–95% without softening). Figure 10.2 compares the amount of brine produced for different production volumes before and after the second pass RO (referred to in the figure as brine minimization).

1. A 12,045 ft deep injection well was operated at the Rocky Mountain Arsenal between 1962 and 1966. The well was linked to over 1300 small earthquakes. The largest earthquake occurred in 1967 (1.5 years after the well was closed) at a magnitude estimated to be 5.0 (USGS, 2012).

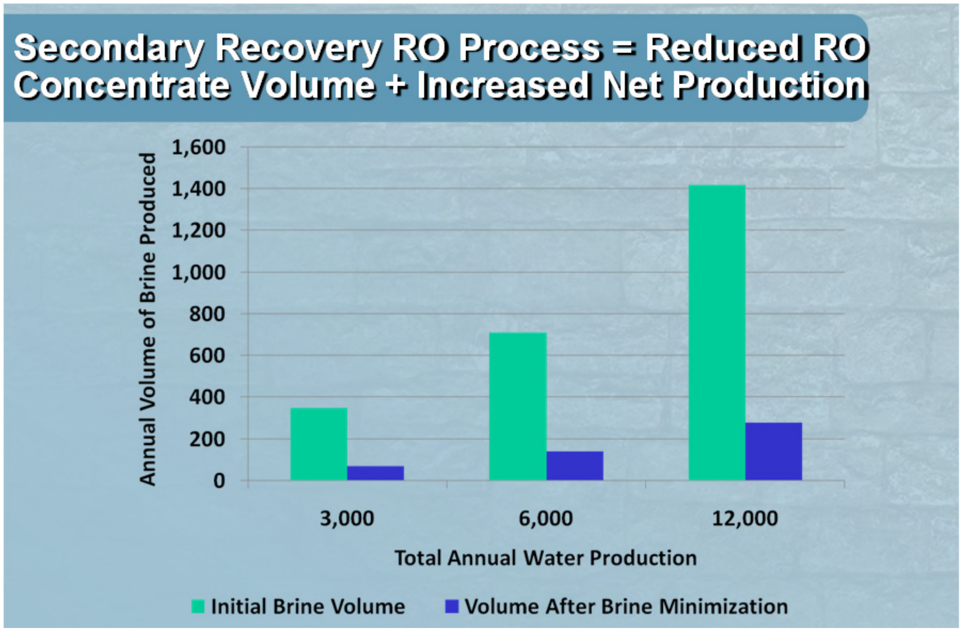

Figure 10.2. Amount of brine produced for different production volumes before and after the second-pass RO.

Cost estimates for the range of CM options considered are depicted in Figure 10.3. Total costs for the selected RO/DWI project are provided in Table 10.3. The amount of $3.2 million for DWI only accounts for the costs associated with the well itself and does not include surface equipment such as pumps and pipes. Permitting costs for the DWI system were estimated at about $100,000. This number is an approximation because it is difficult to separate this permit from all other facility permits.

Cost estimates were developed for the construction of a deep well to support expansion of the facility. The well was included in ECCV's original permit and would be located approximately 1 mile from the treatment facility. Costs estimated for the additional well are provided in Table 10.4.

10.2 Permitting Process

Jurisdiction for the injection well is from EPA Region 8. EPA has jurisdiction for Class I, III, and V wells in Colorado. EPA also has jurisdiction for Class II wells if diesel fuel is used or if the wells are on Indian reservations. If not, Class II wells are regulated by the Colorado Oil and Gas Conservation Commission. The Colorado Department of Public Health and Environment (CDPHE) was only involved with this ECCV permit to approve the water treatment process. As part of the treatment plant approval, CDPHE required an approved method for waste disposal. Authorization for EPA's UIC Program is contained in 40 CFR §§144 and 146. A worksheet with requirements from the Federal Register is provided in Appendix A.

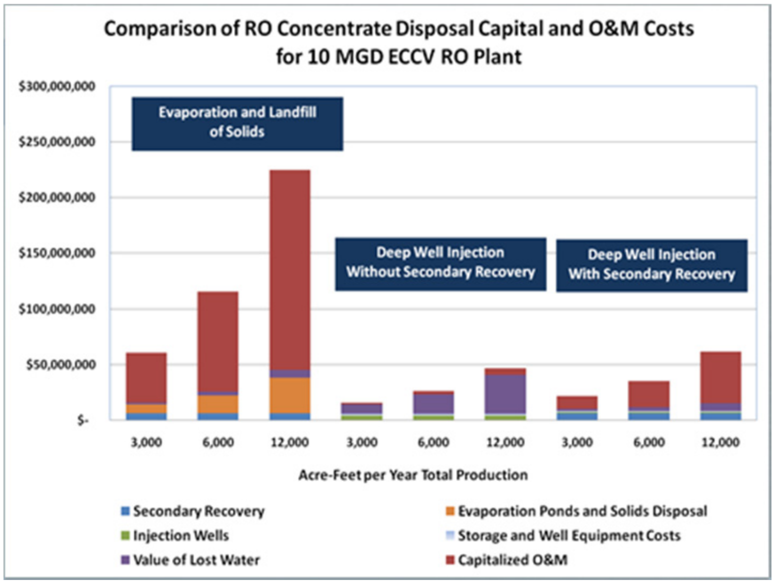

Figure 10.3. Costs and benefits of different brine minimization options.

Table 10.3. Total Water Treatment Capital Costs

Component	Cost
Land	$1.6 million
RO plant construction	$24.5 million
Secondary recovery	$3.7 million
DWI	$3.2 million
Permitting, engineering, and construction management	$5.0 million
Total capital cost	$38.0 million
Capacity with secondary recovery, mgd	10.7
Capital cost per mgd of produced water	$3.55 million
Estimated O&M cost per 1000 gallons produced	$1.30

Notes: DWI=deep well injection; O&M=operation and maintenance; RO=reverse osmosis

A flow chart for the UIC permitting process is included in Figure 10.4. This flowchart was developed from the EPA Region 8 process for obtaining a UIC well permit. EPA's five steps for permit approval include:

Step 1. Administrative review. This step is to ensure that the permit application is complete, containing all items needed to process the permit. It does not require any technical evaluation. EPA has 30 days in which to respond.

Table 10.4. Costs for Construction of an Additional DWI

Item	Estimated Cost (11/2011)
Concentrate brine pipeline	$427,000
DWI pumps	$386,000
DWI pump discharge pipe	$40,000
Deep well drilling and completion	$2,184,000
DWI pumping systems building	$841,000
Site work	$200,000
Electrical and instrumentation	$700,000
Construction contingency	$1,195,000
Mobilization/demobilization	$250,000
General conditions	$350,000
Building permit and fees	$75,000
Contractor overhead and profit	$565,000
Bonds and insurance	$72,000
Engineering, design, construction, and start-up	$1,093,000
Legal and administration	$546,000
Total costs	**$8,924,000**

Note: DWI=deep well injection

Step 2. Technical review. During this step, EPA evaluates the ability of the proposed project to operate without contaminating USDWs. Information to be considered includes the area of review; geology and hydrology information; proposed well construction and operation; and the plugging and abandonment plan. The information is used to develop the conditions and requirements of the permit. Information requested includes:

- *Geologic siting:* EPA examines information on the geology surrounding the proposed well, including data on USDWs, the injection zone, and confining zone as well as complete geologic information, including formation depths and water analyses.
- *Well construction:* EPA examines proposed or existing well construction to ensure that it is drilled, cased, and cemented to prevent movement of fluid into or between USDWs.
- *Area of review*: EPA reviews water wells and groundwater usage and the construction of all wells within an area surrounding the project injection well to ensure that offset wells will not provide a conduit for movement of fluids out of the injection zone into USDWs.
- *Operating conditions, monitoring, and reporting:* EPA determines the maximum injection pressure, allowed volumes or rates, approved fluid type or sources, and monitoring requirements.
- *Plugging and abandonment:* The proposed plugging and abandonment plan is reviewed to ensure that the plugging operation and placement of plugs will prevent movement into and between USDWs.

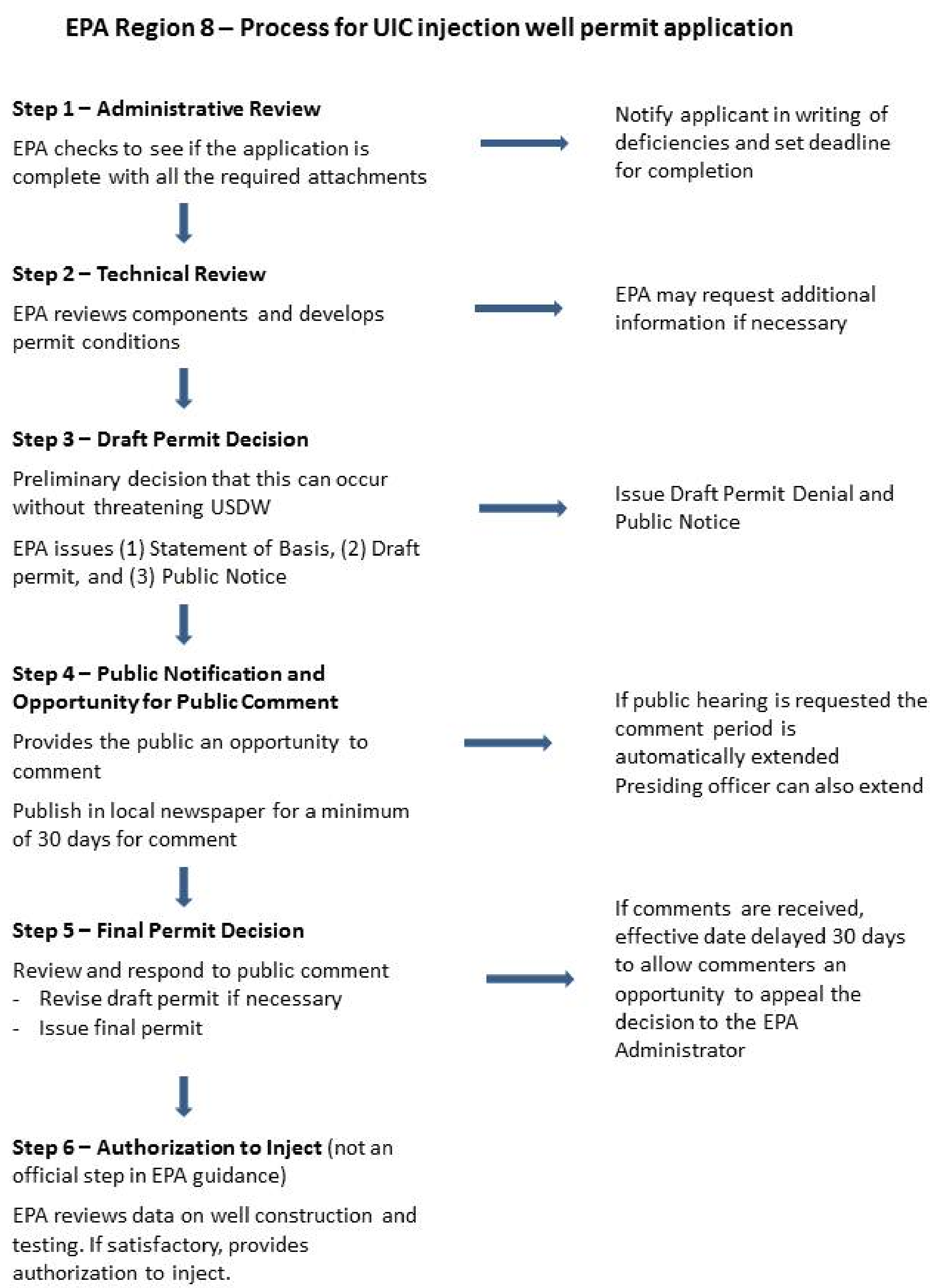

Figure 10.4. EPA Region 8—process for UIC injection well permit application.

During Step 2 there are often many back-and-forth discussions between the proposer and EPA. There is no time clock for this step.

Step 3. Draft permit decision. After the technical review, EPA makes a preliminary decision whether injection can occur without threatening USDWs. If protection is assured, EPA issues:

- a Statement of Basis that details the EPA's permit decision and conditions of the permit
- the draft permit
- materials for public notice

Step 4. Public notification and opportunity for public comment. EPA publishes a public notice in the local newspaper and on its website. The public has a minimum of 30 days to comment. A public hearing may be conducted, and the public comment period is automatically extended until the close of the public hearing.

Step 5. Final permit decision. EPA must review and respond to all relevant comments, revise the draft permit if necessary, and issue the final permit decision. The final decision is effective when signed by the director or delayed 30 days if comments were received (to provide the public an opportunity for an appeal). EPA has the technical authority but can be challenged for procedural matters. Appeals can only be filed by an individual who has previously commented on a draft permit, and such appeals can only pertain to that particular section of the permit that was previously the subject of that individual's comments.

In practice, an additional step occurs between the time when the well permit is accepted and EPA provides permission to inject. This step is included to allow for testing and inspection of the well. Requirements for this step are identified in the permit under Well Operation, Requirements Prior to Commencing Injection.

Step 6. Authorization to inject (not specified in EPA's guidance document, but in the permit requirements). The final permit decision (Step 5) is only for permission to drill, not to inject. From when the permit decision is signed, the utility has 1 year in which to complete the well. During this time, the district is to provide data to EPA that may include a step pressure test, core pressure tests, and cement bonding logs. Authorization to inject is only provided after EPA is satisfied with the construction and performance of the well.

A utility can request an area permit, in which more than one well is identified in the original plan. Only one well needs to be drilled within the 1 year period after the final permit decision. ECCV identified three injection wells in its permit application, but only one well has been constructed,

The overall permit is only valid for 10 years, at which time the utility must reapply.

10.3 Permitting Challenges and Opportunities

ECCV's Northern Water Supply Project was initiated in 2002 when ECCV first obtained the South Platte water rights. During the first phase in 2002 through 2006, ECCV began developing the wellfield. The first well became operational in 2006. It was recognized from the outset that there would be water quality issues that would need to be addressed to obtain the full use of the available rights. Different treatment options were assessed from 2002 to 2006.

ECCV began evaluating options for disposal of the desal brine in 2006 and selected DWI as the primary disposal option. ECCV began assembling the information necessary for well approval, which included visiting and reviewing information from oil and gas injection wells in close proximity to the site. The district also began talking with large and small municipal and other stakeholders. During these discussions, three common questions emerged that needed to be addressed:

1. What is the potential for causing earthquakes?
2. What is the difference between this and hydraulic fracturing?
3. What will be the impact on local wells?

The timeline for the ECCV permit is provided in Table 10.5.

10.4 Lessons Learned

In the course of the project, a number of key lessons were learned.

Step rate test (SRT) requirements. The original step testing of the well was completed with four steps (instead of the seven defined in the procedure) based on water supply limitations and discussions with EPA. These steps were performed in a manner that EPA deemed satisfactory, and EPA authorized an injection pressure of up to 1485 psi. To obtain a higher surface injection pressure, EPA requested additional pressure steps. EPA also strongly recommended obtaining a downhole pressure reading "to provide test results that do not include pipe friction and can be more easily interpreted."

When ECCV went to repeat the SRT, a wire was run down the well with a pressure transducer. During the experiment, unexpected vibrations were experienced at the well head that caused the wire to snap. The cable and pressure transducer ended up at the bottom of the well. After repeated attempts, ECCV was able to retrieve all but the last 1000 ft of wire, remove the production tubing, and reset the production packer. This wire and the pressure transducer remain at the bottom of the well. The utility estimates that the SRT test would have cost $60,000, but with efforts to remove the wire and complete the SRT, the cost rose to almost $225,000.

ECCV is in negotiations with EPA regarding the test results without the downhole pressure information. The SRT guidelines do not specify downhole pressure. Although the utility agrees that it would be good to have downhole pressure data, it is concerned with attempting to do this again. The costs to perform work on the injection well can increase significantly and quickly. Before work is completed on the injection well, a careful evaluation of the goals and potential risks should be performed.

Table 10.5. Permitting Process Timeline

Item Submitted	Date
EPA Statement of Basis	June 1, 2009
EPA Draft Permit (prepared)	November 2009
EPA Draft Permit Approved	February 10, 2010
Authorization To Inject and Minor Modification	December 21, 2011

Note: EPA=U.S. Environmental Protection Agency

Effective planning. The combination of being able to blend water, short-term purchasing of Denver Water, and a slowdown of the economy all provided ECCV with the necessary time to design, obtain the necessary permit for, and construct the desal facility and injection well. This allowed the utility to address growth and economic conditions in an effective manner.

Hydraulic fracturing changes the level of interest. The original well application and approval occurred before hydraulic fracturing by natural gas producers began to receive widespread public interest. With the increase in public concern over fracturing practices of the oil and gas industry, ECCV has noticed increased attention by EPA and others to their permit and operations.

Addressing past history of earthquakes. Because earthquakes were observed with an injection well in the area in the 1960s, EPA requested additional information during the technical review for the draft permit. ECCV had to conduct substantial research to prove that it will not be injecting into the same formation. ECCV is required to monitor for earthquakes in a 5 mile radius of the injection well.

Water rights issues. Water that is injected is considered a consumptive use. Therefore, ECCV needed to obtain sufficient consumptive water rights.

Differences between oil field outfits and municipalities. Drilling a 10,000 ft deep well required using well drillers that typically work in the oil and gas industry. Because oil and gas is regulated by a different agency with different rules, the drillers were unaccustomed to the more stringent requirements associated with Class I wells.

Level of risk. There is also a difference in the amount of risk assumed by owners in oil fields and municipalities. Municipalities often have contracts that are based on completion and satisfactory demonstration. Owners in oil fields recognize the risks of nonfunctioning wells (i.e., dry holes) and therefore do not hold the drillers responsible. This assuming of the risk of a dry hole shifts the burden on the owner and reduces the cost of well construction. ECCV changed the well construction contract to assume more risk after the initial construction bids were received. The work related to retrieving the pressure transducer in the second SRT was completed using oil field practices, which place most of the risk on the owner.

Mineral rights. Had oil or gas been found in the target formation, the mineral leaseholders would have rights to the well and could assume ownership with appropriate compensation. Although this did not occur for the ECCV well, it was another potential risk that ECCV assumed when drilling the well.

Chapter 11

Vero Beach

The groundwater desalting facility at Vero Beach, in Indian River County, FL started operations in 1992 as a 2 mgd facility. The plant, which uses RO technology, is now being expanded to 6 mgd to meet growing water supply needs for the community. Tables 11.1 and 11.2 provide basic parameters for the facility and source water quality.

Table 11.1. Plant Description

Start date	1992
Operating capacity	2 mgd (6 mgd at build-out)
Water source	Groundwater wells
Pretreatment	5 µ cartridge filter, antiscalant, sulfuric acid
Membrane system	Single-train, spiral-wound polyamide Tri-Sep low-pressure
Recovery	75–85%
Product post-treatment	pH adjustment with caustic soda; product blended with water from lime softening plant to improve quality
CM	Past: surface discharge to a canal and then to a river Present: DWI
Concentrate post-treatment	Past: forced air stripping for H_2S removal and increasing dissolved oxygen—required for surface discharge Present: none

Notes: CM=concentrate management; DWI=deep well injection; H_2S=hydrogen sulfide

Table 11.2. Feed Water Quality

Water Quality Parameter	mg/L
Na	191
K	11.3
Ca	62.8
Mg	47.4
HCO_3	200.1
Cl	367
SO_4	95.3
TDS	900
pH	7.75

Notes: Ca=calcium; Cl=chlorine; HCO_3=hydrogen carbonate; K=potassium; Mg=magnesium; Na=sodium; SO_4=sulfate; TDS=total dissolved solids

As the Vero Beach situation reflects, permitting issues such as those for DWI can be complex, and the choice of DWI can be driven by changes in regulatory policy on other disposal options as well as by the need to expand plant capacity where other disposal options are capacity limited.

11.1 History of CM Challenges

Since beginning operation in 1992, the RO facility concentrate has been discharged via a 5750 linear ft, 16 inch diameter polyvinyl chloride pipeline into a 52 linear ft, 24 inch diameter pipe that connects to the Indian River Farms Control District Main Canal. The canal flows east 4300 ft and discharges to the Indian River Lagoon, a Class III marine water body. The outfall is a designated Outfall D-001. It includes 50 ft of submerged 24 inch diameter pipe and is located about 100 ft downstream of the salinity barrier in the canal. In the original NPDES discharge permit, the canal was considered a Class III freshwater body. As seen in similar systems, tidal influences of the estuarine system on the tributaries create significant problems in trying to meet freshwater criteria. The concentrate was too salty for the canal and too fresh for the lagoon. A big issue was which test organism to use in whole effluent toxicity tests. When the permit was renewed, the canal was reclassified as a Class III marine water body, which alleviated chloride and TDS concerns/exceedences.

The concentrate was determined to have major ion toxicity from calcium and fluoride. The facility was under a consent order to initiate a petition for variance from acute toxicity standards for fluoride, and a variance was given. Permits for mixing zones were granted for gross alpha, combined radium, and fluoride. Some exceedences for nickel and copper have been attributed to laboratory error. Biodiversity monitoring was required.

Within the past few years, a diffuser was installed because there was insufficient dilution in the receiving water. Even with the diffuser, however, the facility cannot expand plant capacity using this disposal method; there is not enough stream flow for the mix zones.

The NPDES permit issued in 2008 for the RO plant (in Florida permits are renewed every 5 years or if there is a major change in the system) contained total maximum daily load limits on nutrients. The Indian River in this segment has experienced violations of dissolved oxygen and nutrient standards, according to the Florida Department of Environmental Protection (FDEP)'s ambient monitoring data. The segment was also on the 303d (list of impaired waters) list for these parameters. The effluent limits contained in the permit for total nitrogen (TN) and total phosphorus (TP) are based upon the levels experienced in the effluent for the previous permit cycle. These limits are an annual average of 4.0 mg/L and a daily maximum of 5.0 mg/L for both TN and TP. At these values, the plant could not expand in the future, which was the intent to improve the overall quality of the drinking water and also reduce trihalomethanes. The plant exceeded the nitrogen limit under the existing operation and received a consent order related to that in 2009. The consent order was resolved when the surface water discharges ceased after implementation of the deep injection well.

The city also operates a WWTP, which was under a consent order for the total load of copper and nutrients. The city's WWTP periodically discharges (0.06 mgd in 2007) treated wastewater and continually discharges drinking water byproducts into the Indian River Lagoon. The WWTP became operational in 1958, and in 1992 it was converted to a water reclamation facility (WRF). The WRF provides water treated to public access reuse standards for irrigation use to approximately 500 residents, 3 golf courses, 6 parks, and 1 school, and for cooling use at a nearby power plant. The WWTP is directly adjacent to the Indian River

Lagoon and has a permitted wet weather discharge of up to 60 days per year. Excess reclaimed water discharges to the lagoon during wet weather and storm events are detrimental to the naturally brackish lagoon's water quality primarily from nutrient loading. The WWTP consent order for copper and nutrients was also resolved as a result of the cessation of discharge to the lagoon.

The DWI well method of concentrate disposal and excess reclaimed water disposal has been utilized at facilities in Brevard County to the north and St. Lucie County to the south without any reported adverse impacts. In 2008, Vero Beach began the process of building a deep well for both the WWTP and RO facility. The DWI, now implemented, resolved all the problems and will allow expansion.

11.2 Permitting Process and Regulatory Requirements

Under the federal UIC Program, FDEP has primacy over Class I, III, IV, and V injection wells. EPA Region 4 (Atlanta) has oversight responsibility over Class II wells. Class I hazardous wells are prohibited in Florida, but as of 2008 there were 168 Class I wells (nonhazardous and municipal WWTP), including more than 50 Class I wells injecting municipal desal concentrate. This latter number represents approximately 95% of all such wells in the United States.

FDEP Form No. 62-528.900(1), entitled Application to Construct/Operate/Abandon Class I, III, or V Injection Well Systems, is the general application form for all classes and the different phases of injection consideration, including a permit for monitoring wells. Figure 11.1 represents the UIC Permitting Flow Chart (Roadmap) that was provided by FDEP and applies to operating permits. The reference to a 30 day public notice and public meeting is the EPA requirement, which FDEP has to follow. An additional 14 day notice afterward is a state requirement. The steps are for nearly all UIC permits: all Class I, III, and V wells, except a few types of Class V wells that EPA agrees do not pose a threat to the USDW. All concentrate wells are permitted under the steps in the chart. The normal sequence is for a construction/testing permit to be applied first (p. 5 of the form). This allows well construction and up to 2 years of injection to verify that the well can be operated as designed without endangering USDWs. The well can be used as designed, with no limitation on injected volume. Before that testing period is over, the applicant will apply for an operation permit. All permits run for 5 years. Operation permits are renewed every 5 years.

11.3 Deep Well Design

Parameters for the deep well design and the monitoring well, injectate water quality, and other key features are provided in Tables 11.3 through 11.7 and reflect conditions specified in the FDEP Class I UIC permit (Permit No. 31-0288155-003-UO).

Table 11.3. Injection Well Information

Well type	**Injection zone**
IW 1	**Lower Floridan Aquifer (Oldsmar Formation)**
Casing Diameter (in.)/Type	**Depth (ft) Below Land Surface**
54 steel	120
44 steel	412
34 steel	2000
24 steel	2651
16.6 FRP tubing	2641
Open hole	2651–3070
Pilot hole (filed with cuttings)	3070–3217

Note: FRP=fiberglass-reinforced plastic

Table 11.4. Monitor Well Information

Well type	**Injection zone**
IM 1	**Lower Floridan Aquifer, single zone, above base of USDW**
Casing Diameter (Inches)/Type	**Depth (Ft) Below Land Surface**
34 steel	120
24 steel	405
12 steel	405
5.43 FRP I.D.	1682
2.0 FRP I.D.	1710
Open hole	1682–1765

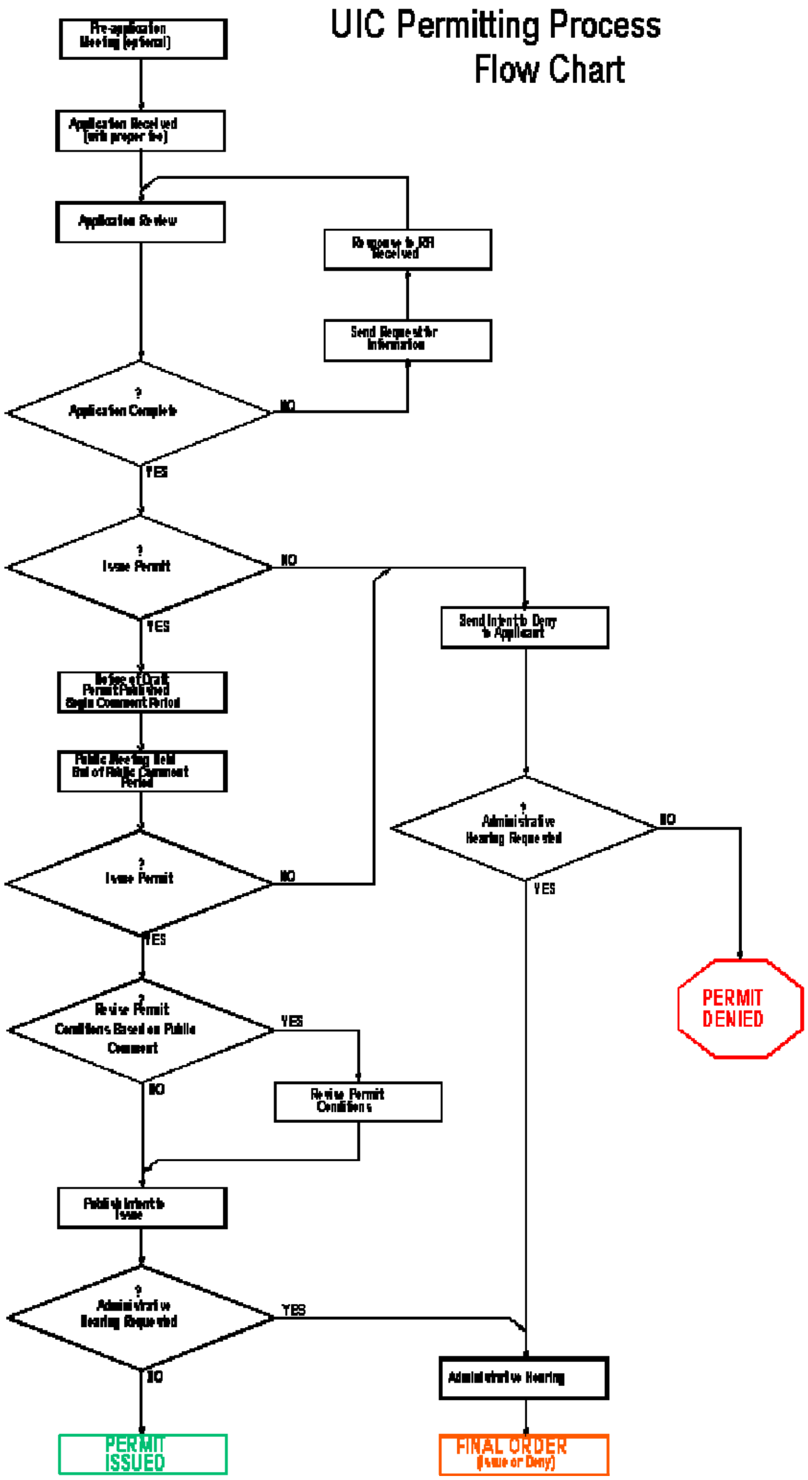

Figure 11.1. Permitting process flow diagram (roadmap) for Vero Beach DWI.

*In accordance with Section 120.57 Florida Statutes, a person whose substantial interests are affected by FDEP's proposed permitting decision has the opportunity to petition for an administrative proceeding (hearing) to challenge FDEP's decision. Thus, the administrative hearing involves only those who have petitioned for the hearing and is not a public hearing.

Table 11.5. Monitoring Requirements (from operating permit)

Recording Parameters	Frequency
Injection pressure (psi): monthly maximum, minimum, average	monthly
Injection pressure (psi): daily maximum, minimum, average	continuously
Annular pressure (psi): monthly maximum, minimum, average	monthly
Annular pressure (psi): daily maximum, minimum, average	continuously
Flow rate (gpm): monthly maximum, minimum, average	monthly
Flow rate (gpm): daily maximum, minimum, average	continuously
Total volume injected (gallons)	daily/monthly
Fluid added to annulus (gallons)	daily/monthly
Pressure added to annulus (psi)	daily/monthly

Table 11.6. Water Quality for Injectate and Monitoring Well (from operating permit)

Recording Parameters	Frequency
Ammonia nitrogen total as N (mg/L)	monthly
Chloride (mg/L)	monthly
Fluoride (mg/L; injectate only)	quarterly
pH (laboratory)	monthly
Residue, total filterable (TDS; mg/L)	monthly
Sodium (mg/L)	monthly
Specific conductivity (umhos/cm; laboratory)	monthly
Sulfate (mg/L)	monthly
Temperature (° C)	monthly
TSS (mg/L; injectate only)	monthly
Total Kjeldahl nitrogen (mg/L)	monthly
Gross alpha (pCi/L; injectate only)	quarterly
Radium 226 (pCi/L; injectate only)	quarterly
Radium 228 (pCi/L; injectate only)	quarterly
TP (mg/L)	monthly
Nitrate as N (mg/L; injectate only)	monthly
TN (mg/L; injectate only)	monthly

Notes: N=nitrogen; TDS=total dissolved solids; TN=total nitrogen; TP=total phosphorus; TSS=total suspended solids

Table 11.7. Monitor Well Parameters

Recording Parameters	Frequency
Monthly pressure (psi/NGVD): maximum, minimum, average	monthly
Daily pressure (psi/NGVD): maximum, minimum, average	continuously

Note: NGVD=National Geodetic Vertical Datum of 1929

11.4 Well Permits

The city concurrently applied to the St. John's River Water Management District (SJRWMD) for Consumptive Use Permit #116045 and submitted FDEP application 31-0288155-001 to construct one Class I industrial waste test well. The well was designed and constructed as an injection well for operation once injection was proven feasible and environmentally acceptable. The well was identified as a test injection well as it is the first well to be constructed in the wellfield. After this permit was granted, a draft permit for operation of the well was submitted. The operation permit specified[1] the maximum sustained wellhead pressure (psi) to be 102 and the daily maximum sustained injection rate to be 6750 gpm (9.72 mgd).

11.5 Other CM Options Considered

DWI has been previously considered but deemed to be too expensive. Disposal to the sewer could not be implemented as the concentrate would interfere with the sewer effluent quality for reuse. The city has considered blending concentrate with reclaimed water and stormwater to dilute the concentrate, but it requires too much reclaimed water to meet groundwater standards for irrigation.

11.6 Dates Corresponding to Permitting Roadmap

- RO system commissioned: 1992
- Application for test/injection well construction and testing permit submitted: April 15, 2008
- Response to request for information (RFI) received: June 27, 2008
- Financial responsibility information submitted: July 6, 2008
- Publication of Notice of Draft Construction Permit issued: September 26, 2008
- Public meeting held: November 6, 2008
- Publication of Notice of Intent (NOI) To Issue Permit: December 22, 2008
- Issuance of test/injection well construction and testing permit: January 7, 2009
- Well construction begun: October 7, 2009
- Testing for operation permit begun: December 29, 2010

1. Permits obtained for test/injection well construction, testing, and operation include Permit No. 31-0288155-001 (construction and testing, FDEP); Permit No. 31-0288155-003-UO (operation, FDEP); and Consumptive Use Permit No. 116045 (SJRWMD) for well construction.

- Application for operation permit submitted to FDEP: October 27, 2011
- RFI from FDEP received: November 28, 2011
- Response to RFI submitted: December 7, 2011
- Supplemental response to RFI submitted: January 10, 2012
- Publication of Notice of Draft Permit: March 1, 2012
- Public meeting held: April 12, 2012
- Publication of NOI To Issue Permit: May 25, 2012
- Issuance of Operating Permit: June 13, 2012
- Date industrial waste NPDES permit became inactive: September 10, 2012

11.7 Well Costs

There were four contracts associated with the overall project:

1. Irrigation wells (drilling, casing): $4,436,000
2. Pipeline (from plant to injection wells: 15,927 ft): $2,834,000
3. Pump station at WWTP to transmit reclaimed water, 3 million gallon storage facility, pump station for the DWI, 484 ft transmission line from RO plant and DWI pump station to DWI, 2 emergency generators (WWTP Pump station, DWI pump station): $3,374,000
4. Design, permitting, and construction oversight services: $923,000
    a. Related to #1: $565,000
    b. Related to #2: done with in-house personnel
    c. Related to #3: $358,000

The city received a $500,000 grant from SJRWMD for construction of the well.

11.8 Challenges Associated with the DWI Permit

Permitting went very smoothly, which is credited to the efforts of the design consultants and FDEP and SJRWMD staff. The design presented by the consultants was thorough, which resulted in few questions from the regulatory agencies. The regulatory staff in turn worked with the consultants and the utility to process the application and resolve questions that arose in a timely manner.

The plant did not encounter any major challenges during the permitting process. It found the permitting process that exists in Florida to be reasonable in protecting the public's interest and state water resources without being unduly burdensome on the utility.

11.9 Lessons Learned

Thorough preparation and planning is the key to avoiding major difficulties in the permitting process.

Chapter 12

Alamogordo

Alamogordo has been planning a desal facility since 2001. The city originally asked for 10,000 AFY in water rights to brackish groundwater but was awarded 4000 AFY by the New Mexico Office of the State Engineer (NMOSE). Several years of litigation by various stakeholders in the region occurred up until 2008, when the Twelfth District Court issued a ruling allowing the city to take up to 4000 AFY from the wellfield. The city's Snake Tank wellfield will be located on Bureau of Land Management (BLM) land, and a ROW is necessary to proceed with development and construction activities. To obtain a ROW, an EIS process was initiated by the BLM. The most recent revision of the EIS is dated May 2012; a Record of Decision (ROD) was issued by the BLM in August 2012 (BLM, 2012).

Reclamation operates the BGNDRF in Alamogordo, NM. This facility has 3 evaporation ponds totaling 4.3 AF in storage (without freeboard). Data on installation and operating costs are included in this chapter to supplement conceptual design costs from the city.

12.1 Project Background

12.1.1 Project Needs

Alamogordo has an abundance of water rights on paper but faces water supply shortages regularly. The city has implemented a strong water conservation program that has decreased per capita consumption by more than 50% from 1992 to 2008 (SWCA Environmental Consultants, 2012). Even with this decreased consumption, the city expects shortages between supply and demand, and the city's growth will be hampered by a lack of reliable drinking water. The city's total combined water rights (surface and groundwater) are 11,769 AFY plus 16 CFS (John Shomaker & Associates and Livingston Associates, 2006). This includes 5418 plus 16 CFS in surface water rights and 6351 AFY in groundwater rights. In contrast, an average of 3974 AFY of surface water has been available for use by the city, and only 1880 AFY has been produced from the city's groundwater wells between 2000 and 2005 (John Shomaker & Associates and Livingston Associates, 2006). Current projections estimate a shortage of 3398 AFY by 2045 (SWCA Environmental Consultants, 2012). Figure 12.1 shows projections provided in the 2006 40 year water development planning document. The city is planning for a desal plant that will produce at least 3200 AFY to help meet this demand. The remaining 198 AFY will come from undetermined water sources or desal efficiency gains.

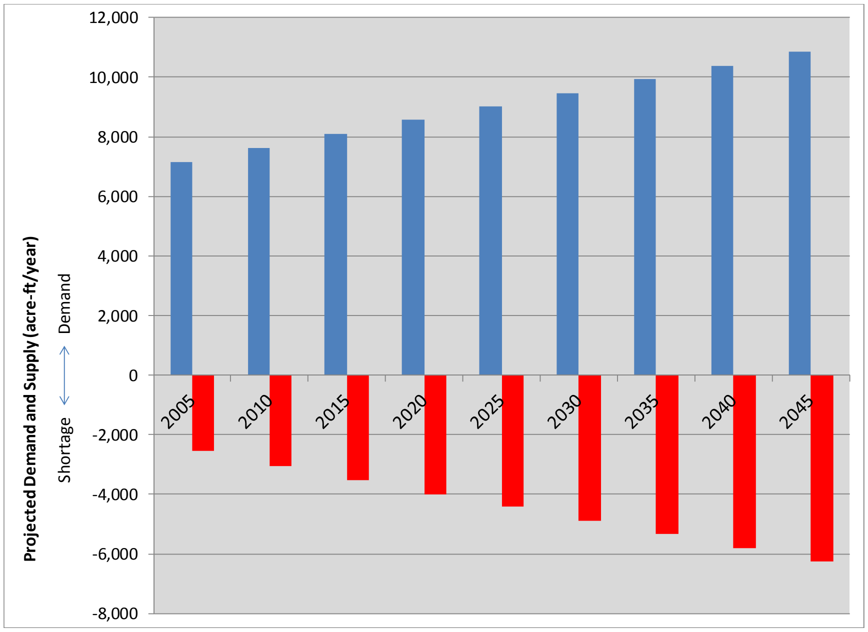

Figure 12.1. Alamogordo projected demand and supply shortages.

Source: John Shomaker & Associates and Livingston Associates (2006)

12.1.2 Desal Planning History

The May 2012 EIS contains a history of planning, litigation, and important decisions from 1983 to 2012 for Alamogordo. The city is not unique; many cities contemplating desal projects may need to consider the impact of the public process and plan appropriately to address environmental, social, and cultural concerns. The city received a ROD from the BLM in August 2012. As of October 2012, the city has not built its desal plant. It is recovering from a loss of a significant surface water source (Bonito Lake) caused by fire-related water quality problems and plans to build a temporary 1.5 mgd desal plant to replace the Bonito Lake water until it is rehabilitated.

12.1.3 Current Status of Project

Alamogordo has begun initial pipeline installations to connect to La Luz 24 inch pipeline. This pipeline is the conduit for bringing Bonito Lake surface water to the city (Figure 12.2). The early phases of construction will involve piping in Alamogordo, and later phases will connect the wellfield to the pipeline. Construction has started in Alamogordo, and the design is complete for the later phases. In addition to connecting to the 24 inch La Luz pipeline, later phases will involve upgrading the wells to allow for additional pumping for peaking needs and redundancy. The current wells are capable of providing 4000 AFY with little to no redundancy. In the near term, the city is contemplating installing a temporary 1.5 mgd desal plant (skid-mounted and possibly housed in a trailer) to treat Snake Tank brackish groundwater at La Luz water treatment plant. Temporary evaporation ponds would be constructed at this site.

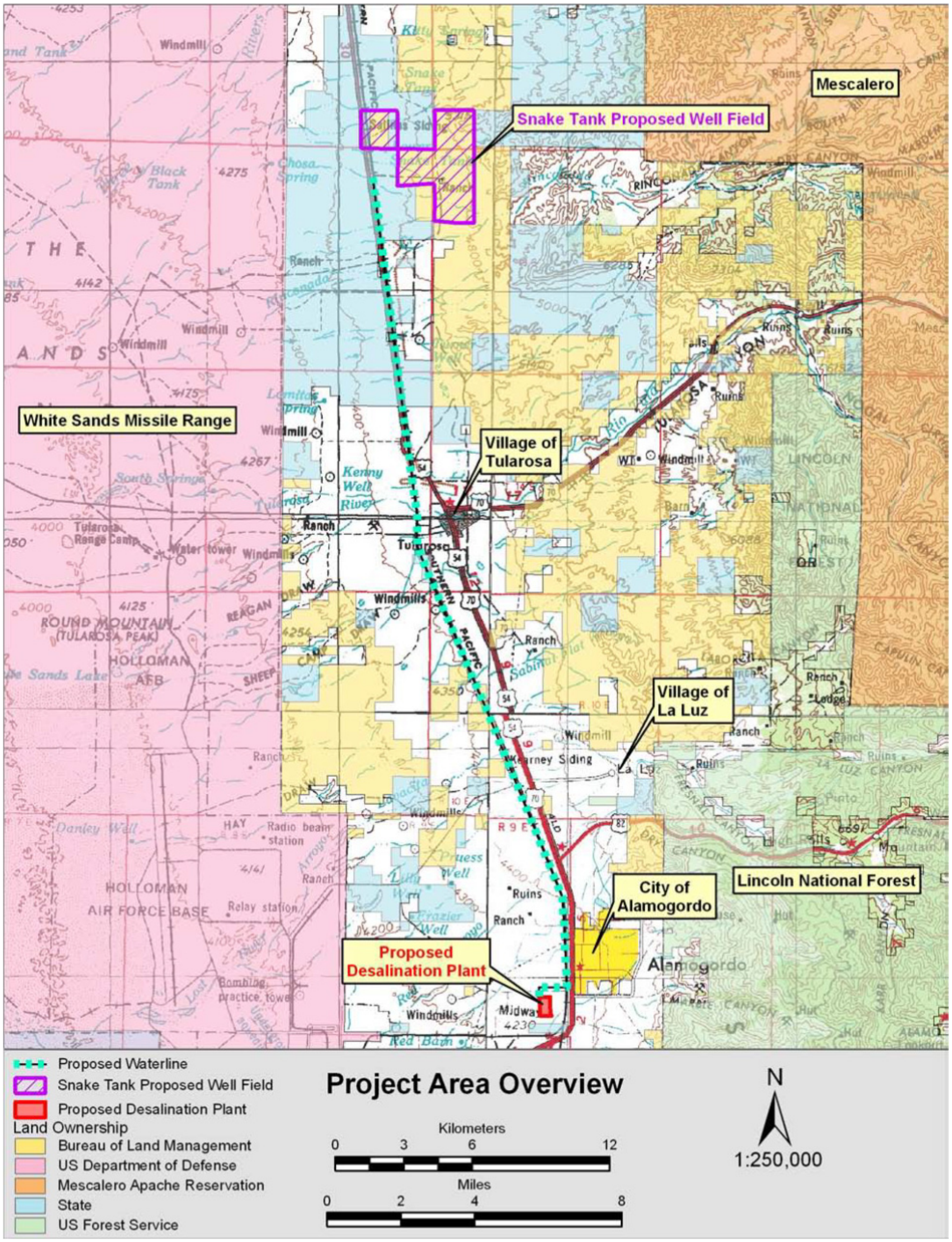

Figure 12.2. Alamogordo brackish groundwater wells and planned desal plant (EIS).

The city had a grant from EPA for preparing the EIS and other related documents, which was recently revoked for project inactivity (Bear, 2012). This should not have a significant impact on the project as a whole.

The city received a ROD on the EIS in August 2012. This is a big step toward designing a desal facility. The permanent desal plant will be located on La Velle Road, and the city plans to relocate the temporary desal plant equipment to this plant. Barring any disputes by other landowners, the city should be able to go out to bid once funding is available.

12.1.4 Basic Project Details

Up to 10 wells near Snake Tank Road (on ~20 acres of BLM land) will be installed to pump water from the Hueco-Tularosa Aquifer. Water quality is between 1500 and 5000 mg/L TDS. Field tests have demonstrated that feed water quality is about 2200 mg/L TDS. Alamogordo is permitted to pump up to 4000 AFY from its Snake Tank wells and up to 5000 AF in any year so long as the 5 year total is no more than 20,000 AF. A pipeline of approximately 32.5 miles will connect the Snake Tank wellfield and the desal plant. The city plans to install the permanent desal plant in phases. Early phases will allow the desal plant to be used as a peaking plant and designed to produce up to 3200 AFY (2.9 mgd) of product water. Later phases will allow the desal plant to provide enough capacity to supply the city's water demand in times of drought and be designed to produce up to 5.8 mgd for short durations. The desal plant is envisioned to include pretreatment followed by a two-stage RO with bypass blending to produce potable water with TDS of 800 mg/L. Pretreatment consists of cartridge filtration and antiscalant addition. The overall system recovery is estimated to be 80 to 84% with blending; the RO recovery is around 70 to 75%.

12.1.4.1 City of Alamogordo

Earlier EIS documents evaluated several CM options, including evaporation ponds, concentrate injection wells, and direct discharge to the sewer or the city's effluent water discharge field. The current site for the desal plant is not large enough for full-scale concentrate disposal by evaporation ponds. The 2012 EIS (pp. 2–21) states that "the groundwater conditions at both locations [desalination plant and WWTP] are suitable for deep-well disposal and would help maintain groundwater levels in the area." The EIS includes a hydrogeologic assessment of the proposed injection wells for the project and analyzes the impacts of their use.

Currently, the city plans to use temporary evaporation ponds and plan for long-term DWI. This is because the facility will initially be operated only intermittently and produce relatively low volumes of both permeate and concentrate. Preliminary plans estimate that 15,000 to 22,500 gpd of concentrate will be produced in the initial phase of the desal plant. The city will construct a 50 ft by 50 ft by 4 ft HDPE-lined 500,000 gallon evaporation pond at the desal plant site. The evaporation pond would have netting to prevent birds from entering. Approximately 120 tons of concentrate solids will be produced annually, and the content is expected to be nontoxic. The city expects to be able to dispose of these solid wastes in its permitted landfill. Table 12.1 shows the estimated desal concentrate quality (SWCA Environmental Consultants, 2012).

Table 12.1. Estimated Desal Concentrate Quality

Ion	Concentration (mg/L)
NO_3	1.9
K	11
Sr	21
SiO_2	35.6
Na	215
Mg	353
Cl	476
HCO_3	698
Ca	1417
SO_4	4394

Notes: Ca=calcium; Cl=chlorine; HCO_3=hydrogen carbonate; K=potassium; Mg=magnesium; Na=sodium; NO_3=nitrate; SiO_2=silicon dioxide; SO_4=sulfate; Sr: strontium

Source: SWCA Environmental Consultants (2012)

The EIS states that the city will consider using zero discharge desalination (ZDD), currently licensed to Veolia Water Systems, to substantially reduce its concentrate volume. ZDD is capable of providing up to 98% recovery and producing severable salable salts as part of the process. ZDD has been evaluated by the Center for Inland Desalination Systems (CIDS) at UTEP to desalinate a brackish groundwater that is very similar to that of the Snake Tank wells. CIDS and Veolia Water North America have been operating a demonstration-scale system at BGNDRF since 2009 and plan to operate a 40 gpm ZDD system in 2012 through 2013. If installed in the city, up to 3.5 mgd (3920 AFY) of product water can be produced from the desal of Snake Tank brackish groundwater. ZDD would allow the city to achieve its targeted water demand of 3398 AFY with a buffer for additional growth in demand or decrease in other water supplies. Calcium sulfate (gypsum), sodium sulfate, magnesium hydroxide, and sodium chloride are all potentially recoverable salts. The ZDD concentrate streams will contain all of the salts removed from the Snake Tank brackish groundwater and would account for only 2% of the volume fed to the system. A small evaporation pond is likely feasible for drying the solids.

The conceptual design costs for the 50 ft by 50 ft by 4 ft evaporation pond is $175,000 to $250,000, and an injection well is estimated to cost $2,625,000 (SWCA Environmental Consultants, 2012). The 2012 EIS summarizes conceptual design costs for the desal plant by phases and year (SWCA Environmental Consultants, 2012). CM represents about 15% of the capital cost. The total cost of CM for Year 1 is $157,000, or about 20% of the total O&M cost.

12.1.4.2 Reclamation's BGNDRF

Reclamation's BGNDRF is designed to have multiple desal research projects in operation, with their combined desal concentrate and other waste streams sent to one of the three evaporation ponds located on-site. Evaporation ponds were chosen for cost and simplicity for the operation of many types of desal processes at BGNDRF, which has four brackish water wells ranging from 1000 to 6000 mg/L TDS. Concentrate disposed of in the evaporation ponds ranges from 2000 to 200,000 mg/L TDS. Figure 12.3 shows the layout of BGNDRF and its evaporation ponds. There are two ponds with 341,000 gallons (without freeboard) capacity and one with 721,000 gallons (without freeboard) capacity. Each pond is constructed of two layers of HDPE with a leakage detector system between the layers. The primary (upper) layer is 80 mils thick, and the secondary liner is 40 mils thick. A 200 mil HDPE geonet acts as a spacer between the primary and secondary liners. BGNDRF's permit from NMED required this type of construction. The installed cost for these ponds, which were built in 2007, was about $562,700 (Shaw, personal communication, August 29, 2012). BGNDRF has a permit from NMED for the evaporation ponds. The permit is valid for 5 years from the date of first discharge. Reclamation estimates annual repairs and maintenance to be around $1000 per year for simple repairs to the evaporation ponds and at least 60 hours of effort to prepare documentation for permit renewals (Shaw, personal communication, August 29, 2012).

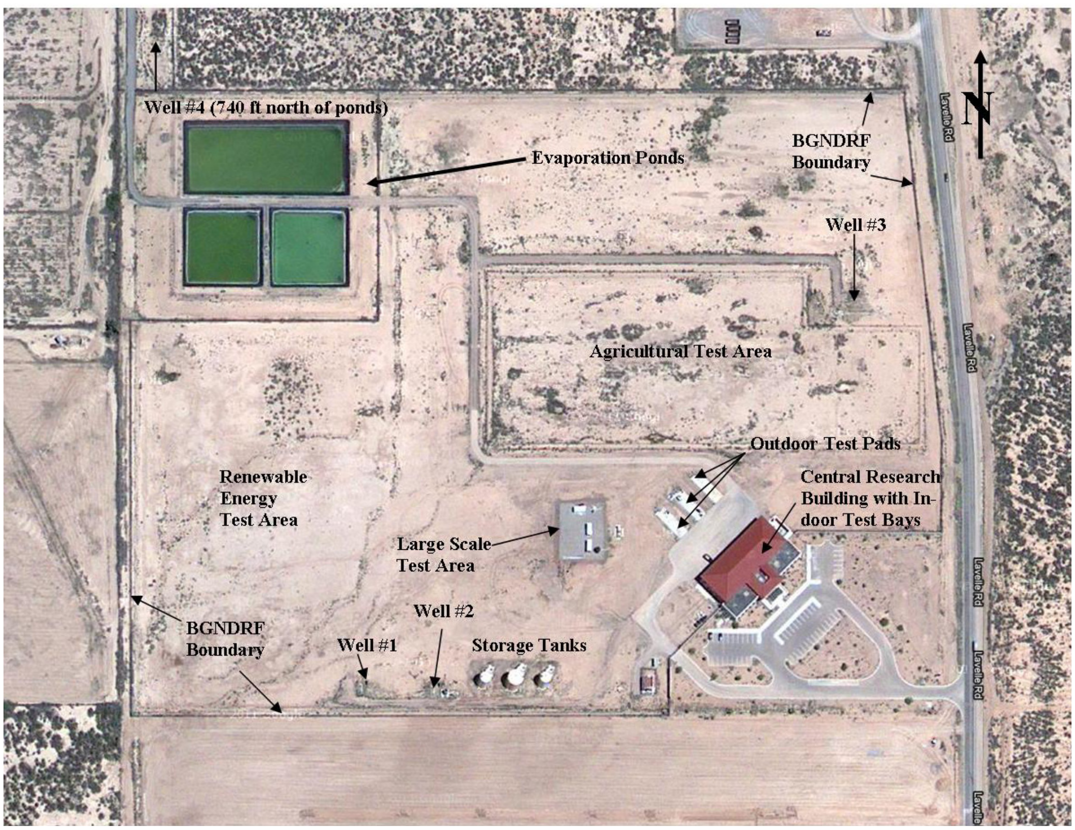

Figure 12.3. BGNDRF site layout and evaporation ponds.
Source: Provided by Randy Shaw, facility manager, BGNDRF.

12.2 Permitting Process and Regulatory Requirements for CM

As of June 2010, four public meetings were held (two for initial scoping in 2004 and two for draft EIS in 2010) as part of the BLM process to grant a ROW to the city. The public scoping meetings conducted by the BLM in 2004 "explained the NEPA [National Environmental Policy Act] process, the project history, the purpose of and need for the action, details about the area's hydrology, and potential methods for obtaining a regional water supply" (SWCA Environmental Consultants, 2012, pp. 1–10). Issues raised during the public scoping process included the project's potential impacts on groundwater levels, geology and soils, biological systems, cultural resources (e.g., prehistoric rock art at the Three Rivers Petroglyph Site, historic acequias), Indian Trust Assets, socioeconomic indicators (e.g., water rates, cost of living, property values, controlling future growth), and impacts on farming and ranching operations. It is interesting that the public did not express concerns regarding the CM options presented.

Table 12.2 describes the permits necessary for a desal plant in Alamogordo. There are no permitted desal concentrate injection wells in New Mexico, so Alamogordo could be the first. NMED has the authority to permit injection wells, and the understanding is that the formation salinity would need to be higher than 10,000 mg/L TDS. Although the city has not yet filed for a permit from NMED, it does not anticipate any problems with permitting the evaporation ponds or injection wells. Previous water analyses do not indicate any problematic constituents such as arsenic or those regulated by RCRA.

12.3 Permitting Challenges and Opportunities

> The city's decision to sponsor the [desalination] project followed years of investigation, preparation, and individual resource studies that examined alternative sources for obtaining a sustainable potable water supply. Several historical milestones…led to the city's decision to implement the project and prepare this EIS. (SWCA Environmental Consultants, 2012, pp. 1–5)

There were several internal and external versions of the EIS. Many of these changes were required by reviewers. Also, Alamogordo's permit had many required modifications, including monitoring wells (to evaluate whether other water rights are impacted by drawdown) and development of a water conservation program. In addition, the city purchased water rights from some stakeholders. The city has not yet obtained any permits for installation, including its planned CM strategy.

Table 12.2. Summary of Potential Permits and Regulatory Requirements for Brackish Groundwater Desal Facility in New Mexico

Permit or Approval	Legislation	Regulatory Agency
§404 Permit/§401 Water Quality Certification or Waiver	CWA	U.S. Army Corps of Engineers/NMED
Consultation with U.S. Fish and Wildlife Service	Endangered Species Act	U.S. Fish and Wildlife Service
Consultation with State Historic Preservation Office	National Historic Preservation Act	New Mexico Historic Preservation Division
General Construction Permit	NMAC 14.5.2	Construction Industries Division
NPDES Construction General Permit	§§318, 402, 405 of the CWA and 40 CFR §122.1	EPA
Stormwater Pollution Prevention Plan	§402 of the CWA	EPA
County Flood Control	County Flood Control Regulations	Otero County Flood Control Authority
Air Quality Construction Permit	Depends on plant design and CM method	NMED
Drilling Permit and Water Allocation	NMAC 1.18.550	NMOSE
Groundwater Discharge Permit	NMAC 20.6.2	NMED Groundwater Quality Bureau

Notes: CFR=Code of Federal Regulations; CM=concentrate management; CWA=Clean Water Act; EPA=U.S. Environmental Protection Agency; NMAC=New Mexico Administrative Code; NMED=New Mexico Environment Department; NMOSE=New Mexico Office of the State Engineer

12.4 Lessons Learned

The city has not actually built its plant and has not had difficulty with the CM portion at this time.

Chapter 13

San Antonio Water System Brackish Water Desalination Plant: Texas General Permit for Deep Well Injection

SAWS is the first utility in Texas to obtain a UIC Class I General Permit for the disposal of brine produced by a desal operation via DWI. This chapter describes its experience with the General Permit process.

SAWS is a public utility owned by San Antonio. It serves approximately 1.3 million people in the urbanized part of Bexar County. The service area for water supply includes most (but not all) of San Antonio, several suburban municipalities, and the adjacent part of Bexar County. In addition to serving its own retail customers, SAWS also provides wholesale water supplies to several smaller utility systems within this area.

SAWS' brackish groundwater desal plant will help San Antonio meet its water needs over the next 50 years while reducing dependency on the Edwards Aquifer. The plant, which will draw water from the Wilcox Aquifer in southern Bexar County, will include 13 production wells over 1500 ft deep. The first phase of the project is scheduled to come online in 2016 and will produce about 10 mgd. The second phase, which will be completed in 2021, will provide another 10 mgd, and a final phase in 2026 will bring an additional 5 mgd.

In planning for the desal facility, SAWS researched a number of options for CM, including DWI, evaporation ponds, land application, discharge to a nearby WWTP, and surface water discharge. SAWS also explored the use of vibratory shear enhanced process (VSEP) for concentrate minimization. A pilot VSEP project found that this technique was not a technically reliable option for SAWS.

The utility concluded that there were two potentially feasible means of concentrate disposal: subsurface disposal (i.e., DWI) and disposal to surface water via the San Antonio River. On the basis of an evaluation of the alternatives, the utility determined that DWI is superior from an environmental perspective and more economical and technically feasible. It was also considered much more publicly acceptable than discharge to the San Antonio River. Whereas disposal to the San Antonio River technically met the TCEQ screening criteria for surface water discharges, the river is a significant ecosystem and an important regional resource, and SAWS is concerned that such a discharge could potentially impair the river water quality in the vicinity of the discharge point or that downstream users could become apprehensive.

SAWS is the first utility in Texas to obtain a General Permit under the state's UIC Class I program for the disposal of brine produced by a desal operation via DWI. The General Permit allows SAWS to construct and operate five Class I wells without the need for an individual permit. Overall, the utility's experience with the General Permit process was very efficient and streamlined, especially compared with the timeline associated with Class I individual permits.

As a first step to the permit process, SAWS prepared an NOI for submission to TCEQ. Figure 13.1 shows the required components of the NOI.

The NOI took only about 2 months to complete, and was completed for 5 proposed injection wells, all located within about 2 miles of the desal plant. The NOI indicated that the proposed wells would inject desal concentrate into the Edwards Aquifer about 4200 to 4800 ft below the surface injection zone. SAWS will likely only need three wells at full implementation but applied for five wells in case of any problems with one or two of the planned wells.

The Edwards Aquifer injection zone is part of the same formation that is used for drinking water in San Antonio; however, the injection wells are located approximately 20 miles down dip from the freshwater portion of the Edwards Formation. There are also a number of known faults in the southern part of the county, which hinder movement of the injection stream north toward town.

Water quality testing for the proposed injection zone (conducted as part of the NOI) showed that TDS levels in the underground aquifer were close to 90,000 mg/L. Thus, the injection zone is not considered a potential USDW, which made the permitting process a bit easier. No geotechnical investigation was necessary for the NOI.

SAWS filed its NOI on June 28, 2011, and received authorization from TCEQ to drill a test well within 5 to 6 weeks. The utility built the well at full scale rather than building a smaller-scale well for testing purposes. Shortly after receiving authorization, SAWS submitted a Notice of Change to TCEQ that would allow construction of an open completion well, which is cased only to the top of the aquifer. The concentrate is then basically injected into a hole in the aquifer. Standard practice for Class I wells is to case the well the entire way down (through the point of injection). TCEQ authorized this change, and the first well has proved successful. It will be used for injection when the desal plant is brought online.

On September 30, 2011, TCEQ officially acknowledged the NOI for all five wells and issued a General Permit number for each well. SAWS received the acknowledgement within 94 days of the NOI filings. Although all wells have been permitted, SAWS will need to file a financial assurance for Wells 2 through 5 prior to drilling. Because SAWS initially determined that only one test well was needed at the time, it filed the financial assurance with TCEQ only for that well. It is required to file the financial assurance for Wells 2 through 5 a minimum of 60 days prior to drilling them.

Overall, SAWS noted that the preparation and requirements associated with the General Permit are pretty much the same as those for a Class I individual permit but with some reduced requirements; however, there is a much faster review time by TCEQ with the General Permit. This is partly due to more reliance on review and certification by outside engineers (rather than on review by TCEQ staff). In addition, there is no public comment period associated with the General Permit, unless deemed necessary by TCEQ, and no opportunity for a public hearing, which serves to minimize the time involved in obtaining a permit. Finally, county groundwater conservation districts do not have jurisdiction with the General Permit as they do with the Class I individual permit, which means there is only one agency involved in the permitting process (aside from the Texas Railroad Commission).

Part I, General Information.

Part II, Railroad Commission Letter: TCEQ requires permit applicants to submit a letter from the Railroad Commission stating that "drilling the disposal well and injecting industrial or municipal waste into the subsurface stratum will not endanger or injure any known oil or gas resources."

Part III, Financial Assurance for Closure: Applicants must submit evidence of financial assurance at least 60 days prior to commencement of drilling operations. The financial assurance is needed in the event that the well would need to be plugged. The financial assurance must be updated annually to adjust for real changes in the cost of plugging services and inflation.

Parts IV through XVIII compose the Technical Report, which addresses aspects of geology; hydrology; well construction, stimulation, operation, and monitoring; plans for contingencies, plugging, and abandonment; reservoir mechanics; area of review and corrective action; wastes and waste management; and pre-injection units.

A fee of $100 is required for each disposal well to be authorized under an NOI.

Figure 13.1. Components of TCEQ's General Permit NOI.

For SAWS, one of the most difficult tasks was getting everything organized on its end and coordinating with all staff members. This included getting all the right signatures on the right documents and explaining things to executives and senior staff. Another challenge with the permitting process is that every time a minor change is made, a change order is required. The change order associated with the open well completion did not take much time; however, the process has the potential to slow things down. For example, if a contractor needs to use a different material than one specified in the permit, a change order is necessary. This provides incentive for applicants to include as little detail as possible in the permit application. Finally, there is also some concern about a change in legislation for the General Permit.

In addition to the General Permit, SAWS also had to complete an environmental assessment (EA) consistent with state guidelines in order to meet TWDB funding requirements. The EA required additional effort above and beyond the effort associated with completing the NOI. A full EIS was not required.

In total, the well took 100 to 150 days to construct. It cost about $4.8 million for construction and about $640,000 for the planning, design, and permitting effort. At the time of this writing, SAWS had just started predesign and engineering for the second well and were on schedule to complete construction by the end of 2013. SAWS staff learned a lot from the construction of the first well and feel that subsequent wells will not take as long.

SAWS also expects that subsequent wells will cost less than the first. This is partly due to lessons learned during construction as well as the hope that fewer water quality and coring samples will be needed after the extensive analysis conducted for the first well. The construction effort for the first well was more expensive than expected in part because SAWS had a hard time finding a contractor to do the work because of high demand in the oil and gas industry, which drove up the price.

Chapter 14

Brownsville

14.1 Project Background

In April 2004, Brownsville began operations at its new Southmost Regional Desalination Plant, which is designed to turn brackish groundwater from the Gulf Coast Aquifer into drinking water. This project was implemented as a joint partnership under the Southmost Regional Water Authority (SRWA). Participating members include the Brownsville Public Utilities Board (BPUB; i.e., the City of Brownsville), the City of Los Fresnos, the Valley Municipal Utilities District, the Town of Indian Lake, and the Brownsville Navigation District. Brownsville owns 92.91% of the plant and has a 30 year contract to operate it. The plant has six RO trains that cost a total of $21.1 million for design, permitting, and construction.

SRWA initiated the desal project because of concerns that there would not be enough water in the Rio Grande to meet demands. Planning for the facility began in the late 1990s, and a feasibility study was conducted in 2000. Construction and implementation were initiated in 2002. To facilitate the completion of the plant by the summer of 2003, multiple contracts were developed and phased for rapid completion. Property issues resulted in wellfield installation later than expected and a subsequent wellfield distribution system; however, the project came online in 2004. Today, it accounts for 25% of local supply.

The desal plant has a capacity of 7.5 mgd but is currently operating at about 6.3 mgd. When the project came online, SRWA produced a total of 7.5 mgd by blending 1.5 mgd of the brackish source water with 6.0 mgd of desalinated water. In 2001, EPA lowered the drinking water standards for arsenic. As a result, SRWA can no longer use the brackish source water for blending as it does not meet the new standards.

The plant currently operates at a 75% recovery rate, with the desal concentrate ranging between 12,000 and 14,000 mg/L TDS. SRWA disposes of desal concentrate via a drainage ditch that eventually discharges into the Gulf of Mexico via San Martinez Lake, which is classified as a hypersaline lake. The drainage ditch runs directly behind the plant and was well established prior to the plant being in operation. SRWA did not really consider other options for concentrate disposal.

The natural drainage ditch only flows during the summer and is about 25 to 30 ft deep. The project partners needed to install rip rap along the banks of the ditch because of erosion, although this has been minimal. Some of the erosion was caused because SRWA initially had some problems with the concentrate surging from the outfall. Other than the rip rap, operational costs have been minimal. Construction costs for disposal were also very low, as construction only involved the installation of an outfall and pipeline to the ditch.

SRWA is planning to eventually expand the plant’s capacity to 9 to 11 mgd. Currently, the discharge only rises to about 1 ft in the drainage ditch. SRWA expects that eventually there will be a limit on how much it can discharge because the drainage ditch fills up during hurricanes and large flood events. So far, there have been no problems with the ditch overflowing, nor is this expected to happen when the plant expands to 9 to 11 mgd.

Overall, SRWA staff are pleased with how the desal operation has performed. Although conventional treatment is cheaper, the desal plant offers a reliable, drought-resistant supply, and participating members have not had to purchase additional water rights because of the project. Key challenges have included increased chemical costs and reduced production resulting from the revised arsenic rule. Coordinating with all of the project members has also been challenging at times.

14.2 Permitting Process and Challenges

SRWA obtained a Texas Pollutant Discharge Elimination System permit from TCEQ to discharge concentrate to the drainage ditch. An industrial waste discharge permit was also required by local authorities for the disposal of backwash cleaning solution to BPUB's wastewater treatment facilities. The state permit required some modeling of hydraulics as well as a public hearing.

In a report for the TWDB, Norris (undated) states that during the course of design and construction, state permitting of the concentrate disposal continued to be an issue with regard to time. The permit took over 18 months to secure and was obtained well into the construction of the facility. The author reports that delays were due to inexperience in reviewing permits of this type and the concentrate being considered an industrial waste; however, continuous education and working with the regulators helped to move the process along. Objections to the permit by unaffected parties also added several months to the process.

In addition, Norris reports that SRWA initially overlooked the requirements associated with local regulations. A local ordinance required SRWA to obtain an industrial waste discharge permit in order to dispose of backwash cleaning solution from the desal process to BPUB's wastewater treatment facilities. The backwash solution met all water quality requirements for discharge; however, it was subject to an application process that rivaled the state's concentrate disposal application (Norris, undated).

Finally, the permit has limits on TDS and selenium levels; however, these levels are relatively high compared to the desal concentrate. SRWA made the argument that the TDS limit should be high because the concentrate is ultimately drained to the ocean; however, because it made this argument, it is now subject to the selenium limit, which only applies to ocean discharge. SRWA must report to TCEQ if selenium levels in the discharge exceed 40% of the limit. This has not yet occurred.

Chapter 15

Sterling

15.1 Project Background

Sterling is located approximately 120 miles northeast of Denver. The city serves a population of approximately 14,000 people and obtains its drinking water from 15 alluvial wells along the South Platte River. Wells are typically 60 to 100 ft deep.

The city was operating under an Enforcement Order from CDPHE to address uranium concentrations that exceed the MCL of 30 µg/L and total trihalomethanes that occasionally approached or exceeded the MCL of 80 µg/L. There was also concern that the wells might be considered groundwater under the direct influence of surface water and have nitrates approaching the MCL, elevated levels of TDS, sulfate, and hardness that may exceed the secondary standards.

To address these issues, the city chose to implement NF after an evaluation of alternatives that included lime softening and modified coagulation/granular activated carbon. The process has NF water blended with an MF process stream.

Four options were evaluated for the disposal of brines produced. These included concentrate discharge to:

1. surface water
2. groundwater
3. evaporation ponds
4. DWI

In the design, if discharge to evaporation ponds or DWI were selected, a second-pass membrane system would be selected to minimize the injection volume. If discharge to surface water or groundwater were selected, a single-pass option would be used. Evaporation and DWI are consumptive uses of water and therefore have an impact on water rights.

The decision was made to use DWI for the following reasons:

- Although discharge to surface water was considered a potentially viable option, it would require treatment processes for sulfate and selenium removal. Regulatory relief would also be needed for sodium.
- Discharge to groundwater would require additional advanced treatment processes. These would be needed to meet the preliminary effluent limits identified by CDPHE. Capital and O&M costs made this impractical.
- Evaporation ponds would require significant land area (>100 acres) with lined basins. This would require large capital costs. Solids remaining would need to be disposed of in landfills.

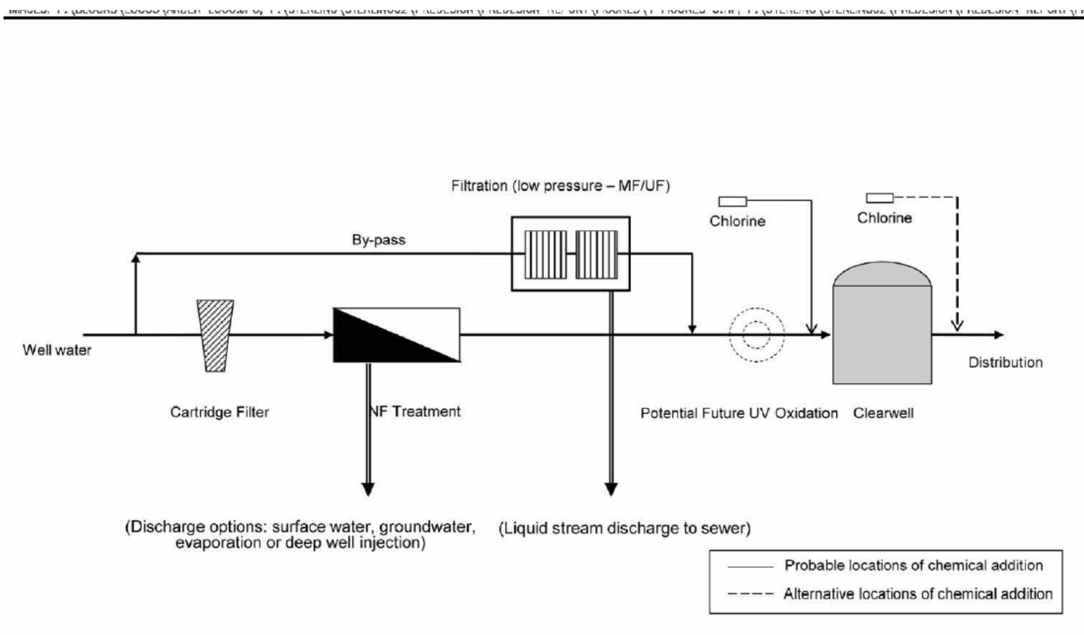

Figure 15.1. Conceptual flow diagram for NF systems and CM options.

Source: Richard P. Arber Associates, Inc. (2009)

Table 15.1. Design Demands

Design Phase	Measure of Demand	Finished Water Demand (mgd)	Raw Water Demand[a] (mgd)	Concentrate Flow[a] (mgd)
Phase I (Year 2022)	average annual	4.19	4.43	0.24
	peak month[b]	7.96	8.42	0.46
	peak day	9.55	10.10	0.55
Build-out (Year 2032)	average annual	4.76	5.03	0.27
	peak month[b]	9.04	9.56	0.52
	peak day	10.86	11.48	0.62

Notes: [a]Raw water demands and concentrate flow are based on an NF system with a 20% blend stream and recovery of 93%; [b]Peak month demands are based on a peaking factor of 1.9 (peak month to average annual).

Source: Richard P. Arber Associates, Inc. (2009)

Table 15.2. Injection Well Specifics

Type Well	UIC Class I Nonhazardous
Surface casing	9 5/8 in. casing to 1400 ft in a 12.25 in. hole to a depth of 1000 ft
Production casing	7 in. casing to 6989 ft (Well 1) and 6040 ft (Well 2) in an 8.75 in. hole
Estimated injection rate	175 to 200 gpm
Maximum pressure	1487 psi[a]
Maximum injection volume	no limitation

Notes: [a]Maximum allowed injection pressure will be evaluated upon completion of SRT.

The treatment train and CM options, design demands, and specifics on the injection wells are described in Figure 15.1 and Tables 15.1 and 15.2, respectively.

Two wells, approximately 1 mile apart, were drilled prior to construction of the treatment facility to ensure the ability and capacity to discharge concentrate. The total cost for both wells was approximately $4.5 million. Each well has sufficient capacity to accept the complete reject stream from the plant on the highest demand day and month. Redundancy of wells was deemed essential to ensure that, once constructed, the plant would not be shut down if a well needed to be taken out of service for any reason.

15.2 Permitting Process

The permitting process was almost identical to that documented for ECCV (Chapter 10). The Sterling permit application was submitted to EPA Region 8 approximately 6 months after ECCV's application was submitted. One difference is that seismicity was added to the well operation requirements in the permit. This was in response to concerns over the potential that DWI would cause earthquakes, which was identified as an issue during ECCV's public comment period. The timeline for the permit is provided in Table 15.3; currently it has been more than 2 years, with final approval to inject still pending. There has been no immediate rush for approval by either the utility or EPA. The plant is not expected to become operational until December 2012. Also, the EPA permit manager was called away on other temporary duties. The data from well testing have been reviewed by EPA, and the utility expects no difficulty in obtaining the final permit.

Table 15.3. Timeline for Permitting

Preliminary engineering report	June 2009
Final area permit	September 2010
Well construction	October 2010–May 2011
Completion of well testing	August 2011
Final approval to inject	Pending

15.3 Lessons Learned

In general, obtaining the permit was fairly straightforward, although it still required over 9 months to obtain the permit. Other lessons learned include:

- There are a significant number of oil and gas wells in the Denver–Julesburg Basin (D-J Basin) around the site of the injection wells. These wells are above the proposed injection site, with TDS levels slightly less than 10,000 mg/L. Had these wells been in the same target formation as the injection well, they would have needed to be included in the area permit, and integrity testing would have been required. There were 4 or 5 wells in a 20 mile radius that went below the D-J Basin sands. These provided the information necessary for the well design.
- There were inconsistencies in naming and designating geological formations in the oil and gas wells drilled in the surrounding area, and therefore it was necessary to work with

EPA to agree upon naming. Inconsistencies in naming also caused challenges and increased costs with the drilling contractor.

- The Sterling permit addressed issues identified from the previous Region 8–issued DWI permit at ECCV. Because concern over potential earthquakes was raised in the ECCV permit, Sterling was able to address this issue in its draft permit, thereby speeding up the process.
- The largest challenge was finding a contractor to drill the wells. Although there are many oil and gas well drillers in the area, few have experience working with municipalities. Drillers of typical water wells are not equipped for the depth or requirements for injection wells. In the oil and gas industry, agreements tend to resemble time and materials contracts. Municipal agreements tend to be fixed price, require a Request for Proposal process, and have stringent insurance and other requirements. Sterling received three bids from contractors who were familiar with municipal contracts and able to subcontract with drillers.

Chapter 16

North Miami Beach Norwood–Oeffler Water Treatment Plant

16.1 Introduction

This case study examines the CM approach applied at North Miami Beach's Norwood–Oeffler Water Treatment Plant, located in Miami–Dade County, FL. A description of the plant is provided in Table 16.1. The facility expansion (started in 2008) includes 17 mgd of desalting capacity via NF (9 mgd) of a blend of Biscayne and more saline Floridan Aquifer source waters, RO (6 mgd) of Floridan Aquifer water, and MF (2 mgd) of bypass water. Concentrate is being managed through DWI. Source waters are the Biscayne and Floridan Aquifers; their raw water qualities are summarized in Table 16.2.

Table 16.1. Plant Description

Plant expansion start date	March 2008
Operating capacity	32 mgd (37 mgd at build-out) 15 mgd lime softening (existing) 9 mgd NF (new) 6 mgd RO (new) 2 mgd MF on bypass
Water source	Groundwater wel Biscayne Aquifer for lime softening and NF Floridan Aquifer for RO
Pretreatment	For both NF and RO: 5rtridge filter, antiscalant, sulfuric acid
Membrane system	For RO: Stage 1 uses higher rejecting/lower flow ESPA2 membrane; Stage 2 uses lower rejecting/higher flow ESPA1 membrane
Recovery	For RO: 75%
Product post-treatment	RO product water degasified; NF and RO product water: addition of NaClO, NH_3, and fluoride; 5 streams are blended to provide product for distribution: lime-softened water, NF permeate, RO permeate, Biscayne raw water bypass, and Floridan raw water bypass
CM	Concentrate from both NF and RO go to DWI; backup system is existing sewer system
Concentrate post-treatment	none

Notes: CM=concentrate management; DWI=deep well injection; MF=microfiltration; NF=nanofiltration; NH_3=ammonia, NaClO=sodium hypochlorite; RO=reverse osmosis

Table 16.2. Typical Water Quality

Parameter	Biscayne Water (mg/L)	Floridan Water (mg/L)
Na[a]		
K[a]		
Ca	83	180
Mg	1.7	140
HCO_3	238	171
Cl	40	2000
SO_4	21	300
Fe	0.3	<0.1
NO_3	<0.1	<0.1
F	0.2	0.1
H_2S	<0.1	1.0
Color	35	<1
TDS	405	3800

Notes: Ca=calcium; Cl=chlorine; F=fluorine; Fe=iron; H_2S=hydrogen sulfide; HCO_3=hydrogen carbonate; K=potassium; Mg=magnesium; Na=sodium; NO_3=nitrate; SO_4=sulfate; TDS=total dissolved solids

[a] Values for Na and K were not provided. However, based on various reports published by the United States Geological Survey (USGS), estimated values for Na and K in Biscayne Water are very small (20 and 2 mg/L, respectively). Estimates for Floridan Water are 900 mg/L for Na and 100 mg/L for K.

16.2 CM Challenges

DWI was considered the only feasible option from the start of the project. Other options were not considered because the facility is located in a residential neighborhood, and no other CM options were technically feasible.

There were two challenges associated with implementing the disposal system. First, there was only one qualified bidder for drilling the well, and the costs were considered excessive. Negotiations ended with the well being downsized to reduce costs. Second, there were difficult negotiations with the local WWTP for providing the backup disposal option, which had to do with accurately metering the flow.

16.3 Permitting Process and Regulatory Requirements

Under the federal UIC Program, FDEP has primacy over Class I, III, IV, and V injection wells. EPA Region 4 has oversight responsibility over Class II wells. Class I hazardous wells are prohibited in Florida, but as of 2008 there were 168 Class I wells (nonhazardous and municipal WWTPs), including more than 50 Class I wells injecting municipal desal concentrate. This number represents approximately 95% of all such wells in the United States.

FDEP Form No. 62-528.900(1), entitled Application To Construct/Operate/Abandon Class I, III, or V Injection Well Systems, is the general application form for all UIC classes and the different phases of injection consideration, including a permit for monitoring wells. Figure 16.1 represents the UIC Permitting Flow Chart (Roadmap) provided by the FDEP, which applies to operating permits.

The reference to a 30 day public notice and public meeting is a federal EPA requirement. An additional 14 day notice afterward is a state requirement. The steps are identical for nearly all UIC permits (all Class I, III, and V wells, except a few types of Class V wells, which EPA agrees do not pose a threat to the potential USDWs).

All concentrate wells are permitted under the steps included in Figure 16.1. The normal sequence is to first apply for a construction/testing permit (p. 5 of the form). This allows well construction and up to 2 years of injection to ensure that the well can be operated as designed without endangering USDWs. The well can be used as designed, with no limitation on injected volume. Before that 2 year testing period has ended, the applicant will need to apply for an operation permit. Operation permits are renewed every 5 years.

16.4 Deep Well Design, Monitoring, and Costs

Injection Well IW-1 is constructed with a design that includes tubing, packer, and fluid-filled annular space around the tubing: 14.46 inch I.D., 0.8 inch thick fiberglass-reinforced plastic tubing is installed within a 20 inch outside diameter steel casing. The depth of the packer center point is 2853 ft below land surface. The injection well injects through an open-hole interval between 2858 ft (the base of the 20 inch final steel casing) and the total depth of the well at 3420 ft below land surface. The open-hole (injection) interval is in the Boulder Zone, within the lower Oldsmar Formation. Table 16.3 provides a summary of the injection well parameters.

The confinement of the injection zone from the overlying USDW aquifers and fluid movement adjacent to the well bore of the injection well are monitored by a dual-zone monitoring well, DZMW-1. Monitoring intervals in DZMW-1 are 1570 to 1590 ft below land surface (upper monitoring interval) and 1800 to 1850 ft below land surface (lower monitoring interval). Tables 16.4 and 16.5 provide information on the monitoring well and overall monitoring requirements, respectively. Tables 16.6 and 16.7 address water quality and other monitoring frequencies required, respectively.

16.5 Permitted Operation

The permit specifies a well maximum wellhead pressure of 140 psi and a peak hourly flow rate of 5120 gpm (7.37 mgd). Only nonhazardous RO reject concentrate and NF (i.e., membrane softening) reject concentrate from the city's Norwood–Oeffler Water Treatment Plant and purge water from the on-site dual-zone monitoring well, DZMW-1, may be discharged into IW-1. The emergency disposal method includes diversion of the reject concentrate to an existing Miami–Dade Water and Sewer Department sanitary sewer force main.

16.6 Costs and Permitting Timeline

The capital costs for development of the DWI well (minus pump and pipe) were $4.9 million. Piping and pumps costs (~$350,000) were minor, as the DWI system is in close proximity to the desal plant.

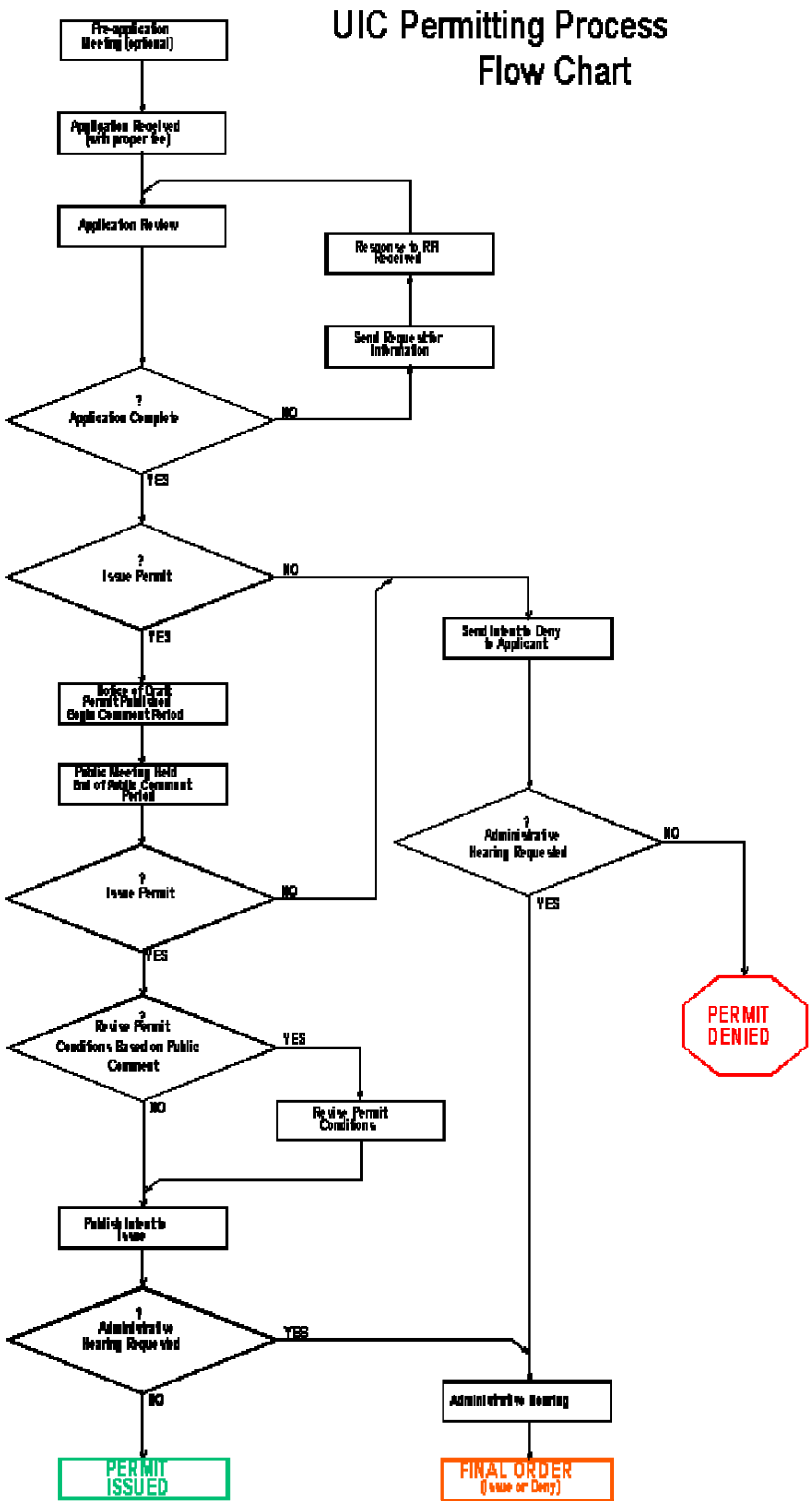

Figure 16.1. UIC permitting process flow chart

Table 16.3. Injection Well Parameters

Casing Diameter (in.)/Type	Depth (ft) Below Land Surface
20 steel	2858
14.46 0.8 in. thick FRP (tubing)	2858
Depth of packer center point	2853
Open-hole injection	2858–3420

Note: FRP=fiberglass-reinforced plastic

Table 16.4. Monitoring Well Information

Well No.	Monitoring Zone	Monitoring Intervals (ft)
DZMW-1	Lower Floridan Aquifer, dual zone, above and below base of USDW	1570–1590 1800–1850

Note: USDW=underground source of drinking water

Table 16.5. Monitoring Requirements

Recording Parameters[a]	Frequency
Injection pressure—sustained (psi): monthly maximum, minimum, average	monthly
Injection pressure—sustained (psi): daily maximum, minimum, average	continuously
Shut-in pressure (psig)	monthly
Annular pressure (psi): monthly maximum, minimum, average	monthly
Annular pressure (psi): daily maximum, minimum, average	continuously
Flow rate (mgd): monthly maximum, minimum, average	monthly
Flow rate—sustained (gpm): daily maximum, minimum, average	continuously
Monthly maximum, minimum, average of daily flow volumes	monthly
Total volume injected (mg)	daily/monthly
Documentation of exercising of valves	monthly

Note: [a]sustained=15 minutes minimum

Table 16.6. Water Quality Monitoring Frequency (Injectate and Monitoring Well)

Recording Parameters	Frequency
Chloride (mg/L)	monthly
pH	monthly
Residue, total filterable (TDS, mg/L)	monthly
Specific conductivity (umhos/cm, laboratory, temperature compensated)	monthly
Sulfate (mg/L)	monthly
Temperature (° C)	monthly
TSS (mg/L, injectate only)	monthly
Total Kjeldahl nitrogen as N (mg/L)	monthly
Ammonia nitrogen total as N (mg/L)	monthly[a]
Nitrate (as N, mg/L)	monthly
Gross alpha (pCi/L)[b]	quarterly

Notes: N=nitrogen; TDS=total dissolved solids; TSS=total suspended solids; [a]Monthly average of all parameters sampled daily; [b]If the sampling for gross alpha particle activity shows a response of ≥15 pCi/L, monthly sampling for the following chemical characteristics shall be implemented until a full three months of data show that gross alpha has declined to below the threshold value of 15 pCi/L: (1) gross alpha (ρCi/L) and (2) combined radium-226 and radium-228 (ρCi/L).

Table 16.7. Other Monitoring Well Recording Frequencies

Monthly pressure or water level (psi/NGVD): maximum, minimum, average	monthly
Daily pressure or water level (psi/NGVD): maximum, minimum, average	continuously

Note: NGVD=National Geodetic Vertical Datum

Dates corresponding to the permitting roadmap (Figure 16.1) are listed herein. The test/injection well construction permit application process took more than 14 months.Testing started nearly 3.5 years later and continued for 2 years. The operating permit was received 5 weeks after completion of the testing and the public meeting. The entire process took about 6.5 years.

- February 7, 2003 — Application for test/injection well construction and testing permit
- April 26, 2004 — Issuance of test/injection well construction and testing permit
- April 26, 2004 — Well construction begins.
- September 18, 2007 — Testing begins.
- April 2008 — Hybrid low-pressure RO system commissioned
- April 3, 2009 — Application for operation permit received
- April 15, 2009 — Supplementary correspondence received

- July 1, 2009 — RFI submitted
- July 24, 2009 — Response to RFI received
- August 14, 2009 — Publication of the Notice of Draft Permit 0210044-003-UO in the *Miami Herald*
- August 25, 2009 — Supplementary correspondence received
- September 3, 2009 — Supplementary correspondence received
- September 15, 2009 — Public meeting held
- September 15–30, 2009 — Consideration of receipt of public comment received as a result of public meeting held on September 15, 2009
- September 17, 2009 — Testing finished
- September 30, 2009 — Publication of the NOI To Issue Permit 0210044-003-UO in the *Miami Herald*
- October 23, 2009 — Issuance of operating permit
- Date unknown — Comments from the UIC Technical Advisory Committee

16.7 Permitting Challenges and Lessons Learned

The utility did not offer any comments about any permitting challenges it faced or lessons learned.

Chapter 17

Workshop Summary: Concentrate Management Issues for Inland Water Utility Desalting in the Arid West

A 2-day interactive workshop was planned and conducted to identify barriers, solutions, and practical paths forward for addressing the challenges of CM for inland municipal water desalting.

Representatives from water utilities, state and federal regulatory and water management agencies, research organizations, technical consulting firms, and research universities were assembled to review the information and analyses generated from the research team's prior efforts (including the series of seven issue papers circulated to the participants and eight case studies), and move forward with additional insights, ideas, and refinements. The workshop was located at the EPWU TecH_2O Center learning facility in El Paso. The workshop was held on October 25 and 26, 2012.

The workshop was very productive, and several key ideas were developed and explored by the diverse suite of nearly 50 participants (listed in Appendix B). The workshop relied extensively on breakout group brainstorming and deliberations. The first set of breakout group activities focused on describing the barriers to CM from inland water utility desalting, with each of the five groups examining different aspects and CM options. Two breakout groups explored DWI issues under Class I of the UIC Program, while another group explored issues related to alternative UIC options for DWI (e.g., Class II, V, and VII). A fourth group focused on HR and beneficial-use approaches and the associated impacts on CM options, and a fifth group explored cross-cutting policy issues.

In the second set of breakout sessions, these same breakout groups explored possible solutions to help address key barriers identified in the previous session and then developed plenary presentation materials to describe the top priority solution options they explored. The solution options developed by each group were presented and discussed in plenary, and then attendees voted (using a dot system) to select the top priority solution options across all groups. The vote tally revealed that each group had one of the top five vote-getters.

The top priority solutions were:

1. Address challenges under Class V of the UIC Program by defining a new subcategory specifically for desal CM wells under Class V. This would include improving how USDWs are defined under this subcategory by using approaches such as examining and expanding how the key term of "endangerment" is defined (so that it can include a treatability component). This was the top vote-getter. Part of this proposed solution pathway includes recharacterizing concentrate as a resource (rather than as a waste) in conjunction with the inclusion of a treatability criterion. This solution is consistent with the recommendations outlined in Chapter 5 that changes in regulations and permitting should allow for site-specific flexibility. This solution includes a treatability component that would allow injection of concentrate into a USDW if it would not significantly

increase the costs of treatment in the event that the aquifer was ever used as a drinking water source. In addition, this solution accounts for the general nature of concentrate by developing a new subcategory specifically for desal CM wells. It stems from the difficulties experienced by EPWU from having to obtain an AE during the permitting process.

2. Develop a compilation and guidance of best practices and permitting processes to help utilities and state and federal regulators develop better capacity for and approaches to issuing and operating under Class I permits. This solution ranked second-highest among the solution options. The guidance and associated tool kit should include components that support collection and dissemination of suitable hydrogeologic information and address public perceptions and concerns. This solution addresses many of the barriers of DWI identified in Chapter 5, including the need for coordination among agencies involved, limited experience with Class I permits in many states, and the need for public outreach and communication.

3. Develop a general permit under Class I using the Texas model for other states with primacy and federal programs (EPA regions) where states do not have UIC Class I primacy. This solution was the third highest ranked solution option. Some key features of the general permit are its ability to streamline the process by its use of specific public notification requirements (precluding a protracted public hearing process) and enabling sign-off by registered PEs rather than requiring a state regulator to sign off. The General Permit developed in Texas worked well for SAWS, as detailed in the case study; however, general permits developed for other states with primacy may require additional flexibility built into the requirements to account for differences in the site-specific nature of desal concentrate.

4. Provide primacy to the states for the AE process. This option received the fourth highest vote total. This would avoid a second-level review by EPA headquarters after a state review had already been completed (a federal review might be limited to administrative procedures only and not technical matters). This solution stems from the experience of EPWU in obtaining an AE.

5. Develop a competition for technological advances to enable beneficial use or higher recovery and facilitate CM. This option ranked fifth overall. This approach might include one competition for conceptual design (to stimulate more creative ideas and include entrants with limited resources) and a second competition for successful pilot demonstration. This solution stems from the fact that many HR and beneficial use options are not available for municipal desal concentrate at the present time; however, there is an increased realization of a longer-term need to develop sustainable technologies and solutions. Whereas CM options remain costly, the recovery of salts and other constituents in concentrate may be an approach toward more sustainable practices.

On the second day of the workshop, the top five priority solution actions were discussed in plenary. The breakout groups then convened to develop a practical path forward to describe how to help implement the top solution item developed by their groups.

In addition to the key themes and solutions described previously, several useful insights were developed and articulated. Many of these insights are consistent with the recommendations and findings developed prior to the workshop. Key workshop findings and insights include (not necessarily in order of priority):

- Under the UIC Program, it would be valuable to develop a category for water utility desalting concentrate that separates it from the industrial category under Class I. This is justifiable by the unique nature of desal concentrate in contrast to industrial and other wastes. It is also justifiable based on the special needs and circumstances faced by inland water suppliers. The desal concentrate category could be in Class I, V, or a new Class VII. The ability to separate desal concentrate from other waste streams would help with public perception and facilitate more suitable regulatory and permitting requirements without creating concern among regulators about setting precedents for other wastes and activities (e.g., mining).
- The challenges faced by utilities with CM extend beyond inland desalting. Similar challenges arise wherever water or wastewater utilities rely on membrane processes (to produce recycled water or for source water treatment to meet regulatory standards for potable water) or need to inject water into groundwater systems (for aquifer storage and retrieval). Approaches that facilitate permitting for desal CM will also help facilitate these other practices and salt management practices in general.
- Solutions to the CM challenge need to be considered across two timeframes. Many of the more meaningful opportunities require a long-term perspective, as changes to federal statutes (e.g., SDWA) or regulations (e.g., the UIC Program) typically take at least 5 years to produce and often require several additional years to move into implementation (e.g., state primacy and associated permit requirements). Therefore, some short-term solutions are also required to address more immediate needs. The use of UIC Class V permits, coupled with AEs, is one such short-term approach; however, even this strategy is likely to be time- and resource-consuming and may not be suitable in many locations.
- Many site-specific hydrogeologic features and other factors mean there is rarely a one size fits all solution to facilitating desal CM.
- There is a lack of necessary hydrogeologic information about the subsurface environment and groundwater resources. This impacts inland desalting in two ways. First, there is a need for better characterization of brackish groundwater resources to indicate where there are available opportunities to tap saline groundwater as a source of potable supply. Second, there is a need to better understand potential storage or disposal sites for DWI of concentrate. A more systematic characterization of saline groundwater resources—such as by USGS or its state counterparts—would help facilitate desal implementation and CM.
- Many of the permitting challenges associated with desal CM reflect a lack of regulatory capacity at the relevant state and federal agencies. Capacity building is needed to address the limited resources available at these agencies (e.g., increase available staff and supporting budgets) given the competing authorities and priorities facing these organizations.
- To facilitate the possible use of evaporation ponds in arid regions such as the southwestern United States, it may be suitable to establish arid area exemptions from the double-liner requirements.
- It was noted by several breakout groups that a broad coalition of interested stakeholders would be necessary to effectively work toward the proposed solutions. Depending on the initiative, potential partners include interested water utilities (potentially brought together through coordinated efforts by utility foundations such as AWWA, WateReuse Association), WRRF, WaterRF, GWPC, National Groundwater Association, Rural Water Association, National Science Foundation, and state and federal regulatory agencies.

Coordinating efforts with existing desal research groups (e.g., UTEP Desalination Research Center; New Mexico State University; Reclamation) will also be important.

Chapter 18

Proposed Solution 1: Defining a New Subcategory Under Class V Specifically for Desalination Concentrate Management Wells

This chapter describes the solution that received the most votes at the project workshop: defining a new subcategory under Class V of the UIC Program specifically for desal concentrate wells. This proposed solution addresses existing challenges under Class V by modifying regulations related to the discharge of concentrate into USDWs. Specifically, under the proposed Class V subcategory, the term "endangerment" would be redefined to include a treatability component. Part of this proposed solution pathway includes recharacterizing concentrate as a resource rather than a waste, in conjunction with the inclusion of a treatability criterion.

18.1 Background

As an industrial waste, municipal desal concentrate falls into the category of Class I for disposal. Class I regulations mandate that the DWI injection zone must be below the lowermost USDW. There are also stringent construction requirements for Class I wells (e.g., tubing and packer, casing, cementing), which are surpassed only by Class I hazardous category requirements. Concentrate is rarely hazardous and different from most other industrial effluents in that it typically contains very few process-added chemicals; it is essentially concentrated raw groundwater. As detailed elsewhere in this report, the requirements associated with Class I present a number of challenges for municipalities and utilities in implementing DWI (36 states or territories do not have any Class I wells).

Accordingly, as described in Chapter 17, one of the working groups at the project workshop was tasked with exploring options for regulating DWI of municipal desal concentrate under alternative classes of the UIC Program. The working group explored the use of Class II wells, permitting under Class V, and the idea of creating a new class specifically for the injection of desal concentrate. Challenges identified by this working group are summarized in Figure 18.1.

Given these challenges, it was agreed that creating a subcategory under Class V would provide the greatest opportunity and flexibility for addressing regulatory challenges associated with DWI of municipal desal concentrate. Currently, Class V wells can be used to inject nonhazardous fluids with a TDS level of less than 10,000 mg/L into or above a USDW. Class V wells are typically shallow, on-site disposal systems (e.g., septic systems); however, this class also includes some deeper injection operations. There are approximately 20 subtypes of Class V wells.

Class II:

- Class II wells are only available where oil and gas operations are occurring and cannot always accept concentrate.
- Injection of concentrate into a Class II well may result in having to obtain permits from more than one regulatory agency (in most states, Class II wells are operated by oil and gas commissions or similar agencies).
- Coordination of agencies and differing agency objectives may present challenges.
- Increased liability for both water agency and oil and gas operators may result in disincentives.
- Public perception of Class II wells can present challenges (e.g., current issues surrounding fracking).

Class V (current regulations):

- Location and geological site suitability may be limited.
- Interpretation of endangerment presents challenges.
- Public perception of desal wells may be unfavorable.
- AE process is becoming harder and may not be available.

New Class VII:

- New regulations may have unintended consequences (i.e., trying to make things better could actually result in something more onerous).
- Creating a new regulation involves time and expense.
- Public perception may be unfavorable.
- New regulations could create primacy issues.

Figure 18.1. Barriers to classification of desal concentrate wells under Classes II and V, and a new Class VII.

18.2 Proposed Solution

The development of a subclass under Class V would allow for a more flexible regulatory framework that takes into account the specific nature of desal concentrate and provides for site-specific flexibility. A key component of the regulations developed for this subcategory would include a new way of looking at the term "endangerment." Currently, the SDWA states that UIC regulations must "contain minimum requirements for effective programs to prevent underground injection which endangers drinking water sources" (i.e., groundwater with a TDS level of less than 10,000 mg/L). Known as the endangerment standard, this is a major driving force in EPA regulations of underground injection.

To prevent endangerment associated with Class V wells, UIC regulations mandate that fluid injected into or above a USDW must have a TDS of less than 10,000 mg/L and meet primary drinking water standards (even if the USDW does not). In some states, Class V injectate must also meet secondary drinking water standards (even if the USDW does not). This interpretation of endangerment can result in situations in which the Class V injectate is treated to a much higher level of quality than the USDW into which it is being injected (i.e., the injectate is treated to meet high standards and then blended with lower quality groundwater).

Under the suggested new Class V subcategory, the permitting process would pay more attention to the quality of the water in the injection zone, specifically, the degree of treatment needed to convert the groundwater in the injection zone into a potable source of drinking water. Rather than relying on strict primary or secondary drinking water standards, the permitting process would include a treatability analysis to evaluate the impact of the concentrate on the costs of future treatment if the groundwater was ever withdrawn for potable use. For example, if a USDW exceeded primary drinking water standards for chlorine, the concentrate may not need to be treated to meet the primary standard for chlorine but perhaps a more relaxed standard that meets the existing quality of water in the injection zone or that would not increase the cost of future treatment for chlorine. In addition to the treatability analysis, the Class V subcategory would include construction and operation standards for municipal desal concentrate wells.

18.3 Pathway to Implementation

The creation of a subcategory under Class V will require changes at the federal level and be a long, involved process. The working group identified both long- and short-term actions for achieving this goal.

Short-term actions include:

- Evaluate policy changes that would help to streamline the permitting process under the new Class V subcategory.
  - Develop case studies to demonstrate a comparative analysis of treatability to aid in the argument for non-endangerment in cases where there are already exceedences in receiving waters.
  - Compile a needs assessment for the potential number of utilities that would benefit from or be impacted by the development of a subclass under Class V and establish a cost–benefit argument for the development of a rule.
  - Help policymakers focus decisions on preventing unintended consequences associated with the new subcategory.
- Conduct public outreach and education efforts, including reframing the injection of concentrate as storage for future beneficial use as opposed to casting it as disposal of waste.

Long-term actions include:

- Through external lobbying (GWPC, AWWA, WateReuse Association, and others), pressure EPA to return to the 2002 determination that the continued evaluation of subclasses under Class V needs to occur and include a subclass for concentrate and drinking water residual management.
- Pressure states to develop minimum construction and operation standards for concentrate disposal that are adequately protective.
- Encourage states to support the regulatory modification and be no more stringent than the Federal rule.

The working group estimates that short-term research efforts would be completed over the next 2 to 5 years. This includes developing case studies, evaluating policy changes, and compiling a needs assessment/benefit–cost analysis. These efforts would be driven and funded by utilities, states, and appropriate research foundations and are estimated to cost $500,000 to $1 million. The working group stressed the importance of leveraging existing resources and information in these efforts, including current research and funding from the UTEP Desalination Research Center, New Mexico State University, Reclamation, and other agencies and organizations.

Short-term policy and support building efforts would be completed over the next 1 to 3 years. These efforts will require involvement and coordination across multiple organizations and key players. Potential partners identified include utilities, states, the GWPC, AWWA, WRRF, National Groundwater Association, and National Rural Water Association. GWPC would likely be the strongest influence in moving this effort forward.

The actual rule-making process of the Class V subcategory would likely take 6 or more years. Challenges include ensuring sufficient resources at EPA, as the cost would likely be very high.

Chapter 19

Proposed Solution 2: Developing a Guidance for Permitting and Operating Class I Wells

19.1 Introduction

Implementation of DWI for CM is often hampered by a lack of knowledge and experience on the part of both regulators and implementing agencies. Although the SDWA UIC Program provides the basic regulatory framework for DWI, permits are issued at the state level (by states with primacy) or by EPA regions. Each state or region must develop its own policies and procedures for permitting, often based on very little direct experience with DWI implementation. For water utilities looking to obtain a permit, regulatory uncertainty and lack of experience with DWI can introduce time delays, increase costs, and result in uncertainty in the selection of disposal options.

On the regulatory side, in states and regions that have already addressed Class I wells for desal CM, there is a concern with people retiring or moving on to other tasks and taking critical knowledge with them. For states and regions that have yet to permit a Class I well, information is needed to allow them to quickly come up to speed and learn from existing applications. There is currently no one source that shares permitting practices among states and captures this critical knowledge.

Further, with Class I wells representing a small portion of all UIC wells (the majority are Class II and V), and municipal wells for CM representing a very small portion of Class I wells, there is a general lack of understanding, experience, and staffing to address and develop Class I permits for CM. As inland desal becomes more important in addressing the need for additional sources of water supply, this will raise the importance of DWI. Policymakers need to be made aware of the importance of UIC for concentrate disposal as well as the need for more staffing and resources to help address the permitting needs.

For water utilities, there is also a lack of design and operational experience. Currently, only five states have permitted Class I wells for disposal of desal concentrate (Mickley, 2006; Mickley et al., 2012). These include Florida, Colorado, California, Texas, and Kansas. The vast majority (approximately 95%) of these wells are in Florida. Our report represents one of the first efforts to document this experience. As documented in many of the case studies, implementation of DWI often involves a steep learning curve. Continued effort is needed to document best practices and provide implementation guidance to assist utilities in implementing DWI.

19.2 Proposed Solution

This proposed solution would develop a compilation of best practices and guidance into a toolkit for Class I DWI wells. The toolkit would support:

- Regulatory agencies responsible for developing and enforcing permits
- Water utilities evaluating different disposal options, associated costs, and potential barriers
- The public and other stakeholders in understanding best practices
- Policymakers in understanding the importance (and challenges) of DWI for concentrate disposal

The toolkit would be key to advancing the science, promoting consistency in regulations, and supporting decision making. Identifying and documenting best practices will encourage their more rapid application and implementation. The components of the toolkit would include:

- Regulatory best practices
- Technical information for design and construction
- Application guides for utilities
- Information for policymakers and the general public

Each of these components is described in more detail in Figure 19.1.

The compilation/toolkit can either be produced in a printed report form or as an online tool. A print version would facilitate review and ratification by EPA or other agencies. An online tool would allow for easier updating, inclusion of best practices and case studies as they emerge and wider-scale availability to regulators, utilities, and the public.

19.3 Why the Solution Is Needed and Useful

This resource toolkit is needed to make the permitting process easier and quicker by making best practices, guidance, and other key information readily available to regulators, utilities, and the public. By summarizing the current state of the art, this would help ensure best practices are used as well as provide the basis for further improvements. This would also raise the profile of DWI by making this information available to a wide audience.

19.4 Pathway Toward Implementation

This solution would require an organization or contractor to collect and analyze relevant information and make this information available through the development of a comprehensive guidance document (i.e., toolkit).

Regulatory best practice

- A listing with links and contact information for state and federal programs for Class I wells
- A review of existing forms and regulatory guidance documents
- An analysis of regulatory approaches that identifies technical criteria, public participation requirements, and other permitting policies
- A review of innovative regulatory approaches (i.e., the general permit) that can support implementation of DWI
- An example permit template based on the best practices identified

Technical information

- Design, construction, and testing standards
- Summary of site-specific factors and how they can be addressed
- Hydrogeologic information needed and sources

Application guide for utilities

- An inventory of DWI CM projects
- Case studies of example applications
- An analysis of the current reality—how long it takes to obtain a permit, barriers to implementation, cost factors, and other design and implementation considerations
- A guide to implementation that addresses factors that include siting a well, obtaining a permit, public involvement, and implementation

Information for policymakers and the general public

- Summary information on inland desal and how it fits into an overall water supply strategy
- Summary information on the importance of DWI for CM
- General information on DWI, including a discussion of the difference between DWI and hydraulic fracturing

Figure 19.1. Desal guidance toolkit components.

The workgroup identified the first and most critical task as documenting regulatory best practices. Expanding the toolkit to support utilities and the general public could be conducted concurrently or in later phases. The approach would consist of the following tasks:

1. Literature search and review
   - Compile and tabulate state programs and program components.
   - Identify applicable programs, contacts, links, and regulatory references.
2. Identify regulatory best practices.
   - Identify and synthesize permit components.
   - Address issues with permits such as hazardous vs. nonhazardous designation.
   - Document site-specific challenges.

- Identify innovative regulatory approaches (e.g., the General Permit as implemented by Texas) that can support implementation of DWI.
- Prepare an example permit template based on the best practices identified.

3. Review/ratification
    - Develop a process for review or ratification by states or EPA.

The workgroup estimated that this effort would require 18 to 24 months at a cost of $250,000. Expanding the toolkit for utilities and the general public would add an additional $150,000.

The workgroup felt that this project could be sponsored and managed by GWPC, WaterRF, WERF, or WRRF. It was felt that GWPC should be actively involved because it has a strong relationship with state regulators and could facilitate state review. Review by the National Research Council was also discussed as a potential activity to obtain constructive input, add credibility, and increase dissemination.

In addition to developing the guidance toolkit, the working group identified the need for advocacy to promote the use and acceptance of DWI. Specifically, advocacy efforts will be needed with policymakers at the state and local levels. To address this need, the working group recommended a potential project that would consist of the following tasks:

1. Decide where advocacy is needed to further the application of Class I DWI.
    a. Determine which states/areas are most appropriate, perhaps identifying five to six states in the desert Southwest or other applicable area of the country.
2. Conduct a pilot study by assisting the implementation of a Class I DWI well in one state.
    a. Identify the driver/motivation for Class I DWI (e.g., in New Mexico, including brackish groundwater as a resource in the Water Resources Master Plan).
    b. Identify key stakeholders and conduct a workshop (e.g., Alamogordo, BGNDRF, Reclamation, regional, state engineer).
    c. Conduct a pilot in one town (e.g., Alamogordo).
3. Develop pilots in the remaining four to five states.

This project could be sponsored and managed by GWPC, WaterRF, WERF, or WRRF. Active participation of the appropriate state agencies would be needed, for example:

- Texas—TWDB
- Arizona—Central Arizona Project, Arizona Department of Water Resources, University of Arizona Water Resources Center
- New Mexico—NMOSE

The working group estimated that a budget of $250,000 would be required for 2 years of advocacy and documentation of the pilots. This advocacy would need to accompany a project for which DWI was to be implemented. The costs for the implementation project would need to be developed on a site-specific basis.

19.5 Roles for Key Participants/Stakeholders

To ensure credibility of the guidance manual/toolkit, sponsorship and management should be provided by one of the major research organizations (GWPC, WRRF, WaterRF, or WERF).

The GWPC should be a major participant because it has a longstanding relationship with the state regulators.

The content needs to be reviewed or ratified by EPA's UIC Program, the National Research Council, or other representative of state organizations.

Chapter 20

Proposed Solution 3: Developing a General Class I Permit

20.1 Solution Goal

The general changes sought are to make Class I UIC regulations more appropriate to municipal desal concentrate. This in turn will:

- Make permitting easier and less burdensome, time-consuming, and uncertain
- Reduce costs associated with permitting
- Make permitting more widely available for disposing of municipal desal concentrate (where hydrogeologic conditions are suitable)

The proposed solution focuses on addressing regulatory barriers for implementing Class I DWI.

20.2 Proposed Solution

The solution entails implementing a general permit specifically for nonhazardous desal concentrate and DWTRs. The permit could be implemented at a state level for states with Class I well primacy and at a federal level where states do not have Class I primacy. The general permit is to be modeled after the Texas General Permit described in the next section.

20.3 Description of Texas General Permit

A description of the Texas General Permit was provided in Chapter 5. In the early 2000s, representatives from TWDB met with EPA to explore potential changes to UIC Class II regulations to facilitate injection of municipal desal concentrate under that oil and gas UIC category. EPA indicated that it did not have the resources, nor was it inclined to make rule changes to facilitate CM through the Class II program. EPA suggested that Texas should instead consider relaxing its Class I regulations (keeping them equivalent to or more stringent than the federal regulations) to allow for municipal concentrate that could be shown to meet appropriate standards. It suggested a general permit for Class I nonhazardous wastes for municipal drinking water desal concentrate.

In 2007, Texas began developing a General Permit for Class I desal concentrate and other drinking water residuals. Texas also has a General Permit for NPDES permits; the Class I DWI General Permit was somewhat modeled after it. The Class I General Permit is entitled: General Permit for Class I Injection of Nonhazardous Desalination Concentrate and Nonhazardous Drinking Water Treatment Residuals (Water Code Ann. §§27.021 and 27.025). The permit, issued in 2009, offers several changes relative to the existing Class I requirements, including:

- A 0.25 mile radius for review and public comment (as opposed to the 2.5 mile radius previously required for all Class I permit detailed characterization and study)
- No requirement for concrete on all casing strings if it can be shown that the design is adequate for the risks
- Less frequent mechanical integrity tests (every 5 years as opposed to annually)
- Permit review every 10 years (as opposed to every 5 years)

The major advantage is that the General Permit is more reliant on professional geologists and engineers interpreting the data and applying their professional seals rather than requiring internal agency review. The end result is the intent to get permits approved in 90 days rather than the typical 1 year minimum.

In addition, the General Permit reduces public notice requirements. A general NOI is issued to which the public can comment; but no additional opportunity for comment is provided. Any permitting, however, needs to be done with due diligence, transparency, website information, and public education. The limiting of public participation is not meant to make permitting secretive.

Prior to the General Permit, all Class I categories had the same standards as the Hazardous Class I category. In the General Permit, state standards were relaxed back to federal standards.

20.4 General Description of Need

Class I injection may not be an available disposal option in every state. DWI may not be feasible in some regions because of hydrogeologic conditions, and in some locations the technical/hydrogeological feasibility of Class I injection has not been determined. Some states do not allow Class I permits. In several locations, there has been a growing consideration of DWI for concentrate disposal based on increased numbers of municipal desal facilities and decreased availability of other disposal options. In regions where Class I injection is feasible and allowable, the conditions for permitting can vary.

As discussed in Chapter 4, regulation of Class I wells can vary from state to state for the following reasons:

- Whether the state has primacy for Class I wells
- If so, the particular state regulations within the context of being at least as stringent as federal regulations

Class I injection is becoming a preferred option for municipal desal concentrate disposal in some locations (such as Florida and Texas), and Class I injection may be the only option available in some locations. The complexity of permitting and the time required to obtain permits have been major challenges for utilities seeking DWI permits. Chapter 5 references two recent studies that discuss these challenges.

20.4.1 2006 GWPC Report

A report describing, among other groundwater issues, the challenges in implementing DWI and related UIC problems in general was published by the GWPC in 2007, entitled Ground

Water Report to the Nation: A Call to Action (GWPC, 2007b). The report lists the main UIC problems as:

- Some UIC regulations are unnecessarily burdensome and have no environmental benefits and as a result place impediments on beneficial new technologies that provide new sources of safe water supplies (e.g., desal and associated concentrate disposal) and the ability to capture and sequester CO_2. The GWPC message was for EPA to revise the classification scheme (which was subsequently done for CO_2, creating a new Class VI for sequestering carbon).

- Severe shortfalls of UIC Program resources have limited the implementation of standardized programs and program revisions. The GWPC message was for Congress to increase annual funding for the UIC Program.

- Class V wells represent a higher risk area than what is generally perceived. Class V regulation's historical and ongoing lack of clarity is somewhat understandable given the large number of wells and types of wells (20 subcategories) and injectates. The GWPC message was that, from an environmental impact perspective, historical Class V wells have more risk than Class I and II wells and should receive more study and regulation.

20.4.2 2006 UIC National Technical Workgroup Report

The UIC National Technical Workgroup is composed of experts from across EPA's UIC Program and periodically investigates specific issues and generates reports. In December 2006, the workgroup issued a report entitled Drinking Water Treatment Residual Injection Wells: Technical Recommendations as part of an ongoing effort to develop an EPA position on DWTR disposal (U.S. EPA, 2006). The definition of DWTR includes, but is not limited to, desal concentrate. The study group identified 104 currently permitted or authorized injection wells that were classified as Class I nonhazardous or Class V wells and their permit requirements. The requirements were stated to be generally similar to federal Class I requirements. The report makes the following statement:

> The resulting recommendations address the concern that the existing regulations contain unnecessary administrative, construction, operation, and monitoring requirements because they are not specific to DWTR injection. Another benefit of using this (recommended) approach is that it allowed for flexibility and additional cost saving opportunities. (U.S. EPA, 2006, p. 3)

The terms "appropriate" and "flexible" are used throughout the report, suggesting that permit requirements could be improved if made on a case-by-case basis that reflected the nature of desal concentrates (and other DWTRs).

Together, the GWPC and UIC National Technical Workgroup reports offer confirmation of the regulatory challenges associated with the injection of municipal desal concentrate.

20.5 Why a General Permit Will Help

Section 20.3 listed several helpful changes in permitting realized in Texas by implementation of the General Permit. The changes were in both technical and procedural requirements. The main technical requirement changes included:

- Reduce the radius for review and public comment to 0.5 mile (as opposed to the 2.5 mile radius previously required for detailed characterization and study).
- Eliminate the requirement for concrete on all casing strings if it can be shown that the design is adequate for the risks.
- Reduce the frequency of mechanical integrity tests (every 5 years as opposed to annually).

Primary changes in procedural requirements included:

- Set the permit review at every 10 years (as opposed to every 5 years).
- Rely on outside professional hydrogeologists and engineers to interpret and approve data rather than requiring internal agency review.
- Reduce public notice requirements to a general NOI.

In total, the General Permit state standards were relaxed back to federal standards with the intent to get permits approved in 90 days rather than the 1 year minimum it has taken in the past.

The General Permit simplifies the permitting process without reducing attention to environmental concerns and reduces the time-related project risk associated with uncertainty in whether DWI will be permitted. If implemented on a broader basis (other states and at the federal level), the general permit would:

- Make permitting for municipal desal concentrate more consistent from state to state, thus facilitating the use of shared information and knowledge
- Facilitate states new to addressing DWI of municipal desal concentrate to get a program in place and operating
- Likely lead to greater use of DWI of municipal desal concentrate and thus help to solve a concentrate disposal challenge particularly pressing in the arid Southwest where concentrate disposal options are limited

The general permit for some states not having primacy over Class I wells would require both a state review and the regional EPA review, which doubles the permitting effort. Implementation of a general permit at the federal level may eliminate this wasteful effort. Increased implementation of general permits by other states and possibly at the federal level may encourage states not presently allowing Class I injection to consider it for municipal desal concentrate.

20.6 Potential Pathway Toward Implementation

Implementation of a general permit at state and federal levels will require convincing the regulatory groups at these levels of the need and benefit of it and providing them with a well-reasoned approach to allow implementation. Toward this goal, we suggest that a project be funded to research, gather, and develop information necessary to communicate the issues involved and define a path involving advocates and support groups to assist regulatory groups in considering and implementing general permits.

More specifically, this would involve the following:

- Develop a project proposal for a plan to implement the general permit concept on a national level.
- The project team might include utility representatives, regulatory agency representatives, and environmental groups.
- Project tasks might include:
  - Research current permitting processes, including differences between state primacy agency processes and the federal process.
  - Research legal barriers in target states.
  - Define how implementation might occur in different states and at the federal level.
  - Define key participants and stakeholders and how they can be engaged to facilitate selling and implementing the general permit concept.
  - Identify advocacy groups (likely including GWPC, AWWA, Water Environment Federation, Association of State Drinking Water Administrators, Association of Clean Water Administrators, and others).
  - Develop a white paper to provide information about the Texas General Permit process and the benefits of this permitting process to other regions/states.
  - Develop a position paper/business case detailing positives and negatives and defining a process necessary to implement general permits (such as state or federal statutes).
  - Develop a strategy for contacting state and federal regulatory groups, such as approaching selected states as an initial strategy.

In total, the project deliverable would be a guidance document for state and federal implementation of a general permit. Such a project might be funded at a $300,000 level over a period of 2 years.

Chapter 21

Proposed Solution 4: Amending the Aquifer Exemption Process

This chapter explores a recommended solution entailing the elimination (or limitation) for federal EPA approval of a delegated state's program revision for an AE associated with desal concentrate disposal. In essence, this proposed solution would provide primacy to UIC delegated states for the AE process. This would avoid a second-level review by EPA headquarters after a state review has already been completed (a federal review might be limited to administrative procedures only and not technical matters). This could greatly expedite the process, eliminate uncertainty for the utility, and avoid a time-consuming, expensive duplication of effort.

21.1 Background

Following EPA approval of a state UIC Program, the state will, from time to time, make program changes that will constitute revisions to the approved program. One type of program revision requiring EPA approval is the designation of an exempted aquifer. As discussed previously, one solution proposed from the workshop is to eliminate or limit the requirement for EPA approval of a delegated state's program revision for an AE associated with DWI of desal concentrate disposal.

21.2 Defining an Exempted Aquifer

During UIC Program development, the EPA director may identify aquifers and portions of aquifers that are actual or potential USDWs (40 CFR §144.1[g]). The director may also designate exempted aquifers that would otherwise qualify as USDWs[1] to be protected but that have no real potential to be used as drinking water sources (40 CFR §144.1[g]). Therefore, they are not USDWs. No aquifer is an exempted aquifer until it has been affirmatively designated under criteria established by the EPA.[2]

---

1. USDW means an aquifer or its portion: (1) (a) which supplies any public water system; or (b) which contains a sufficient quantity of groundwater to supply a public water system; and (i) currently supplies drinking water for human consumption; or (ii) contains fewer than 10,000 mg/L TDS; and (2) which is not an exempted aquifer. 40 CFR §144.3.

2. 40 CFR §144.7(b)(2). §146.4 Criteria for exempted aquifers. An aquifer or a portion thereof which meets the criteria for an "underground source of drinking water" in §146.3 may be determined under 40 CFR §144.7 to be an "exempted aquifer" if it meets the following criteria: (1) it does not currently serve as a source of drinking water; and (2) it cannot now or in the future serve as a source of drinking water because: (a) It is mineral, hydrocarbon or geothermal energy producing, or can be demonstrated by a permit applicant as part of a permit application for a Class II or III operation to contain minerals or hydrocarbons that considering their quantity and location are expected to be commercially producible; (b) It is situated at a depth or location which makes recovery of water for drinking water purposes economically or technologically impractical; (c) It is so contaminated that it would be economically or technologically impractical to render that water fit for human consumption; or (d) It is located over a Class III well mining area subject to subsidence or catastrophic collapse; or (e) The TDS content of the groundwater is more than 3000 and less than 10,000 mg/L and it is not reasonably expected to supply a public water system.

21.3 The AE Process

Subsequent to program approval or promulgation, the director may, after notice and opportunity for hearing, identify additional exempted aquifers. For approved state programs, exemptions of aquifers are treated as program revisions (40 CFR §144.7[b] [3]). Currently, there are 33 states with primacy over UIC Programs. Table 21.1 is a list of UIC Program delegation.

Table 21.1. States with UIC Program Primacy

Alabama	Department of Environmental Management (Classes I, III–V)
	State Oil and Gas Board (Class II)
Arkansas	Department of Environmental Quality (Classes I, III–V)
	Oil and Gas Commission (Class II)
Commonwealth of N. Mariana Islands	Division of Environmental Quality (Classes I–V)
Connecticut	Department of Environmental Protection (Classes I–V)
Delaware	Department of Natural Resources and Environmental Control (Classes I–V)
Georgia	Environmental Protection Division (Classes I–V)
Guam	Environmental Protection Agency—EPA Region 9 (Classes I–V)
Idaho	Department of Water Resources (Classes I–V)
Illinois	Environmental Protection Agency (Classes I, III–V)
	Department of Natural Resources (Class II)
Kansas	Department of Health and Environment (Classes I, III–V)
	Corporation Commission (Class II)
Louisiana	Department of Natural Resources (Classes I, III–V)
	Office of Conservation (Class II)
Maine	Department of Environmental Protection (Classes I–V)
Maryland	Department of Environment (Classes I–V)
Massachusetts	Department of Environmental Protection (Classes I–V)
Mississippi	Department of Environmental Quality (Classes I, III–V)
	Oil and Gas Board (Class II)
Missouri	Department of Natural Resources (Classes I–V)
Nebraska	Department of Environmental Quality (Classes I, III–V)
Nebraska	Oil and Gas Conservation Commission (Class II)
Nevada	Division of Environmental Protection (Classes I–V)
New Hampshire	Department of Environmental Services (Classes I–V)
New Jersey	Department of Environmental Protection (Classes I–V)

New Mexico	Environment Department (Classes I, III–V)
	Oil Conservation Division (Class II)
North Carolina	Department of Environment and Natural Resources (Classes I–V)
North Dakota	Department of Health (Classes I, III–V)
	Industrial Commission (Class II)
Ohio	Environmental Protection Agency (Classes I, III–V)
	Department of Natural Resources (Class II)
Oklahoma	Department of Environmental Quality (Classes I, III–V)
	Corporation Commission (Class II)
Oregon	Department of Environmental Quality (Classes I–V)
Puerto Rico	Environmental Quality Board (Classes I–V)
Rhode Island	Department of Environmental Management (Classes I–V)
South Carolina	Department of Natural Resources (Classes I–V)
Texas	Commission on Environmental Quality (Classes I, III–V)
	Railroad Commission (Class II)
Utah	Department of Environmental Quality (Classes I, III–V)
	Department of Natural Resources (Class II)
Vermont	Department of Environmental Conservation (Classes I–V)
Washington	Department of Ecology (Classes I–V)
West Virginia	Division of Environmental Protection (Classes I, III–V)
	Division of Environmental Protection (Class II)
Wisconsin	Department of Natural Resources
Wyoming	Department of Environmental Quality (Classes I, III–V)
	Oil and Gas Conservation Commission (Class II)

Through the UIC AE process, delegated states are first to determine if an aquifer, or part of an aquifer, is exempt from protection as a USDW. Often the request for an AE is submitted simultaneously with an application for an injection well. An AE granted by a delegated state is then submitted by the state to EPA for approval as a program revision.

An AE program revision is either "non-substantial" or "substantial." Proposed exemptions of an aquifer are substantial if the aquifer contains water of less than 3000 mg/L TDS that is (1) related to any Class I well, or (2) not related to action on a permit, except in the case of enhanced recovery operations authorized by Rule 40 CFR §§144.7(b)(3)(ii) and 145.32(b)(4). Any program revision that requires action by EPA but is not considered substantial is a non-substantial revision.

Approval of non-substantial program revisions is delegated to the EPA regional administrator and may be given by letter from the administrator to the governor or his or her designee (40 CFR §145.32[b][4]). The proposed non-substantial program revision will become final if the state director submits the exemption in writing to the administrator and if the administrator has not disapproved the designation within 45 days (40 CFR §144.7[b][3][ii]).

Upon determining that a program revision is substantial, an EPA region will:

1. Send copies of the proposed revision to the State Program Division
2. Address public participation requirements
3. Resolve problems with the state
4. Prepare an Action Memorandum and a Federal Register notice of Administrator's Approval (U.S. EPA, 1984)

Any disapproval of an AE program revision shall state the reasons and constitute final agency action for purposes of judicial review (40 CFR §144.7[b][3]).

The EPA official guidance (U.S. EPA, 1984) does not specify the time period for EPA review of an AE program revision. EPA provides for a 90 day review period of a state's primacy application, and a program revision follows a similar process. A flow chart of the UIC Program process is shown in Figure 21.1. A substantial program revision requires mailed and Federal Register public notice and an opportunity to comment lasting at least 30 days (40 CFR §145.32[b]). The regulations provide that, for a non-substantial program revision, the program revision is final if disapproval is not received in 45 days; however, real-world examples reveal the process takes much longer than 90 days.[3]

3. TCEQ submitted a non-substantial program revision in February 2012, which EPA acted on almost 7 months later. On February 27, 2012, TCEQ submitted its application, and on April 9, 2012 (41 days later), EPA sent a letter requesting information and asserting that the letter "concludes" the 45 day automatic approval process.

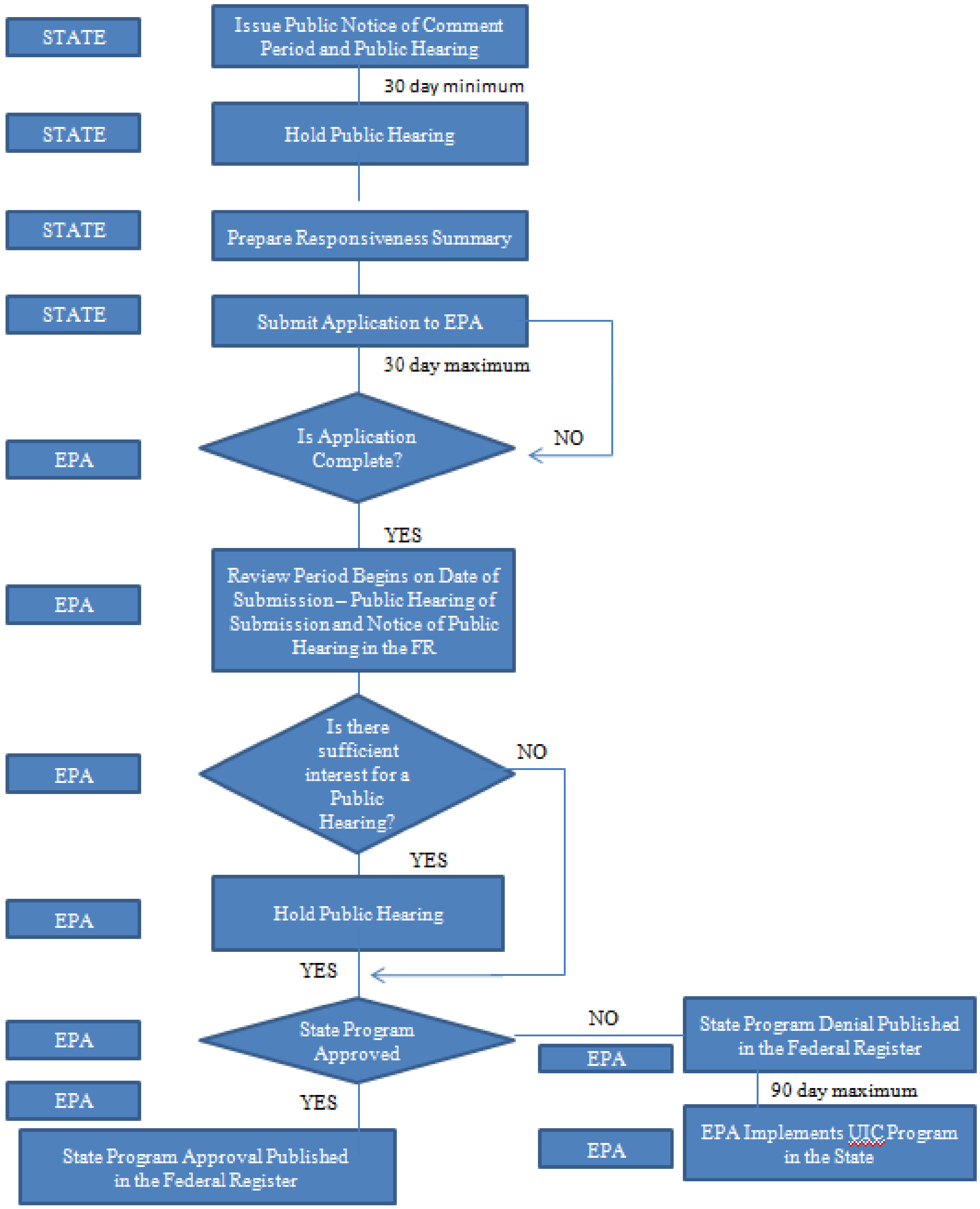

Figure 21.1. State UIC Program approval process.

21.4 Proposal To Modify the AE Program Revision Process

The program revision process can be time-consuming and appears to create an unnecessary duplicative review by EPA of the AE criteria, which the delegated state has already performed. For example, the state must follow federal criteria to grant an exemption and provide notice and an opportunity for a hearing. Presumably, EPA repeats the same process when the AE is submitted for EPA approval as a program revision.

Workshop participants discussed eliminating the EPA review and allowing delegated states to make the final decision on an AE with submission to EPA for it to administratively update the state's program to reflect the exemption. The workshop participants recognized that AEs exist for a wide variety of injection wells, including Class III (in situ mining), Class I (hazardous waste), Class II (oil and gas saltwater disposal), and Class I and V (DWTR wells). The AE revision proposed here is limited to wells associated with desal concentrate disposal. Moreover, the proposal should be considered along with defining a new subcategory of desal-related CM injection wells, as discussed in Chapter 18.

21.5 Potential Pathways Toward Implementation and Roles for Participants/Stakeholders

Each delegated state administering a UIC Program has entered a Memorandum of Agreement (MOA) with the EPA regional administrator setting forth the terms of delegation (40 CFR §145.25[b]). The MOA must include a provision that any AEs pursued by the state subsequent to approval of the state program will be treated in accordance with 40 CFR §144.7(b)(3).[4] Section 144.7(b)(3) is the regulation requiring a program revision. It follows that, at a minimum, 40 CFR §144.7, as well as each delegated state's MOA, would need to be amended to implement the proposal.

EPA rulemaking is a lengthy process that should be preceded with building a coalition or stakeholder group to measure interest, garner support, and proceed with petitioning EPA for a rule amendment. A list of potential steps includes:

- Compile a list of cases illustrating the cost and time involved to obtain AEs, highlighting where cost and time reductions can be achieved.
- Prepare a one page talking paper or brochure explaining the AE process inefficiencies. The brochure would be a public official/public information document.
- Develop strategic message using the talking paper described previously.
- Identify proponents and opponents. AEs are often associated with Class II mining wells so that proponents (and opponents) will include a broader spectrum than those seeking an exemption for disposal of DWTRs.
- Build a broad coalition (refer to Table 21.1 for states with delegated UIC Programs). The approach should be low-key.
- Approach state agencies with UIC primacy to get initial buy-in; state primacy agencies will be the lead in changing the delegation agreement.

4. GWPB Guidance No. 34, Attachment 1, at 4.

- Work with state agencies to determine the timing and approach for EPA and relevant state and federal committees.

If support is obtained with UIC-delegated states, the EPA rulemaking should proceed. This is a multiyear process requiring meetings with EPA and stakeholders, public notice, and comment. If the rulemaking is successful, delegated states will require amendments to their MOAs. The MOA revision would take at least 1 year. Overall, the process is estimated to take 5 to 7 years.

Chapter 22

Proposed Solution 5: Promoting Technological Innovation for High Recovery and Beneficial Use

One of the breakout groups focused on the issues and barriers associated with HR desal processes, many of which require tremendous amounts of energy consumption (e.g., traditional ZLD) and produce super concentrates with a high salinity (e.g., ZDD and concentrate enhanced recovery reverse osmosis. The group suggested that there is a need for economically, environmentally, and socially viable and proven technologies to achieve >90% recovery with brackish water desal. Regulatory issues involving hazardous designations and beneficial use need to be ironed out. There is a need to match source water quality with desal and CM technologies. Training of utility operators must be performed. Finally, there is a need to determine beneficial use options and technologies to lower the cost of CM.

22.1. Issues

The group identified the following high and medium priority issues:

22.1.1. High Priority Issues

- Match technology to water quality. There is no one size fits all approach with HR desal. Each type of water chemistry, as well as the needs of the water utility, presents different challenges and technology needs.

- There is a need to bridge the gap between unproven technologies that have shown promise in the laboratory or in small-scale piloting efforts and the practical need for large-scale, utility-sized operations. EPA's Best Available Technology program model may be a way to address the need to match technology and assess the feasibility of unproven technologies.

22.1.2. Medium High Priority Issues

- Environmental constraints and regulatory uncertainty: HR processes that produce superconcentrates are an unknown territory in terms of regulation. These waste streams can have TDS as high as 200,000 mg/L, which is closer to petroleum and other industrial waste than typical municipal waste streams. Another question regarding superconcentrates is whether it is more beneficial to dispose of them as solid or liquid waste streams.

22.1.3. Medium Priority Issues

- Technology complexity: HR processes typically incorporate many types of nontraditional (at least from the water utility perspective) technologies, which can be complex in terms of piping configurations and operational aspects. Highly trained workers will be required.

- End-use options and market for byproducts: Some HR processes produce useful byproducts such as gypsum, magnesium hydroxide, sodium chloride, or mixed salts. Even though these products are useful to industry, the market is saturated, and identifying a need for them can be a challenge. The team suggested that there is a need to evaluate the market for mixed and purified salts and identify innovative opportunities for the use of desal byproducts and that partnering with industry consortia would be the best way to avoid recreating the wheel.

The group identified several potential projects that might help address these priorities. The highest ranking potential solution was the notion of offering a prize for the best technology innovation—the Salt Prize. This concept addressed several of the high and medium priorities and could be a way to reduce the cost of desal by identifying innovative, low cost CM strategies that are environmentally sound. There was a general feeling that this concept would lower the cost of desal, improve the environmental impact of HR processes, and be socially acceptable. The project could be modeled after the X Prize contests that have had tremendous impact in water treatment, space exploration, and other technically challenging fields. The suggested outline is as follows.

22.2 The Salt Prize—Turning Waste into Dollars

Goal/objective: Reduce the cost of desal by identifying innovative, low cost CM strategies that are environmentally sound.

Approach

1. Problem statement: Find a sustainable (cost-effective, environmentally responsible, socially acceptable) solution to CM that will lower the cost of desal. The goal is to not limit participants. Potential solutions will increase the recovery of desal. The target recovery would not be specified so as not to impose limits. Solutions can include, but are not limited to:
    - Identification of lower cost disposal options of desal concentrate
    - Generation of saleable products (e.g., recovered salts, metals) from desal concentrate that generate revenue or reduce cost of disposal
    - Reuse of brine as a liquid stream
2. Participants: open to all
3. Two-round process:
    - Round 1 (perhaps 3–6 months in duration): Allow for a smaller award for a design contest (i.e., idea only; white paper approach).The goal would be to provide seed money for the next phase of demonstration. Winners get a small award, maybe 10% of the final award. The idea is that somewhere on the order of five groups would be awarded at the conclusion of Round 1.
    - Round 2 (duration of perhaps 12–24 months): Demonstration(s) occur to prove concepts chosen from Round 1. At the conclusion of this round, design reports and presentations would lead to a winning team or individual receiving a substantially larger award for a demonstrated concept.

4. Need to determine how to deal with intellectual property (IP) issues. This might be modeled after the X Prize, but it would need to be investigated in order to suitably protect IP and determine the details of ownership.

Tools and Guidance

This could possibly be modeled after the Tulane X Prize or the Houston low impact development design competition.

Public Outreach and Education

Use existing databases, foundations, conferences, and industry groups to get the word out. Press releases and a website would be utilized throughout the project. The Salt Prize would endeavor to get the younger generation involved. College students could be brought in through professional organizations (e.g., American Institute of Chemical Engineers, American Society of Civil Engineers, and WERC, a consortium for environmental education and technology development that holds environmental design contests) and other existing design contests. Another concept was to identify a Capstone project for senior undergraduate engineering and science (design contests) and business (business plan competitions) students.

Funding To Make It Happen

Potential funding groups identified the American Membrane Technology Association, AWWA, WRRF, WERF, WaterRF, Electric Power Research Institute, utilities, vendors, engineering firms, industry users (e.g., Freeport McMoRan), Reclamation, the National Science Foundation, EPA, oil and gas companies, the bottled water/food/drink industry, Advanced Research Projects Agency—Energy, the military, TWDB, Arizona Water, Multi-state Salinity Coalition, and other state funding sources.

Advocacy (Lobbying and Champions)

Stakeholders, such as utilities, would be the champions for such an effort. In fact, they may offer their problem as part of the prize itself. The Salt Prize would be a consortium of the funding and managing groups. The audience and other stakeholders include utilities, vendors, environmental groups, engineering firms, and regulatory agencies.

Resources

At least $1 million would be needed to encourage participation. It is possible that much more, likely $1.5 to $2 million, would be required for a truly useful end product. The cost to administer the contest must not be ignored.

Timeframe: 35–60 months

Identify funding and advertise program: 1 year

Round 1: 6–12 months

- Participants develop concepts/white papers: 3–6 months
- Consortium evaluates concepts and determines winners: 3–6 months

Round 2: 16–33 months

- Advertise program: 1–3 months, likely overlapping with review session in Round 1
- Participants demonstrate concepts: 12–24 months
- Consortium evaluates concepts and determines winner: 3–6 months

Final award presentation could be made at a national conference involving a keynote presentation: 1–3 months

References

Arroyo, J. *Desalination: Where Do We Go from Here?* Texas Water Development Board. Presented at the 2011 WateReuse Symposium in Phoenix, AZ, September 14, 2011.

Bear, J. Alamogordo Loses Desal Plant Grant. *Alamogordo Daily News,* June 6, 2012. http://www.alamogordonews.com/alamogordo-news/ci_20810380/alamogordo-loses-desal-plant-grant (accessed October 11, 2012).

Brandhuber, P.; Burbano, A. *Demonstration of Membrane Zero Liquid Discharge Systems for Drinking Water Systems—A Literature Review*. Water Environment Research Foundation: Alexandria, VA, 2013.

Bureau of Land Management. Alamogordo Regional Water Supply Project Environmental Impact Statement: Record of Decision, August 2012. http://www.blm.gov/pgdata/etc/medialib/blm/nm/field_offices/las_cruces/las_cruces_planning/alamogordo_water_project.Par.87234.File.dat/final_alamo_ROD_errata_92012.pdf (accessed October 11, 2012).

Drewes, J. *An Integrated Framework for Treatment and Management of Produced Water—Technical Assessment of Produced Water Treatment Technologies*. Colorado School of Mines: Golden, CO, 2009.

El Paso Water Utilities. *Water: Setting the State for the Future*. 2012. http://www.epwu.org/water/desal_info.html (accessed August 2012).

Groundwater Protection Council (GWPC). *Class I Inventory of the United States*. Oklahoma City, OK, 2007a. http://www.gwpc.org/ (accessed September 5, 2012).

GWPC. *Ground Water Report to the Nation…A Call to Action.* Groundwater Protection Council: Oklahoma City, OK, 2007b. http://www.gwpc.org/ (accessed September 12, 2012).

Hannam, K. M.; Oring, W.; Herzong, M. P. Impacts of salinity on growth and behavior of American avocet chicks. *Waterbirds* **2003,** *26,* 119–125.

Hightower, M. Desalination of Inland Brackish Water: Issues and Concerns, n.d. http://wrri.nmsu.edu/tbndrc/inland.html (accessed August 30, 2012).

Hoffman, D.; Ohlendorf, H. M.; Aldrich, T. W. Selenium teratogenesis in natural populations of aquatic birds in Central California. *Archives of Environmental Contamination and Toxicology* **1988,** *17,* 519–525.

Hutchison, B. El Paso Desalination Plant [Power Point presentation], 2007. http://www.ibwc.state.gov/Files/ibwc080907.pdf (accessed April 10, 2014).

John Shomaker & Associates and Livingston Associates. *City of Alamogordo 40-year Water Development Plan 2005–2045*. Alamogordo, NM, 2006. http://ci.alamogordo.nm.us/Assets/IntraInterNET/articles + and +info/articles/FINAL + Alamogordo + 40-Year + Plan + 2005-2045 + 11-22-06.pdf (accessed October 11, 2012).

Jordahl, J. *Beneficial and Non-traditional Uses of Concentrate.* WateReuse Foundation: Alexandria, VA, 2006.

Krieger, R. A.; Hatchett, J. L.; Poole, J. L. *Preliminary Survey of the Saline-water Resources of the United States*; Geological Survey Paper 1374. U.S. Government Printing Office: Washington, DC, 1957.

Mickley, M. C. *Membrane Concentrate Disposal: Practices and Regulation*; Desalination and Water Purification Research and Development Program Report No. 123. Agreement No. 98-FC-81-0054. Prepared for the U.S. Department of the Interior, Bureau of Reclamation, by Mickley & Associates, Boulder, CO, April 2006.

Mickley, M. *Survey of High Recovery and Zero Liquid Discharge Technologies for Water Utilities.* WateReuse Foundation: Alexandria, VA, 2008.

Mickley, M.; Jordahl, J.; Arakel, A. Development of a Knowledge Base on Desalination Concentrate and Salt Management. WateReuse Foundation: Alexandria, VA, 2012.

National Research Council (NRC). Irrigation-induced Water Quality Problems. Washington, DC, 1989.

National Research Council (NRC). *Desalination: A National Perspective*. Committee on Advancing Desalination Technology: Washington, DC, 2008.

Norris, J. W. Southmost Regional Water Authority Regional Desalination Plant, n.d. https://www.twdb.texas.gov/publications/reports/numbered_reports/doc/R363/D7.pdf (accessed August 2012).

Protection of Environment, Title 40 Code of Federal Regulations, Sections 144, 146 (2013).

Richard P. Arber Associates, Inc. *Sterling Water Treatment System: Preliminary Engineering Report.* Lakewood, CO, June 2009.

Shaw, R. facility manager, BGNDRF, personal communication, August 29, 2012

SWCA Environmental Consultants. *Alamogordo Regional Water Supply Project: Final Environmental Impact Statement*; EIS, BLM/NM/PL-12-07-1793. U.S. Bureau of Land Management: Las Cruces, NM, 2012. http://www.blm.gov/pgdata/etc/medialib/blm/nm/field_offices/las_cruces/las_cruces_planning/alamogordo_water_project.Par.43946.File.dat/ARWSP_FEIS_Vol1.pdf (accessed October 11, 2012).

United States Environmental Protection Agency (U.S. EPA). S*tatement of Basis and Purpose: Underground Injection Control Regulations*; Office of Drinking Water. National UIC Program Docket Control Number D01062' Washington, DC, June 1979.

U.S. EPA. *Statement of Basis and Purpose: Underground Injection Control Regulations*. Office of Drinking Water. National UIC Program Docket Control Number D01079; Washington, DC, May 1980.

U.S. EPA. *Guidance for Review and Approval of State Underground Injection (UIC) Programs and Revisions to Approved State Programs*. GWPB Guidance No. 34, Washington, DC, 1984.

U.S. EPA. *Drinking Water Treatment Residual Injection Wells: Technical Recommendations*. UIC National Technical Workgroup, December 20, 2006.

U.S. EPA. *Lesson 8 Area of Review*, 2012a. http://water.epa.gov/learn/training/dwatraining/upload/EPA-DWA-Intro-to-Permitting-Module-2.PDF (accessed September 12, 2012).

U.S. EPA. *UIC Inventory by State—2011*, 2012b. http://water.epa.gov/type/groundwater/uic/upload/uicinventorybystate2011.pdf (accessed October 2, 2012).

U.S. EPA. *UIC Program Primacy*, 2012c. http://water.epa.gov/type/groundwater/uic/Primacy.cfm (accessed September 28, 2012).

United States Geological Survey. *Colorado: Earthquake History*, 2012. http://earthquake.usgs.gov/earthquakes/states/colorado/history.php (accessed June 2012).

Appendix A

Federal Register Requirements

Federal Regulations Applicable to Expiring Class I Non-Hazardous Well Permits
- Informal Worksheet –

144.36(a) Effective for a fixed term not to exceed 10 years

144.37 Continuation of expiring permit:

a) If EPA is permitting authority, can continue until effective date of new permit if:

1) Permittee submitted complete application for new permit, and

2) R.A. has not issued a new permit before the old one expired.

b) Continued (original) permit remains fully effective & enforceable until the new one is issued.

144.51(b) Duty to reapply

If permittee wants to continue expiring permit activity, must apply for and obtain a new permit.

Part 146, Subpart B - Criteria & Standards for Class I Wells,
40 CFR §146.14 Information to be considered by Director:

"For an existing or converted new Class I well the Director may rely on the existing permit file for those items listed below which are current and accurate in the file".
"For both existing and new Class I wells certain maps, cross-sections, tabulation of w ells within the area of review and other data may be included in the application by reference provided they are current, readily available to the Director (for example, in the permitting agency 's files) and sufficiently identified to be retrieved."

1) Information required in 144.31 [General in formation requirements] and 144.31(g) [information requirements specific for Class I hazardous wells],

2) A map showing the subject well, area of review, number and name of all producing and injection wells, dry holes, surface water bodies, springs, mines,(surface & subsurface), quarries, water wells, and other pertinent features including residences and roads, faults if known or suspected,

3) Tabulation of data on all wells within area of review that penetrate injection zone, to include description of well type, construction, date drilled, location, depth, record of plugging and/or completion and any other information required by the Director,

4) Maps and cross sect ions of general lateral and vertical limits of all USDWs with in area of review, their position relative to the injection zone, direction of water movement in each USDW where known,

5) Map and cross sections detailing geologic structure of local area and illustrating regional geologic setting,

6) Proposed operating data:
1) Average and maximum daily rate and volume of injected fluid
2) Average and maximum injection pressure
3) Source and analysis of the chemical, physical, radiological and biological characteristics of injection fluids,

7) Proposed formation testing program,

8) Proposed stimulation program,

9) Proposed injection procedure,

10) Schematic or other appropriate drawing of the surface and subsurface construction details,

11) Contingency plans to cope with well failures and shut-in's,

12) Plans for meeting requirements of:

<u>146.13 (b) Monitoring Requirements</u>:

1) Annual (or a s necessary) injected fluid analysis

2) Continuous recording of injection pressure, rate and volume, and tubing/casing annulus pressure

3) Demonstration of mechanical integrity

4) Type, number and location of wells in area of review used to monitor USDWs for fluid migration and pressure,

<u>146.13 (d) Ambient Monitoring:</u>

1) Pressure buildup in injection zone annually through valid observation of pressure falloff curve

2) Other monitoring required by the Director

13) For improperly completed or plugged wells in area of review, any necessary corrective action under 144.55,

14) Construction procedures including casing & cementing program, logging, drilling and testing,

15) Certification of financial resources necessary to plug and abandon the well.

Protection of Environment, Title 40 Code of Federal Regulations, Sections 144, 146 (2013).

Appendix B

Workshop Participants

"Desalination Concentrate Management Policy Analysis for the Arid West"
TecH2O Water Resources Learning Center - El Paso, Texas
October 25-26, 2012

1	JUDY ADAMS	Brownsville Public Utilities, Water Plants Manager
2	ED ARCHULETA	EPWU, President and CEO
3	JORGE ARROYO	TWDB, Special Projects Director
4	MARLO BERG	Texas Commission for Environmental Quality (TCEQ)
5	JEFF BIGGS	Tucson Water, Administrator
6	DEANA BOLLACI	WateReuse Foundation, Project Manager
7	LUCY CAMACHO	UTEP, Center for Inland Desalination Systems (CIDS)
8	MALYNDA CAPELLE	UTEP, Center for Inland Desalination Systems (CIDS)
9	JANET CLEMENTS	Stratus Consulting
10	SHONNIE CLINE	Water Research Foundation
11	LORRIE COUNCIL	TCEQ, Manager of UIC Permits
12	BRAD CROSS	LBG-Guyton Consultants
13	UZI DANIEL	West Basin Municipal Water District
14	TOM DAVIS	UTEP, Center for Inland Desalination Systems (CIDS)
15	SAEID DELAGAH	U.S. Bureau of Reclamation
16	ROBERT DIAZ DE LEON	City of Sunland Park
17	RICHARD DONAT	San Antonio Water System, Planner
18	CHRIS DOUGLASS	East Cherry Creek Valley Water & Sanitation, Project Supervisor
19	BILL DUGAT	Bickerstaff Heath Law Firm
20	MIKE FAHY	EPWU, Project Manager
21	SAM FERNALD	NMSU, Water Resources Research Institute
22	JONATHAN GLEDHILL	Policy Navigation Group (PAC)
23	HECTOR GONZALEZ	EPWU, Government Affairs Manager
24	CHUCK GRAF	AZ Department of Environmental Quality

25	BILL HARGROVE	UTEP, Center for Environmental Resources Management (CERM)
26	BILL HUTCHISON	Ground Water Consultant
27	JEFF JOLLIE	EPA Office in Washington, D.C., Drinking Water Protection Division
28	BEN KNAPE	Retired from TCEQ
29	RAY LEISSNER	EPA Office in Dallas, TX
30	SEAN LISKE	City of Aurora, CO (PAC)
31	SCOTT MEFFORD	Consultant to East Cherry Creek Valley
32	MICHAEL MICHEAU	Atkins Global Consulting
33	ARI MICHELSEN	TAMU, Texas Agrilife Research Center Director
34	MIKE MICKLEY	Mickley & Associates
35	JEFF MOELLER	Water Environment Research Foundation (WERF) (PAC)
36	BRUCE MOORE	So. NV Water Authority, Colorado River Area Manager
37	KEVIN MORRISON	San Antonio Water System, Desalination Project Manager
38	JOHN O'DONNELL	Murray, Scheer, Montgomery
39	JEFF OXENFORD	Stratus Consulting
40	DAN PEARSON	HillCo Partners
41	BOB RAUCHER	Stratus Consulting
42	DON REDMOND	TCEQ, Legal Department
43	SCOTT REINERT	EPWU, Water Resources Manager
44	THOMAS RUIZ	NMED, Legal Department
45	RANDY SHAW	USBR, National Desalination Research Facility
46	ZHUPING SHENG	Professor, Texas Agrilife Research Center
47	ANTHONY TARQUIN	UTEP, Civil Engineering Dept.
48	JENNIFER WARNER	Water Research Foundation (PAC)




WATEREUSE

1199 North Fairfax Street, Suite 410
Alexandria, VA 22314 USA
703.548.0880
703,548.5085 (fax)
foundation@watereuse.org
www.WateReuse.org