NATIONAL WATER RESEARCH INSTITUTE

Final Report of an NWRI Independent Advisory Panel:

Recommended DPR General Guidelines and Operational Requirements for New Mexico

Prepared by:

NWRI INDEPENDENT ADVISORY PANEL
James Crook, Ph.D., P.E., BCEE
Joseph Cotruvo, Ph.D., BCES
Andrew Salveson, P.E.
John M. Stomp, P.E.
Bruce M. Thomson, Ph.D., P.E.

Prepared for:

New Mexico Environment Department
Environmental Health Division
Runnels Building
Santa Fe, NM 87505

Under Contract #14-667-5000-0002

January 22, 2016

Disclaimer

This report was prepared by an NWRI Expert Panel (Panel), which is administered by the National Water Research Institute (NWRI). Any opinions, findings, conclusions, or recommendations expressed in this report were prepared by the Panel. This report was published for informational purposes.

About NWRI

A 501c3 nonprofit organization, the National Water Research Institute (NWRI) was founded in 1991 by a group of California water agencies in partnership with the Joan Irvine Smith and Athalie R. Clarke Foundation to promote the protection, maintenance, and restoration of water supplies and to protect public health and improve the environment. NWRI's member agencies include Inland Empire Utilities Agency, Irvine Ranch Water District, Los Angeles Department of Water and Power, Orange County Sanitation District, Orange County Water District, and West Basin Municipal Water District.

For more information, please contact:

National Water Research Institute
18700 Ward Street
P.O. Box 8096
Fountain Valley, California 92728-8096 USA
Phone: (714) 378-3278
Fax: (714) 378-3375
www.nwri-usa.org

Jeffrey J. Mosher, Executive Director
Gina Melin Vartanian, Editor

Publication Number: NWRI-2015-08

ACKNOWLEDGMENTS

This report is the product of an Independent Advisory Panel, administered by the National Water Research Institute (NWRI), a 501c3 nonprofit based in Southern California. The Panel process was funded by the New Mexico Environment Department (NMED) under Contract #14-667-5000-0002. The overall goal of this effort is to provide NMED with expert guidance and recommendations to develop general guidelines and operational requirements for the implementation of direct potable reuse (DPR) in the State of New Mexico.

The Panel members greatly appreciate the support of the State of New Mexico in developing this report. In particular, the Panel acknowledges the following:

New Mexico Environment Department:

- Jim Chiasson, P.E., Bureau Chief, Construction Programs Bureau
- Angela Cross, P.E., Regulatory Engineer, Drinking Water Bureau
- Peter Nathanson, P.E., Technical Services Manager, Drinking Water Bureau
- John E. Pijawka, Water System Specialist, Drinking Water Bureau
- Joe Savage, Water Resource Coordinator, Drinking Water Bureau
- Andrea Telmo, P.E., Project Manager, Construction Programs Bureau

New Mexico Office of the State Engineer:

- Tom Blaine, P.E., New Mexico State Engineer

The Panel also appreciates the outstanding services of staff at NWRI, who administered the Panel process, organized and attended Panel meetings in New Mexico, and helped develop, prepare, and edit the Panel report. Specifically, the Panel thanks:

National Water Research Institute:

- Jeff Mosher, Executive Director
- Gina Vartanian, Outreach and Communications Manager

The Panel also thanks Dr. George Tchobanoglous of the University of California, Davis, who provided many of the figures used herein.

CONTENTS

TERMINOLOGY

Advanced treated water: Water produced from an advanced water treatment facility for direct potable and indirect potable reuse applications.

Advanced water treatment: General term used to describe the overall process and procedures involved in the treatment of wastewater beyond secondary treatment to produce advanced treated water.

Advanced water treatment facility: The treatment facility where advanced treated water is produced. The specific combination of treatment technologies employed will depend on the quality of the treated wastewater, type of potable reuse (i.e., indirect potable or direct potable), and water quality goals.

Barrier: A measure implemented to control microbial or chemical constituents in advanced treated water. A barrier can be technical, operational, and/or managerial in nature. Log-reduction credits are assigned only for technical barriers.

Close coupled processes: Two or more processes in series where the performance of the first process in series can affect the performance of the subsequent process or processes.

Concentrate: A liquid waste stream containing elevated concentrations of total dissolved solids and other constituents.

Constituent: Any physical, chemical, biological, or radiological substance or matter found in water and wastewater.

Constituents of concern: Any substance that has an adverse effect on human that is regulated in drinking water or under consideration.

Constituents of emerging concern: Chemicals or compounds not regulated in drinking water or advanced treated water. They may be candidates for future regulation depending on their toxicity, potential human health effects, public perception, and frequency of occurrence.

Contaminant: Any physical, chemical, biological, or radiological substance or matter that has an adverse effect on air, water, or soil. The term "constituent" is used in place of "contaminant" in this report.

Critical control point: A point in advanced water treatment where control can be applied to an individual unit process to reduce, prevent, or eliminate process failure and where monitoring is conducted to confirm that the control point is functioning correctly. The goal is to reduce the risk from pathogen and chemical constituents.

Direct potable reuse: There are two forms of direct potable reuse: (1) advanced treated water is introduced into the raw water supply upstream of a drinking water treatment facility; and (2) finished drinking water from an advanced water treatment facility permitted as a drinking water treatment facility is introduced directly into a potable water supply distribution system.

Disinfection byproducts: Chemicals that are formed by the reaction of a disinfectant (e.g., chlorine or ozone) with organic and/or inorganic matter found in treated water or wastewater.

Drinking water: Water that is supplied to a community for potable uses, including drinking, cooking, bathing, and other household uses that meet the standards prescribed by the U.S. Environmental Protection Agency's National Primary Water Regulations (40 CFR Part 141) and any applicable state or local regulations.

Engineered storage barrier: A storage facility used to provide retention time – before advanced treated water is introduced into the drinking water treatment facility or distribution system – to (1) conduct testing to evaluate water quality or (2) hold the water in the event it does not meet significant operating specifications.

Environmental buffer: A groundwater aquifer or surface water reservoir, lake, or river into which recycled water is introduced before being withdrawn for potable reuse. In some cases, environmental buffers allow for (1) response time in the event the recycled water does not meet specifications and (2) time for natural processes to affect water quality. Highly treated water in a surface reservoir must be treated as a surface water source in a conventional surface water treatment plant. Groundwater replenishment provides storage and transport. Where tertiary effluent is applied by spreading, the environmental buffer provides both treatment and storage.

Finished water: Water produced by an advanced water treatment facility that also meets all federal, state, and local regulatory requirements for a drinking water treatment plant. Finished water can be introduced directly into a water supply distribution system.

Inactivation: Killing or rendering microorganisms incapable of reproducing, thereby preventing their ability to cause illness.

Indirect potable reuse: The introduction of treated or advanced treated water into an environmental buffer such as a groundwater aquifer or water body before being withdrawn for potable purposes. Indirect potable reuse can also be accomplished with tertiary effluent when applied by spreading (i.e., groundwater recharge) to take advantage of soil aquifer treatment.

Log (base 10) reduction: Log reduction corresponds to a reduction in the concentration of a constituent or microorganism by a factor of 10. For example, a 1-log reduction would correspond to a reduction of 90 percent from the original concentration. Similarly, a 2-log reduction corresponds to a reduction of 99 percent from the original concentration.

Log (base 10) reduction credit: The number of credits assigned to a specific treatment process (e.g., microfiltration, chlorine disinfection, or ultraviolet disinfection), expressed in log units, for the inactivation or removal of a specific microorganism or group of microorganisms.

Pathogens: Microorganisms (e.g., bacteria, viruses, *Giardia*, or *Cryptosporidium*) capable of causing illness in humans.

Potable reuse: Augmentation of a drinking water supply with recycled water.

Recycled water: Municipal wastewater that has been treated to meet specific water quality criteria with the intent of being used for beneficial purposes. The term "reclaimed water" is synonymous with recycled water.

Redundancy: The use of multiple treatment barriers to attenuate the same type of constituent, so that if one barrier fails, performs inadequately, or is taken offline for maintenance, the overall system still will perform effectively.

Resilience: Protocols and strategies, including for different unit processes, to address treatment failures and bring systems back online.

Risk: In risk assessment, the probability that something will cause some type of injury combined with the potential severity of that injury.

Robustness: The use of a combination of treatment technologies to address a broad variety of constituents and changes in concentrations in source water.

Source control: The elimination or control of the discharge of constituents into wastewater collection system that (1) can impact wastewater treatment, (2) are difficult to treat, and/or (3) may impair the final quality of the secondary effluent entering the advanced water treatment facility.

Treatment reliability: The ability of a treatment process or treatment train to consistently achieve the desired degree of treatment, based on its inherent redundancy, robustness, and resilience.

Treatment train: A grouping of treatment technologies or processes to achieve a specific treatment or water quality goal or objective.

ACRONYMS

AOP	Advanced oxidation process
ATW	Advanced treated water
AWTF	Advanced water treatment facility
BAF	Biologically active filtration
BOD	Biochemical oxygen demand
CCP	Critical control point
CEC	Constituent of emerging concern
CF	Cartridge filter
CFR	Code of Federal Regulations
CIP	Capital improvement plan
COC	Constituent of concern
CT	Chlorine concentration (in mg/L) times modal contact time (in minutes)
DBP	Disinfection byproduct
DPR	Direct potable reuse
DWHA	Drinking Water Health Advisory
DWTF	Drinking water treatment facility
EC	Electrical conductivity
ESB	Engineered storage buffer
FRT	Failure response time
FE	Flow equalization
FS	Filter screen
GAC	Granular activated carbon
GWUISW	Groundwater under the influence of surface water
H_2O_2	Hydrogen peroxide
IPR	Indirect potable reuse
IU	Industrial user
LT2 ESWTR	Long Term 2 Enhanced Surface Water Treatment Rule
MCL	Maximum contaminant level
MCLG	Maximum contaminant level goal
MF	Microfiltration
MOR	Monthly operating report
NDMA	N-Nitrosodimethylamine
NF	Nanofiltration
NMED	New Mexico Environment Department
NPV	Net present value
NWRI	National Water Research Institute
O_3	Ozone
O&M	Operation and maintenance
PDT	Pressure decay test
POTW	Publicly owned treatment works
RO	Reverse osmosis
SCADA	Supervisory control and data acquisition
SDWA	Safe Drinking Water Act

SIC	Standard Industrial Code
SWTR	Surface Water Treatment Rule
TCEQ	Texas Commission on Environmental Quality
TDS	Total dissolved solids
TMF	Technical, managerial, and financial
TOC	Total organic carbon
TSS	Total suspended solids
UF	Ultrafiltration
USDA	U.S. Department of Agriculture
U.S. EPA	U.S. Environmental Protection Agency
UV	Ultraviolet light
UVT	Ultraviolet light transmittance
WRRF	WateReuse Research Foundation
WWTP	Wastewater treatment plant

ABBREVIATIONS FOR UNITS OF MEASURE

MGD	Million gallons per day
mg/L	Milligrams per liter
mL	Milliliter
ng/L	Nanograms per liter
NTU	Nephelometric turbidity unit
PFU	Plaque forming unit
µg/L	Microgram per liter

CHAPTER 1: INTRODUCTION

Throughout the United States, water utilities are seeking new strategies to help meet future water demands and develop more sustainable and resilient water supplies. One such strategy is direct potable reuse (DPR), in which advanced treated wastewater is used as a water source to augment public water supplies. As interest in potable reuse has grown, so has the need for providing guidelines for DPR; however, neither national guidance nor regulations exist currently.

On behalf of the New Mexico Environment Department (NMED), the National Water Research Institute (NWRI) of Fountain Valley, California, a 501c3 nonprofit, appointed local and national water industry experts to an Independent Advisory Panel (Panel) to develop proposed and general DPR guidelines and operational requirements for the State of New Mexico. This report is the final product of the Panel process.

1.1 Panel Process

The Panel was formed in 2014 under Contract #14-667-5000-0002 between NMED and NWRI. During 2014-2015, the Panel met in New Mexico three times: once in the Village of Cloudcroft (which is implementing a DPR project) and twice in Albuquerque. Meetings spanned one to two days and included interaction with NMED staff. An outline of the Panel report was drafted and expanded upon at these meetings, with the Panel completing the report in 2016. Background information about the NWRI Panel process can be found in Appendix A.

1.2 Panel Members and Support Staff

The five-member Panel represents a broad range of disciplines and experience in the following areas related to potable reuse:

- Engineering, including treatment technologies, project design, and operations.
- Water recycling criteria, including public health, potable reuse, and groundwater recharge regulations.
- Water quality, including chemistry, microbiology, analytical methods, drinking water regulations, and performance monitoring.

Specifically, Panel members include:

- *Chair:* James Crook, Ph.D., P.E., BCEE, Environmental Engineering Consultant (Boston, Massachusetts)
- Joseph Cotruvo, Ph.D., BCES, Joseph Cotruvo and Associates (Washington, D.C.)
- Andrew Salveson, P.E., Carollo Engineers (Walnut Creek, California)
- John M. Stomp, P.E., Albuquerque Bernalillo County Water Utility Authority (Albuquerque, New Mexico)
- Bruce M. Thomson, Ph.D., P.E., University of New Mexico (Albuquerque, New Mexico)

The Panel was supported by the following staff at NWRI, who administered the Panel and contributed to the development of the Panel report:

- Jeff Mosher, Executive Director, NWRI
- Gina Vartanian, Communications and Outreach Manager, NWRI

Brief biographies of the Panel members and NWRI support staff can be found in Appendix B.

1.3 Purpose of the Panel Report

Based on current experience and information, the Panel believes DPR is a viable option to augment public water supplies in the State of New Mexico and the United States in general. As a result, the State is encouraged to develop guidelines specifically for implementing DPR projects in New Mexico. The purpose of this Panel Report is to provide NMED with recommendations for general DPR guidelines and operational requirements for the State of New Mexico that would be protective of public health. This report reflects a consensus of the Panel.

1.4 Use of Panel Recommendations

The recommendations in the Panel report are advisory; NMED can use these recommendations as appropriate. The Panel would like NMED to consider the following when reviewing the recommendations:

- **Application of DPR Guidelines to Indirect Potable Reuse.** There are two forms of planned potable reuse: indirect potable reuse (IPR) and DPR. What differentiates IPR from DPR is the use of an environmental buffer (e.g., a groundwater basin or surface water reservoir). IPR is otherwise similar to DPR; therefore, the recommendations for DPR projects in this report can be applied to IPR projects. Although the specific criteria for groundwater basins and surface water reservoirs are not addressed in this report, examples do exist in other states, like California.

- **Development of Guidelines for New Mexico.** The proposed recommendations provided in this Panel report can be used as the basis of guidelines for potable reuse (IPR and DPR) in New Mexico; however, the information presented in this report may need further review or clarification to complete this process. This effort was conducted in a limited timeframe and the state-of-knowledge of potable reuse is constantly expanding.

- **Consideration of Alternatives.** When New Mexico develops guidelines for potable reuse, a provision should be included that allows a utility to propose an alternative to any of the recommended potable reuse criteria or requirements. The utility would need to demonstrate to NMED that the proposed alternative provides at least the same level of protection to public health. NMED would need to review and approve the proposed alternative prior to implementation. This type of provision allows flexibility for utilities to propose innovative approaches for potable reuse. California has a similar provision in its regulations for Groundwater Replenishment Using Recycled Water (CCR, 2015).

1.5 Organization of the Panel Report

This Panel report is organized into the following chapters:

1. Introduction
2. Defining Direct Potable Reuse
3. Water Quality Considerations
4. Source Control for DPR
5. Enhanced Wastewater Treatment
6. Advanced Water Treatment Technologies
7. Process Control and Monitoring
8. Operation and Maintenance
9. Technical, Managerial, and Financial Capacity
10. Public Acceptance and Outreach
11. Small Water System Considerations
12. References

For easier access, Panel recommendations are compiled and provided in a bulleted list at the end of each chapter. The recommendations provided in Chapters 1 to 10 are intended primarily for medium and large water systems (utilities). Possible considerations for small water systems are provided in Chapter 11. References are provided in Chapter 12.

1.6 Recommended Resources

Although a number of resources were used to develop this report and are identified in the References chapter, the Panel highlights the following four documents as integral to the development of the recommendations provided herein and encourages NMED to use them as resources in its efforts to develop DPR general guidance and operational requirements for the State of New Mexico.

- National Research Council (2012). *Water Reuse: Potential for Expanding the Nation's Water Supply through Reuse of Municipal Wastewater*. National Research Council, National Academies Press: Washington, DC. http://www.nap.edu/catalog.php?record_id=13303 (accessed 9/3/2015)

- National Water Research Institute (NWRI) (2013). *Examining the Criteria for Direct Potable Reuse*. Independent Advisory Panel Final Report prepared for Trussell Technologies, Inc., under WateReuse Research Foundation Project No. 11-02, National Water Research Institute: Fountain Valley, CA. https://www.watereuse.org/product/11-02-1 (accessed 9/4/2015)

- Tchobanoglous, G., J. Cotruvo, J. Crook, E. McDonald, A. Olivieri, A. Salveson, and R.S. Trussell (2015). *Framework for Direct Potable Reuse*, WateReuse Association, Alexandria, VA. http://www.nwri-usa.org/pdfs/DPR-Framework----FINAL.pdf (accessed 1/18/2016)

- Texas Water Development Board (2015). *Final Report: Direct Potable Reuse Resource Document*. Report prepared for the Texas Water Development Board by Alan Plummer Associates, Inc.: Fort Worth, TX. http://www.twdb.texas.gov/publications/reports/contracted_reports/doc/1248321508_Vol1.pdf (accessed 9/3/2015) http://www.twdb.texas.gov/publications/reports/contracted_reports/doc/1248321508_Vol2.pdf (accessed 9/3/2015)

1.7 Panel Recommendations for NMED: Introduction

- Based on current experience and information, the Panel believes DPR is a viable option to augment public water supplies in the State of New Mexico and the United States in general. As a result, the State is encouraged to develop guidelines specifically for implementing DPR projects in New Mexico.
- The purpose of this Panel Report is to provide NMED with recommendations for general DPR guidelines and operational requirements for the State of New Mexico that would be protective of public health. The Panel recommendations are advisory; NMED can use these recommendations as appropriate.
- The recommendations for DPR in this report can be applied to IPR projects, taking into consideration the role of the environmental buffers in IPR.
- The recommendations can be used as the basis of guidelines for potable reuse in New Mexico; however, the information presented in this report may need further review or clarification to complete this process.
- When potable reuse guidelines are developed for the State of New Mexico, a provision should be included that allows a utility to propose an alternative to any of the specified criteria or requirements as long as the alternative provides at least the same level of protection to public health.
- NMED should use the highlighted documents in this Panel report as resources in its efforts to develop DPR general guidance and operational requirements.

CHAPTER 2: DEFINING DIRECT POTABLE REUSE

2.1 Clarification of Potable Reuse

According to the National Research Council, "potable reuse" is defined as the augmentation of a drinking water supply with recycled water (NRC, 2012).

Unplanned potable reuse (also called "*de facto* potable reuse") involves the use of a drinking water supply – such as source water from rivers – containing a significant fraction of wastewater effluent, typically from upstream wastewater discharges (NRC, 2012). In this situation, the water supply has not been permitted as a water reuse project. The practice of *de facto* potable reuse is widely recognized and has existed for decades throughout various parts of the United States.

Planned potable reuse involves the treatment of a municipal wastewater for the purpose of converting it into a source of drinking water. Two forms of planned potable reuse occur: IPR and DPR. The principal difference between these two forms of potable reuse is that IPR includes an environmental buffer using either groundwater or surface water before being withdrawn for potable purposes. DPR involves projects that do not have an environmental buffer or involve an environmental buffer of insufficient size for IPR.

2.1 Description of Direct Potable Reuse

DPR involves the advanced treatment of wastewater effluent for the purpose of augmenting drinking water supplies. According to Tchobanoglous et al. (2015), the two forms of DPR are:

- **DPR with advanced treated water (ATW)** produced in an advanced water treatment facility (AWTF) is introduced into the raw water supply immediately upstream of a drinking water treatment facility (DWTF), as shown in Figure 2.1(a). To date, the few permitted operational DPR projects in the United States involve the use of this form of DPR.
- **DPR with finished water** produced in an AWTF that is also permitted as a DWTF is introduced directly into a drinking water supply distribution system, either downstream of a DWTF or within the distribution system, as shown in Figure 2.1(b). This form of DPR does not retreat the water through an existing DWTF.

2.2 Use of Engineered Storage Buffer for DPR

An engineered storage buffer (ESB) can be included as part of the DPR system. It provides storage of the ATW or finished water, as well as allows for monitoring of the ATW or finished water, before the water is (1) introduced before the DWTF or (2) blended with the DWTF or introduced directly into the distribution system (see Figure 2.1).

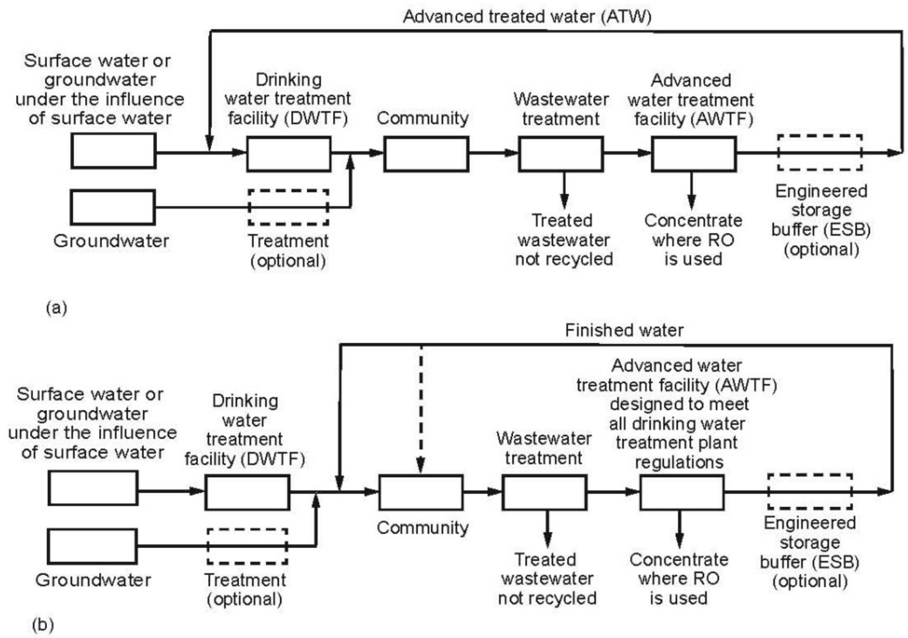

Figure 2.1. Flow diagrams for DPR: (a) with ATW introduced upstream of a DWTF; and (b) with finished water introduced into the drinking water supply distribution system downstream of a DWTF. Figure courtesy of Tchobanoglous et al. (2015).

The ESB is designed to:

- Provide a failure response time (FRT) that allows for specific water-quality testing, evaluation of results, and response to those results. The FRT can account for offline and/or online monitoring of treatment process performance. Because of the cost of the ESB, which is based upon the flowrate of the system and the FRT, online performance monitoring becomes the focal point for system monitoring and compliance.
- Provide an opportunity to include advanced monitoring and DPR system control. Examples include an integrated control system that uses online monitoring results for all advanced treatment processes to document that each process is functioning properly and the combined processes are meeting the design targets for pathogen and organics removal.
- Provide the ability to hold the water prior to diversion in the event the water does not meet water-quality specifications.

The use of an ESB can provide a number of benefits (e.g., storage, holding, time for monitoring) for a DPR project. It is recommended that the use of ESBs be considered for DPR projects to take advantage of these benefits.

An ESB may be able to be replaced by redundant treatment with effective monitoring. The redundant treatment allows for the continuous production of ATW if one of the major treatment processes is out of specification. This approach relies upon the performance of the online monitoring systems and the ability to immediately divert flow in the event of further process failure (Tchobanoglous et al., 2015).

2.3 Panel Recommendations for NMED: Defining Direct Potable Reuse

- NMED should adopt definitions for IPR and DPR for regulatory purposes, including DPR with ATW and with finished water, to provide clarity to State agencies and utilities interested in implementing potable reuse projects in the State of New Mexico. The definitions should be consistent with the terminology used in this report, taking into consideration other state and/or national definitions.
- Due the lack of an environmental buffer (or environmental buffer of sufficient size), DPR should include the use of additional or redundant treatment and online monitoring and/or the use of ESBs.
    - The use of ESBs may be considered for DPR projects to take advantage of the benefits (e.g., storage, holding, time for monitoring), but ESBs are not required for DPR.
    - As an alternative to an ESB, sufficient treatment redundancy and online monitoring can be installed.

CHAPTER 3: WATER QUALITY CONSIDERATIONS

Public health protection requires that microbial and chemical constituents in wastewater be removed to the extent practical before discharge to the environment or for other uses (Tchobanoglous et al., 2015); therefore, DPR systems must be protective of public health from both microbial and chemical constituents.

3.1 Criteria for Microbial Constituents

Microbial constituents in recycled water can include bacteria, viruses, helminths, and protozoan parasites. For DPR, which uses wastewater as the source water, pathogenic (i.e., disease-causing) microorganisms present significant acute risks to the consumer and are the most important design and operating concern for DPR systems.

Under the Safe Drinking Water Act (SDWA), DPR facilities with AWT will need to be approved as drinking water sources. DPR facilities with finished water will be regulated as DWTFs under the SDWA and would need to meet Surface Water Treatment Rule (SWTR) and Long Term 2 Enhanced Surface Water Treatment Rule (LT2 ESWTR) regulations.

3.1.1 Drinking Water Regulations for Microbial Constituents

The U.S. Environmental Protection Agency (U.S. EPA) has established a maximum contaminant level (MCL) of <1 fecal coliform or *E. coli* organism per 100 milliliter (mL) in drinking water. Total coliforms no longer have a drinking water MCL, but monitoring and follow-up response requirements do exist.

The SWTR requires DWTFs using surface water sources and groundwater under the direct influence of surface water (GWUDI) to provide treatment that includes filtration and disinfection, ultimately achieving a minimum of 4-log reduction of virus and 3-log reduction of *Giardia*. The level of treatment required under the LT2 ESWTR is based primarily on the concentration of *Cryptosporidium* oocysts in the source water.

The average *Cryptosporidium* source water measurements determine which of four treatment Bin categories the water supply is assigned, as shown in Table 3.1.[1] Risk reduction to less than 1/10,000 illnesses per year is the design goal. In addition, the turbidity requirement in the LT2 ESWTR is less than 0.3 nephelometric turbidity units (NTU) in 95 percent of filtered water samples per month in each filter and never to exceed 1 NTU. Most public water supplies are in the Bin 1 treatment category.

[1] Filtered water systems are classified in one of four treatment bins based on monitoring results (i.e., 2 years of monthly sampling for *Cryptosporidium*). Most systems are classified in the lowest bin and do not have additional treatment requirements beyond the minimum 2-log. Systems classified in higher bins must provide additional treatment to further reduce *Cryptosporidium* levels by 90 to 99.7 percent (1.0 to 2.5 log), depending on the bin. All unfiltered water systems must provide at least 99 or 99.9 percent (2- or 3-log) inactivation of *Cryptosporidium* using two disinfectants, depending on the results of monitoring (U.S. EPA, 2013).

The performance criteria established under the LT2 ESWTR regulations are based on the log reduction of pathogens and indicator organisms. Log reduction is defined as:

$$\text{Log Reduction} = -\log\left(\frac{N_{final}}{N_{initial}}\right) = \log\left(\frac{N_{initial}}{N_{final}}\right)$$

Where $N_{initial}$ is the initial concentration of organisms in the feedwater and N_{final} is the final concentration of organisms in the treated water. Thus, a log reduction of 2 corresponds to 99 percent removal of the organism, log reduction of 3 corresponds to 99.9 percent removal, and so on.

Table 3.1: Treatment Bin Classifications
Based upon *Cryptosporidium* Concentrations in Source Water

Bin Category	1	2	3	4
Cryptosporidium Concentration	<0.075/L	0.075-1/L	1-3/L	>3/L
Required Total Log Reduction*	2	4	5	5.5

*The "additional" *Cryptosporidium* treatment requirements beyond Bin 1 would be based on the type of filtration treatment employed (e.g., conventional filtration, direct, slow sand, etc.).

3.1.2 Treatment Targets for DPR: Pathogens

Currently, there are no federal or state regulations that specifically address DPR; however, individual states have undertaken efforts to develop treatment criteria for pathogens.

3.1.2.1 Texas TCEQ DPR Approach

Faced with an urgent need for additional water supplies in parts of the state, the Texas Commission on Environmental Quality (TCEQ) approved two DPR projects (e.g., the Raw Water Production Facility at Big Spring and the now shutdown Emergency DPR Project in Wichita Falls) on a case-by-case basis in accordance with the innovative/alternative treatment clause in the Texas Administrative Code [30 TAC §290.42(g)] that allows "any treatment process that does not have specific design requirements" listed in that chapter to be considered for permitting (TAC, n.d.). According to the Texas Administrative Code, innovative/alternate treatment processes will be considered on an individual basis. Where innovative/alternate treatment systems are proposed, the licensed professional engineer must provide pilot test data or data collected at similar full-scale operations demonstrating that the system will produce water that meets all requirements.

Water treatment regulations for pathogens are predicated on reducing the risk of infection to minimal levels, as defined by Trussell et al. (2013). The concentration end goals for targeted pathogens in finished potable water correspond to a modeled annual risk of infection of one in 10,000 or less (Trussell et al., 2013). TCEQ's case-by-case approach to developing treatment requirements for potable reuse projects is based on determining the difference between the finished water pathogen values and the measurement of project-specific secondary effluent pathogen concentrations.

TCEQ has established baseline log reduction requirements for DPR, shown in Table 3.2, using wastewater treatment plant (WWTP) effluent as the starting point. The reduction requirements are based on the 10^{-4} (one in 10,000) annual risk of illness level. The baseline removal requirements are a starting point for the TCEQ approval process (TWDB, 2015). The levels could be revised based on data collected to characterize the wastewater effluent. This site-specific WWTP effluent characterization is used to evaluate the need for additional log reduction requirements above the baseline targets.

Table 3.2: TCEQ Microbial Reduction Criteria[a]

Microbial Group	Criterion (Minimum Log Reduction)
Enteric virus	8
Cryptosporidium spp.	5.5
Giardia lamblia	6

[a]The baseline targets are for the advance treatment process only (i.e., they represent the required reduction between treated wastewater and the finished drinking water). The TCEQ sets project-specific requirements for pathogen reduction and inactivation for DPR. These minimum baseline targets may be increased based on site-specific data.

Source: TWDB (2015).

The pathogen sampling requirements are, in general, analogous to those required for *Cryptosporidium* under LT2 ESWTR, but extend to sampling for *Giardia* and enteric virus as well. This process has been applied to three approved projects in Texas (i.e., Raw Water Production Facility at Big Spring, Wichita Falls Emergency DPR Project, and City of Brownwood DPR Project).

In awarding log reduction credits, TCEQ focuses strictly on a drinking water based approach, which means challenge testing alone is not sufficient to determine inactivation credits given to common disinfection processes, such as ozonation and ultraviolet irradiation. These processes must adhere strictly to CT (concentration × time) requirements (for ozone) and the validation provisions under the U.S. EPA’s *Ultraviolet Disinfection Guidance Manual* (U.S. EPA, 2006a). Membrane-based processes must be able to pass daily integrity tests, as described in and required by the U.S. EPA’s *Membrane Filtration Guidance Manual* (2005), to receive any log reduction credit; therefore, log reduction credit for reverse osmosis (RO) membranes and membrane bioreactor processes are not currently allowed under the Texas approach (which is not the case in California).

Because pathogens are removed through primary and secondary treatment, the result of using wastewater effluent pathogen numbers are lower log-reduction targets compared to other efforts (e.g., California's IPR regulations set their log reduction requirements from raw wastewater to drinking water).

Beyond the theoretical calculation of log reduction credits, TCEQ also requires significant pilot testing to be completed before a project can achieve final approval. This testing can be achieved from the operation of a dedicated, smaller-scale pilot unit that appropriately mimics the proposed final treatment solution, or through "full-scale verification." This second approval method allows treatment facilities to be approved for construction without completing a pilot study prior to the design of the full-scale system. With a full-scale verification approach, which was the basis for the City of Wichita Falls Emergency DPR project, for example, the full-scale facilities were operated in "pilot mode" to collect the data necessary for final approval while finished water was sent to disposal pending final approval by TCEQ to deliver water.

3.1.2.2 NWRI Expert Panel DPR Approach

NWRI convened an expert panel to develop a set of criteria protective of public health to evaluate treatment technologies for DPR that might be applied throughout the United States. The panelists included former staff of the California Department of Health Services (environmental engineers James Crook and Harvey Collins) and former staff of the U.S.EPA (toxicologist Richard Bull, chemist Joseph Cotruvo, and microbiologist Walter Jakubowski). This effort was part of a WateReuse Research Foundation project on *Equivalency of Advanced Treatment Trains for Potable Reuse* (WRRF 11-02). As shown in Table 3.3, the panel recommended 12-log reduction of virus, 10-log reduction of *Cryptosporidium*, and 9-log reduction or inactivation of total coliform (NWRI, 2013), and concluded that these were conservative and actually would achieve risks of illness lower than 1/10,000 per year. The panel also concluded that a 10-log reduction of *Cryptosporidium* will ensure the same or greater removal of *Giardia*, since *Giardi*a is larger and more easily disinfected than *Cryptosporidium*. These log-reduction requirements include the full treatment cycle from raw wastewater to finished potable water, including primary, secondary, and tertiary wastewater treatment.

Table 3.3: NWRI Panel Microbial Reduction Criteria[a]

Microbial Group	Criterion (Minimum Log Reduction)
Enteric virus	12
Cryptosporidium spp.[b]	10
Total coliform bacteria[c]	9

Notes: [a]Reduction criteria for ATWF, including secondary treatment; [b]Addresses *Giardia* and other protozoa as well; [c]Addresses enteric pathogenic bacteria, such as *Salmonella* spp.

Source: Adapted from NWRI (2013).

3.1.2.3 LT2 ESWTR Treatment Bin Classification Approach

It may be possible to use the LT2 ESWTR methodology as a construct to determine required pathogen log-reduction credits for DPR, but additional work would be needed. LT2 ESWTR concepts would be applicable to post-secondary or tertiary treated wastewater as a source. The LT2 ESWTR requires establishing the range of *Cryptosporidium* concentrations in source waters and installing appropriate treatment technologies to ensure consistent achievement of less than 1/10,000 annual risk from *Cryptosporidium*. Given the expected performance of secondary or tertiary treatment processes, additional log reduction goals beyond those in the LT2 ESWTR and SWTR would be needed.

As described in Section 3.1.1., the LT2 ESWTR log-reduction requirements for *Cryptosporidium* base the Bin classification of a public water system on a mean concentration of monthly samples collected from the raw water source over a 2-year period. Using the mean *Cryptosporidium* concentrations shown in Table 3-1, a secondary- or tertiary-treated wastewater effluent would probably be classified as Bin 2 or 3, which would require up to additional 5-log reduction of *Cryptosporidium,* 4-log reduction of virus, and 3-log reduction of *Giardia*. Applying this construct to DPR would require a consideration of additional log reduction requirements because:

- The original source of supply is wastewater, without the benefit of pathogen attenuation that may occur in a natural environmental buffer.
- Secondary or tertiary wastewater treatment performance varies from one facility to the next, impacting pathogen concentrations in the feedwater to a potential AWT.
- The impact of disease outbreaks in a community on pathogen loads to a WWTF is not well defined.

3.1.2.4 California IPR Approach

The regulation of IPR in California (Trussell et al., 2013; CDPH, 2014) manages pathogens in potable reuse applications. The approach uses the most conservative values found in the literature for pathogen occurrence in wastewater: 12-log reduction of virus, 10-log reduction of *Cryptosporidium,* and 10-log reduction of *Giardia* beginning with raw sewage (see Table 3.4).

Table 3.4: California IPR Microbial Reduction Criteria

Microbial Group	Criterion (Minimum Log Reduction)
Enteric virus	12
Cryptosporidium	10
Giardia	10

A portion of that amount can be achieved during wastewater treatment. The Division of Drinking Water of the California State Water Resources Control Board has approved pathogen log-reduction credits for primary and secondary treatment (WRD, 2013), as well as for advanced treatment processes.

3.1.2.5 California versus Texas Approaches

California and Texas regulate potable reuse by applying significant levels of conservatism in their approaches. California starts from worst-case wastewater influent pathogen concentrations and imposes additional safety factors on the total log reduction requirements that must be achieved. Texas is conservative in its approach to crediting treatment processes with log reduction credits. Both approaches are considered by their respective regulatory agencies to be protective of public health from pathogen risks.

3.1.3 Panel Recommendations for DPR Pathogen Criteria

One of the following three approaches could be adopted by NMED for DPR pathogen criteria:

- Texas TCEQ DPR approach (see Section 3.1.2.1)
- NWRI Expert Panel approach (see Section 3.1.2.2)
- California IPR approach (see Section 3.1.2.4)

These three approaches provide an appropriate level of public health protection for pathogens. Implementing the approach to use the LT2 ESWTR methodology as a construct (see Section 3.1.2.3) for DPR would require additional review and studies.

The selection of a preferred approach by NMED would depend on how each of the three recommended approaches listed above would be implemented in New Mexico. For instance, the Texas approach starts with log reductions after wastewater treatment, whereas the California IPR and NWRI Panel approaches use raw wastewater as the starting point.

3.2 Criteria for Chemical Constituents

For DPR, chemical constituents typically represent primarily long-term chronic risks and could impact corrosion within the drinking water distribution system, as well as aesthetics (i.e., color, taste, and odor) (TWDB, 2015). Chemical constituents could include organic and inorganic chemicals, radionuclides, disinfection byproducts (DBPs), pesticides, synthetic organic chemicals, pharmaceuticals, and consumer care products. They represent both regulated and unregulated constituents.

It is important to note that the chemical nitrate presents a potential acute risk and, as a result, is of particular importance to DPR. It is regulated by the U.S. EPA in drinking water and occurs in wastewater that is not fully denitrified. It will need to be controlled as part of the wastewater or advanced water treatment process for DPR.

Utilities considering the implementation of DPR projects should conduct comprehensive analytical studies on the types and quantities of chemicals that can be present in their influent wastewater, AWTF feedwater, and the final ATW. As discussed in Chapter 4, an aggressive source control program is essential for any potable reuse project (IPR or DPR) to limit the discharge of chemical constituents into the wastewater collection system (TWDB, 2015).

3.2.1 Existing Requirements and Resources

The basic requirement for controlling chemical constituents would be to meet all U.S. EPA and State drinking water MCLs and other requirements that apply to public drinking water supplies in New Mexico. Other chemicals may be identified by the State that warrant the establishment of additional water quality or performance specifications. For instance, in California, certain chemicals of public health interest have notification levels (e.g., N-Nitrosodimethylamine [NDMA] and 1,4-dioxane). The target values for other chemicals of interest could be determined using the same principles for developing Maximum Contaminant Level Goals (MCLGs) and MCLs. If published values do not exist for these chemicals, specifications could be developed for MCLGs on an *ad hoc* basis. Authoritative sources include: U.S. EPA's Drinking Water Health Advisories (U.S. EPA, 2012, 2015a), U.S. EPA's "human health benchmarks for pesticides" in drinking water (U.S. EPA, 2015b), and the World Health Organization's *Guidelines for Drinking Water Quality* (WHO, 2011).

3.2.2 Targets for DPR: Chemicals

A number of chemicals known to be detrimental to human health above certain concentrations are regulated through MCLs. Potable reuse projects should meet these requirements and other requirements set by the State for drinking water. Because of the original source (wastewater), and because of public concern about chemical contaminants, potable reuse projects should track a suite of unregulated chemicals in the wastewater source.

A number of efforts have examined the need to address chemical constituents in potable reuse, including:

- Research has been conducted on the concentrations of unregulated trace organic constituents (e.g., pharmaceuticals, personal care products, flame retardants) in wastewater, their attenuation through conventional WWTPs, and further breakdown during advanced treatment (Baronti et al, 2000; Lovins et al., 2002; Schäfer et al., 2005; Sedlak and Kavanaugh, 2006; Steinle-Darling et al., 2010; Linden et al., 2012; Salveson et al., 2010, 2012; Snyder et al., 2012; Cotruvo et al, 2012, and many others). The majority of these constituents are not found in treated wastewater effluent at concentrations that have been shown to present risks to human health.

- For ATW, the presence of trace chemical constituents is not a significant concern with the exception of a small number of compounds that are difficult to treat due to the levels of treatment employed. California has set requirements to limit total organic carbon (TOC) concentrations to <0.5 milligrams per liter (mg/L) because TOC is a bulk parameter of treatment efficacy for organic chemicals, including unregulated and unknown chemicals. This TOC level was not set based on health criteria, but instead based upon the ability of treatment schemes for groundwater recharge to meet this low TOC level (e.g., surface spreading of tertiary recycled water, direct injection of ATW).

- Both 1,4-dioxane and NDMA are difficult to treat by conventional and membrane-based treatment. NDMA is a DBP formed during water and wastewater treatment, while 1,4-dioxane is a potential local concern related to industrial activity in the sewershed. These compounds are amenable to treatment by advanced oxidation processes (AOP) such as ultraviolet light-hydrogen peroxide (UV-H_2O_2) oxidation. California has established a performance expectation for UV oxidation; whereas NDMA has a low notification level (10 nanograms per liter [ng/L]). California has set the performance expectation for AOP based upon 0.5-log reduction of 1,4-dioxane, understanding that 1,4-dioxane is a conservative surrogate for the wide-range destruction of organics following RO (CDPH, 2014). Also, a source control program for chemical and pharmaceutical disposal in the wastewater system should be applied to mitigate or eliminate the occurrence of these compounds and others (see Chapter 4).

- Conventional DBPs, such as trihalomethanes, haloacetic acids, bromate, and chlorate, are regulated by the Stage 1 and Stage 2 Disinfectant and Disinfection Byproduct Rules (U.S. EPA, 1998, 2006b). The existing regulatory structure for DBPs is well defined; however, attention should be paid to the potential for DBP formation when implementing any change to the source water of a DWTF, including ATW.

3.2.3 Panel Recommendation for DPR Chemical Criteria

The Panel recommends a tiered approach for chemical criteria for DPR. The tiers would be based on the type of monitoring:

- Regulated chemical constituents, including DBPs.
- Unregulated chemical constituents that are of public health interest.
- Unregulated chemical constituents that provide information on the effectiveness of treatment.

These three tiers are as follows:

Tier 1 – SDWA and State Requirements. Potable reuse projects should meet all chemical MCL requirements under the SDWA and other requirements set by the State of New Mexico for drinking water.

Tier 2 – Unregulated Chemicals (including Constituents of Emerging Concern [CECs]) of Interest from the Standpoint of Public Health. Included in Table 3.5 is a variety of chemicals that could occur in wastewater and are not regulated in drinking water that should be looked for in the source wastewater. If detected, some of them should be monitored in the product water as well (NWRI, 2013).

Tier 3 – Unregulated Chemicals (Including CECs) that Are Useful for Evaluating the Effectiveness of Organic Chemical Removal by Treatment Trains. The chemicals listed in Table 3.6 are considered useful for evaluating the effectiveness of alternative treatment trains and treatment performance. These constituents are detected frequently and at sufficiently high concentrations related to their detection limits to make them useful measures of the removal of health-significant organic chemicals with a variety of structures and varying physical chemical properties. All these chemicals may not need to be measured. Instead, the Panel suggests selecting compounds of varying properties to evaluate treatment performance (NWRI, 2013).

Table 3.5. Nonregulated Chemicals of Interest from the Standpoint of Public Health (If Present in Wastewater)

Chemicals	Criterion (if applicable)	Rationale	Source
Perfluorooctanoic acid	0.4 micrograms per liter (µg/L)	Known to occur, frequency unknown	Provisional short-term U.S. EPA Health Advisory
Perfluorooctane sulfonate	0.2 µg/L	Known to occur, frequency unknown	Provisional short-term U.S. EPA Health Advisory
Perchlorate	15 µg/L, 6 µg/L	Of interest, same analysis as chlorate and bromate	U.S. EPA Health Advisory, California Maximum Contaminant Level (MCL)
1,4-Dioxane	1 µg/L	Occurs at a relatively low frequency in wastewater, but likely to penetrate RO membranes	Division of Drinking Water, California State Water Resources Control Board notification level
Steroid Hormones			
Ethinyl estradiol	None, but if established, it will approach the detection limit (low nanogram per liter [ng/L]).	Should evaluate its presence in source water	Bull et al. (2011)
17-β-estradiol	None, but if established, it will approach the detection limit (low ng/L).	Should evaluate its presence in source water	Bull et al. (2011)

Table 3.6. Chemicals that Should Be Useful for Evaluating the Effectiveness of Organic Chemical Removal by Treatment Trains

Pharmaceuticals[a]	Criterion[b] (if applicable)	Rationale	Source
Cotinine, Primidone, Phenyltoin	1 µg/L, 10 µg/L, 2 µg/L	Surrogate for low molecular weight; partially charged cyclics	Bruce et al. (2010) Bull et al. (2011)
Meprobamate, Atenolol	200 µg/L, 4 µg/L	Occur frequently at ng level	Bull et al. (2011)
Carbamazepine	10 µg/L	Unique structure	Bruce et al. (2010)
Estrone	320 ng/L	Surrogate for steroids	Based on an increased risk of stroke and deep vein thrombosis in women taking the lowest dose (0.625 mg/day) of conjugated estrogens/1000[a]
Other Chemicals			
Sucralose	150 mg/L[c]	Surrogate for water soluble, uncharged chemicals, moderate molecular weight	CFR Title 12, revised 4/1/12
Tris (2-Carboxyethyl) phosphine) hydrochloride	5 µg/L	Chemical of interest	Minnesota Department of Health guidance value (MDH, 2015)
N,N-diethyl-meta-toluamide	200 µg/L	Common constituent in highly treated wastewaters	Minnesota Department of Health guidance value (MDH, 2015)
Triclosan	2100 µg/L	Chemical of interest	Risk-based action level (NRC, 2012)

Notes: [a]Conjugated estrogens (largely estrone conjugates) administered without progestin increased significantly the risk of deep vein thrombosis and stroke in a large clinical study of postmenopausal women conducted over 5.1 years (it involved groups of >5,000 treated and 5,000 placebo subjects). Cited in RxList (2012). [b]In the case of pharmaceuticals, the criterion is given as the drinking water equivalent concentration for the lowest therapeutic dose/1,000. In the case of the anticonvulsant drugs, the lowest daily maintenance dose in adults/10,000 was used in recognition of the teratogenic potential of these drugs (Primidone); however, the numbers for carbamazepine and phenyltoin are based on reported carcinogenicity. [c]Sucralose is based upon an acceptable daily intake established by the U.S. Food and Drug Administration of 5 milligrams per kilogram (mg/kg) per day × 60 kg/2 liters (L).

3.3 Panel Recommendations for NMED: Water Quality Considerations

- For DPR, pathogens represent the greatest acute health risk and are the most significant design and operating concern for DPR systems.
- NMED should choose one of the following pathogen treatment criteria for DPR: (1) Texas TCEQ approach; (2) California IPR approach; or (3) NWRI Expert Panel approach. NMED can evaluate the approaches to determine which best meets the needs of the State. Each approach involves specific assumptions and implementation requirements that should be reviewed as part of this process. These three approaches provide an appropriate level of public health protection for pathogens.
- It may be possible to use the LT2 ESWTR methodology as a construct to determine required pathogen log-reduction credits for DPR, but additional work would be needed.
- Treatment target criteria for chemical constituents should include meeting all U.S. EPA and State drinking water MCLs, as well as other requirements that apply to public drinking water supplies in New Mexico (Tier 1). In addition, monitoring could be required for unregulated chemicals (including CECs) of interest from a public health standpoint (Tier 2) and unregulated chemicals that are useful for evaluating treatment effectiveness (Tier 3).
- NMED should consider requiring utilities interested in implementing DPR to conduct studies on the types and quantities of chemicals present in their influent and effluent wastewater. These studies could be part of the DPR project application process.
- Source control can mitigate or eliminate the presence of many chemical constituents in the wastewater collection system and obviate monitoring and treatment for them (see Chapter 4 on Source Control for DPR).

Chapter 4: Source Control for DPR

One of the most beneficial, efficient, and cost-effective strategies for managing and treating constituents of concern (COCs) is to keep them out of the wastewater system through an aggressive source control program (Tchobanoglous et al., 2015; TWDB, 2015).

Source control programs augment federal pretreatment programs and are designed to control, limit, or eliminate the discharge of constituents into wastewater that can be difficult to treat or impair the final quality of treated watered intended for DPR.

The source control program will require strong interagency cooperation and responsiveness between the entities operating the WWTP, AWTF, and DWTF. In addition, it will involve cooperation and coordination between these entities and the community, whether through permitting (e.g., for industries) or voluntary action (e.g., for residents).

4.1 Background on Pretreatment and Source Control

The National Pretreatment Program was established as part of the Clean Water Act to reduce the level of contaminants discharged by industry and other non-domestic wastewater sources into municipal sewer systems, thereby reducing the amount of contaminants released into the environment through wastewater (U.S. EPA, 2014). Under this federal program, industrial and commercial dischargers, referred to as industrial users (IUs), are required to obtain permits or other control mechanisms to discharge wastewater to publicly owned treatment works (POTWs), which collect and transport wastewater to treatment facilities. The General Pretreatment Regulations (40 CFR Part 403) of the National Pretreatment Program require all large POTWs (those designed to treat flows of more than 5 million gallons per day [MGD]) and smaller POTWs (that accept wastewater from IUs that could affect the treatment plant or its discharges) to establish local pretreatment programs (U.S. EPA, 2011).

4.2 Pretreatment Program for Potable Reuse

Although not all POTWs are required to implement pretreatment programs, any community or utility pursuing a DPR project, regardless of size, should consider the impacts of industrial and commercial contributions on the wastewater supply and implement an aggressive local pretreatment program. A smaller utility can implement its own pretreatment program with many of the basic elements, but may or may not have to submit the program to the State or U.S. EPA for approval. Utilities with formal programs are subject to annual inspections and occasional audits. NMED may want to consider requiring a local pretreatment ordinance as a condition of permitting a DPR system.

The following activities should be undertaken as part of a pretreatment program:

- **Understanding the Sewershed.** Investigate what chemicals are used and disposed of by homeowners and/or commercial establishments (e.g., pesticides and cleaning products). Also, identify the potential for spills and other sources of chemicals (e.g., dry cleaners) that may enter the wastewater collection system. Action response plans are needed for spills.

- **Survey.** Conduct (1) an initial survey of discharges into the system to determine what industrial contaminants already exist and (2) sample the raw wastewater and secondary effluent of the current system for drinking water constituents and CECs. This sampling, if done routinely, provides important information about pollutants in the raw wastewater and the ability of the primary and secondary processes to reduce these pollutants. The information then can be used to determine what advanced treatment processes and monitoring are necessary to be protective of public health.

- **Classification of businesses.** Compile a list of current commercial and industrial entities that discharge into the wastewater system. Use the Standard Industrial Code (SIC) approach to inventory businesses that discharge into the collection system. Source control criteria will need to be established for new industries or businesses (e.g., medical care facilities, dental clinics, photo processors, and silver jewelry manufacturers) that move into the area.

- **Residential programs.** Education and outreach programs can be used to inform the public about the proper disposal of pharmaceuticals and household products containing chemicals that may be difficult to treat.

4.3 Enhanced Source Control for Potable Reuse

While beneficial, pretreatment programs generally do not completely eliminate pollutant loadings from industrial sources. Hence, an important preventative approach when pursuing and planning for potable water reuse is the implementation of a source control program in conjunction with a pretreatment program to eliminate or control the discharge of COCs that might impact the production of ATW from an AWTF (Tchobanoglous et al., 2015).

A source control program for potable reuse is not focused solely on wastewater compliance; rather, it should be enhanced to control for COCs from a drinking water perspective. These enhancements should go beyond requirements in the Clean Water Act and pretreatment regulations defined in the Code of Federal Regulations (40 CFR Part 403) to address COCs that pose a risk to drinking water quality in areas where potable reuse occurs or is planned.

4.3.1 Goals of a Source Control Program for Potable Reuse

The goals of an effective source control program (Tchobanoglous et al., 2015) include:

- Understand the sources of chemical constituents entering the sewershed from readily managed point sources (e.g., industries, health care facilities, commercial businesses, homes, and waste haulers).
- Minimize the discharge of potentially harmful or difficult-to-treat chemical constituents to the wastewater collection system.

- Improve wastewater water quality and advanced water treatment performance.
- Provide the public with confidence that the wastewater collection system is being managed with potable reuse in mind.

Source control cannot eliminate all COCs; however, it is important to identify the contaminants that may be present in the sewershed, mechanisms by which they may be introduced to the wastewater collection system, and actions that can be taken to minimize their introduction in the wastewater collection system.

4.3.2 Considerations

Although mechanisms exist to control the majority of COCs to manageable levels through source control, possible challenges can arise while pursuing these activities, such as:

- One region having stricter source control requirements than other regions, which would place industry in the stricter source control region at a disadvantage.
- U.S. EPA-approved analytical methods may be required for legal enforcement of source control regulations, but some constituents of concern lack U.S. EPA-approved analytical methods or the U.S. EPA-approved method does not have a sufficiently low detection limit.
- Discharge limits for some constituents, such as radionuclides, are set through federal requirements, which are not flexible. Changing the requirements is an arduous process.
- In some cases, to minimize the impact from large industrial dischargers, it may be necessary to divert certain industrial discharges to alternative treatment facilities.

4.4 Principal Elements of a Source Control Program for Potable Reuse

The principal elements of an effective DPR source control program are provided in Table 4.1. The source control program should be tailored to the individual service area.

4.5 Examples of Enhanced Source Control Related to Potable Reuse

Some utilities have developed local or statewide "No Drugs Down the Drain" programs (e.g., www.nodrugsdownthedrain.org), drug take-back programs, and/or household hazardous waste collection programs. Other utilities have enhanced pretreatment program elements to augment their pollution prevention efforts.

As an example, the Orange County Sanitation District and Orange County Water District in California operate an IPR project called the Groundwater Replenishment System, which produces 100 MGD of advanced treated water from treated wastewater using microfiltration (MF), RO, and AOP (UV with H_2O_2). The following enhanced source control activities have been implemented for this IPR project, including:

- Developing a list of target COCs based on drinking water regulations.
- Assessing the fate of target constituents through the treatment system.

- Focused monitoring based on the list of target constituents and their potential ability to persist through the treatment system.
- Characterizing wastewater streams to identify the sources and levels of COCs in an effort to minimize them.
- Increasing outreach to dischargers to manage COCs at the source.
- Maintaining an inventory of constituents discharged into the wastewater collection system so that new COCs can be evaluated rapidly.

In addition, guidance is provided in TWDB (2015) regarding source control recommendations and enhanced source control program elements to "provide an effective barrier for DPR." For instance, one recommendation includes establishing local limits to control COCs and provisions to take action to protect the DPR project.

Table 4.1. Principal Elements of an Enhanced Source Control Program for DPR

Element	Description
Regulatory Authority	• Legal authority • Discharge permits • Enforcement • Alternative control programs
Monitoring and Assessment of the Wastewater Collection System Service Area (Sewershed)	• Routine monitoring program • Constituent prioritization program • Evaluation of technically-based local limits
Source Investigations	• Industrial and commercial business inventory • WWTP-AWTF joint response plan
Maintenance of Current Inventory of Chemicals and Constituents	• Chemical inventory program • Waste hauler monitoring program • Chemical fact sheets
Public Outreach Program	• Industrial discharges • Service area pollution prevention partnership program • Public education and outreach program
Response Plan for Identified Constituents	• Interagency collaboration • Response to water quality deviations

Sources: U.S. EPA (2011), TWDB (2015), and Tchobanoglous et al. (2015).

4.6 Panel Recommendations for NMED: Source Control for DPR

- NMED should require that a local pretreatment ordinance be established as part of a DPR permitting process.
- A utility pursuing a DPR project, regardless of size, should implement an aggressive education and source control program in conjunction with the pretreatment program.
- A source control program for a DPR project should control COCs from a drinking water perspective. The source control program should go beyond pretreatment regulations to manage COCs.
- NMED should encourage interagency cooperation and responsiveness between the entities operating the WWTP, AWTF, and DWTF to ensure pretreatment and source control are conducted effectively.
- The principal elements of an effective DPR source control program include: (1) regulatory authority; (2) monitoring and assessment of the sewershed; (3) source investigations; (4) updated inventory of chemicals and constituents; (5) public outreach; and (6) response plan.

CHAPTER 5: ENHANCED WASTEWATER TREATMENT

For DPR projects, the principal goal of wastewater treatment prior to AWT is to remove or inactivate physical, chemical, and microbial constituents from raw wastewater so that the treated effluent can be reused safely and effectively as a source for drinking water. The different levels of wastewater treatment (e.g., primary, secondary, and tertiary treatment) and different treatment processes (e.g., biological wastewater treatment, filtration, disinfection) result in treated effluent quality with a wide range of differences in concentrations of nutrients, metals, microorganisms, organics, and solids.

The role of a WWTP in a DPR project is to provide a consistent, high-quality effluent optimized for further processing. The WWTP and AWTF should be designed as an integrated system to ensure compatibility among unit operations and provide reliable performance without unnecessary duplication.

Most existing WWTPs, however, are not designed for potable reuse applications. As such, enhancements can be made to existing WWTPs to improve the quality of effluent for subsequent advanced treatment (Tchobanoglous et al., 2015).

5.1 Value of Higher-Quality Wastewater Effluent for DPR Applications

Secondary treatment involves the removal of biodegradable organic matter and suspended solids. In federal regulations, secondary treatment is defined as meeting minimum standards for biochemical oxygen demand, total suspended solids, and pH in effluents discharged from municipal WWTPs (Tchobanoglous et al., 2014).

For the DPR process, the benefits of using higher-quality (i.e., enhanced) secondary treatment (which may involve nutrient removal, filtration, disinfection, or both filtration and disinfection) include:

- Reduced contaminant load, leading to reduced demands on subsequent treatment processes.
- Improved performance of subsequent advanced treatment processes.
- Increased reliability of the overall DPR treatment train.

Nitrification and denitrification can be incorporated in most secondary treatment processes to control and remove nitrogen in wastewater. Nitrification involves converting ammonia to nitrate, while denitrification involves reducing and/or removing nitrate.

For the DPR process, the benefits of nitrification and denitrification include:

- Reduced membrane fouling rates (Trussell et al., 2009) for advanced treatment.
- Reduced degree of nitrate removal that must be achieved in the AWTF.
- Reduced DBP formation potential, especially for NDMA.

- Reduced level of COCs in secondary effluent (Salveson et al., 2012).

Tertiary treated water is more desirable than secondary treat water because tertiary treatment usually involves additional removal of residual suspended solids by granular media filtration or membrane filtration. Disinfection and nutrient removal may also be included in tertiary treatment. Tertiary treatment can also be performed at the AWTF.

For the DPR process, the benefits of tertiary treatment include:

- Improved feedwater quality to the AWTF, which improves AWTF performance.
- Reduced measure of complexity and reduced effects of close-coupled processes (i.e., the performance of a process in the series can affect the selection and performance of subsequent processes), which are key contributors to engineering failures (Salveson et al., 2014).
- Redundant disinfection barrier added to the subsequent advanced treatment train.

5.2 Modification of Existing Wastewater Treatment Processes

Modifying existing WWTPs for use in a DPR project requires increased careful technical evaluation, innovative engineering, and possible upgrades to the wastewater management infrastructure, along with related operation and management activities. In general, WWTPs will need to be designed or modified to optimize overall performance, enhance reliability, and produce an effluent quality that is suitable as a feedwater supply for an AWTF producing ATW.

Some measures that can improve the performance and enhance the reliability of existing and proposed WWTPs include:

- Enhanced screening process and, possibly, fine screening.
- Influent flow and load equalization.
- Elimination (or equalization) of untreated return flows.
- Operational mode for biological treatment process to improve reliability and produce an effluent of consistent quality.
- Improved disinfection while preventing DBP formation.
- Post-treatment filtration (suspended solids can present a major challenge to AWTF processes, such as RO and AOP).
- Improved online and offline process monitoring.

More information about such modifications can be found in Tchobanoglous et al. (2015) and TWDB (2015).

5.3 Panel Recommendations for NMED: Enhanced Wastewater Treatment

- To better support potable reuse activities in the State of New Mexico, future WWTPs will need to be designed to produce an effluent optimized for further processing by AWTFs.
- The WWTP and AWTF should be designed as an integrated system to ensure compatibility among unit operations and provide reliable performance without unnecessary duplication.
- Enhancements should be made to existing WWTPs to optimize overall performance, enhance reliability, and produce an effluent quality that is suitable as a feedwater supply for an AWTF producing ATW.
- To the extent practical, NMED should identify a list of enhanced WWTP technologies to provide guidance for future potable reuse projects.

CHAPTER 6: ADVANCED WATER TREATMENT TECHNOLOGIES

The purpose of advanced water treatment is to produce ATW from treated wastewater that meets all applicable federal, state, and local potable reuse regulations to serve as a source of water supply (Tchobanoglous et al., 2015). The treatment process must be sufficiently robust that it will pass regulatory review and public scrutiny. The use of advanced water treatment can help gain acceptance for potable reuse. Over the past decade, a number of new technologies have been developed for use at an AWTF and the performance of existing technologies has been significantly improved.

6.1 Treatment Technologies Used for Advanced Water Treatment

A summary is provided in Table 6.1 of the principal advanced treatment technologies currently used to remove particulate, colloidal, and dissolved inorganic and organic constituents found in the effluent from WWTPs. Note that these treatment technologies represent options rather than requirements, and reflect the current state-of-the-science. In addition to enhanced conventional drinking water treatment, different AWTFs will employ different treatment technologies, based on specific water quality goals, operational objectives, regulatory requirements, available research, and technological advancements.

6.2 Examples of Typical Treatment Trains

A number of different treatment technologies grouped together to achieve a specific treatment objective is known as a "treatment train." AWTF treatment trains should be designed to eliminate acute risks (i.e., pathogens) and minimize potential chronic risks (i.e., chemical constituents) (Salveson et al., 2014). Examples of advanced water treatment trains are shown in Figure 6.1 and described in Sections 6.2.1 and 6.2.2. For more examples of possible treatment trains, see Chapter 5 of TWDB (2015).

6.2.1 Treatment Trains with Reverse Osmosis

The treatment train shown in Figure 6.1(a) is a typical treatment train that may be used for the production of ATW. It represents "full advanced treatment," which includes MF, RO, and AOP.

The treatment train shown in Figure 6.1(b) is a modification of the treatment train shown in Figure 6.1(a); here, ozone and biologically active filtration (BAF) are added to achieve additional oxidation and the biodegradation of constituents, gain disinfection credit, and improve MF performance. It also allows for the decreased size or need for the ESB.

It should be noted that RO is an important unit process for removing salinity (total dissolved solids [TDS]) in situations where salinity is a water quality problem.

Table 6.1 Summary of Technologies for Advanced Water Treatment

Treatment Option	Use	Notes
Filter screens (FS)	Remove large suspended solids in unfiltered and filtered secondary effluent.	Filter screens are needed to protect downstream membranes.
Flow equalization (FE)	Eliminate diurnal flow rate variations, reduce the size of downstream units, and reduce variations in water quality.	Constant flow with consistent water quality to the advanced treatment process reduces wear and tear on equipment (e.g., stress cracks in equipment from cycling) and results in improved performance.
Ozone (O_3) followed by biologically active filtration (BAF)	Pretreatment step used before MF or UF to achieve a reduction in pathogenic microorganisms and trace organics, and condition treated secondary effluent to enhance the performance of downstream processes like MF and UF.	It has been demonstrated that O_3/BAF ahead of MF/UF provides a greater benefit than O_3/BAF after MF/UF, but ahead of RO (Trussell et al., 2015). In some cases, the use of O_3/BAF may eliminate the need for RO for advanced water treatment.
Granular activated carbon (GAC) adsorption	Removal of trace organic compounds.	Can be used in conjunction with other technologies for the removal of trace organic compounds.
Microfiltration (MF)	Remove residual suspended particles by mechanical sieving.	Typical membrane pore size range is 0.07 to 2.0 micrometers (μm).
Ultrafiltration (UF)	Remove residual suspended particles by mechanical sieving.	Typical membrane pore size range is 0.008 to 0.2 μm. UF is often used in place of MF.
Cartridge filtration (CF)	Remove suspended and colloidal impurities from chemicals added to prevent fouling on RO membranes.	Typical filter cartridge pore size range is 5 to 10 μm.
Electrodialysis (ED)	Remove salt from solution through the use of selective membranes.	No notes.
Nanofiltration (NF)	Remove residual suspended particles and polyvalent cations by mechanical sieving.	Typical membrane pore size range is 0.001 to 0.02 μm. NF has been used in place of RO when only softening or partial demineralization is needed.
Pasteurization	Heat water to a specified temperature and time to kill or inactivate microorganisms.	No notes.
Reverse osmosis (RO)	Remove dissolved constituents and colloidal solids, including salts and trace organics, by means of size exclusion and solution/diffusion.	Typical membrane pore size range is 0.0001 to 0.002 μm.
Advanced oxidation process (AOP)	Destroy or alter chemical constituents that are not completely removed by conventional biological treatment processes or by filtration, especially trace organics.	AOP may contain a range of processes, but most commonly uses O_3 with H_2O_2 or UV with H_2O_2. More recent projects are implementing UV with sodium hypochlorite for AOP. The use of UV, O_3, and sodium hypochlorite also provides disinfection benefits.

Treatment Option	Use	Notes
Post-processing (when RO is used, decarbonation and stabilization are typically involved)	Decarbonation is used to remove (i.e., strip out) carbon dioxide from RO product water to increase pH and reduce the amount of chemicals added to stabilize it. Stabilization involves the addition of a chemical (typically lime) to the RO product water to reduce its corrosive properties.	A variety of different corrosivity indices (e.g., Aggressiveness Index, Langelier Saturation Index) are used to assess the stability of product water.
Engineered storage buffer (ESB), with or without free chlorine	Store water between the AWTF and DWTF.	In some cases, travel time in the pipeline from the AWTF to the DWTF may serve the same purpose.

Sources: Adapted from Tchobanoglous et al. (2014, 2015).

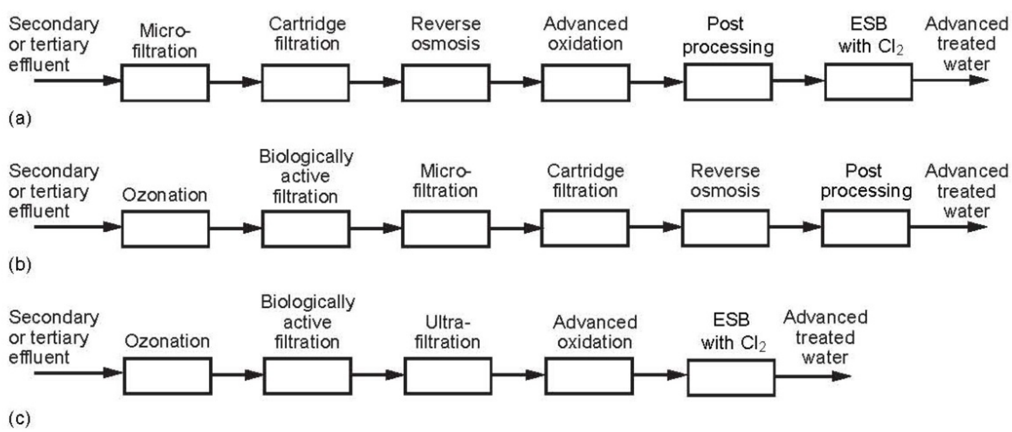

Figure 6.1. Three typical advanced water treatment trains for the production of ATW: (a) treatment train employing microfiltration, reverse osmosis, advanced oxidation, and an engineered storage buffer with free chlorine; (b) treatment train employing ozone with biologically active filtration, microfiltration, reverse osmosis, and advanced oxidation; and (c) treatment train employing ozone with biologically active filtration, ultrafiltration, advanced oxidation, and an engineered storage buffer with free chlorine (Tchobanoglous et al., 2015).

6.2.2 Treatment Trains without Reverse Osmosis

Because of cost and logistical issues associated with managing RO concentrate, interest exists in developing treatment trains capable of removing or converting chemical constituents without physically separating them from the product water. RO is especially problematic in arid regions such as New Mexico because some of the feedwater (about 15 percent) is lost as concentrate that must be addressed through disposal or other means.

The treatment train shown in Figure 6.1(c) does not include RO, but uses other processes (BAF, UF, AOP, and ESB with free chlorine) to meet chemical and pathogen treatment goals, although ultrafiltration prior to AOP may result in a high organic load that may challenge the effectiveness of the AOP. The lack of TDS removal and a higher level of TOC in the effluent are the principal differences between the RO-based treatment trains shown in Figures 6.1(a) and 6.1(b) and the treatment train without RO that is shown in Figure 6.1(c) (Tchobanoglous et al., 2015).

6.2.3 Role of the Engineered Storage Buffer

As noted in Section 2.2, the use of an ESB is optional for DPR, but there can be benefits to having an ESB. Some water analyses can be made during the ESB storage time, which may be several hours. This monitoring may help provide additional confirmation of water quality, to ensure the ATW will only be released to the DWTF (or a finished water will only be released to the distribution system) as long as it is in full compliance with operational and regulatory parameters. The ESB could be sized to hold the water for the time period equivalent to the FRT, which allows for system monitoring, verification of results, potential resampling, calibration of monitoring devices, determination of failure, and operational response. The ESB would be part of an integrated control system that uses online monitoring results for all advanced processes to document that each process is functioning properly and the combined processes are meeting the design targets for the removal of chemicals and pathogens.

Several configurations can be used for the design of the ESB, such as plug-flow pipelines, lined and possibly covered reservoirs, baffled tanks, or tanks in parallel operated in a fill, store, and draw mode. Free chlorine can be added to the ESB, resulting in additional disinfection credits in line with U.S. EPA standards.

An ESB may be replaced by additional or redundant treatment with appropriate and effective monitoring. The additional treatment allows for the continuous production of ATW if one of the major treatment processes is out of specification. This approach relies on the use of online monitoring systems and the ability to immediately divert flow in the event of further process failure (Tchobanoglous et al. (2015).

6.2.4 Operational Bypass

For DPR, it is critically important to verify ATW system performance during startup or when there are operational issues that require a portion of the system to be taken out of service for maintenance or repairs. A bypass from the outlet of the system into the sewer system (if available) or recycled back to the start of the treatment process should be included in all projects.

This bypass will allow the operators to verify and document that all systems are operating in accordance with the Operation and Maintenance (O&M) Manual.

6.3 Representative Performances of Various Treatment Trains

Final water quality (i.e., solids concentrations, organics, nutrients, metals, and microorganisms) will vary depending upon the treatment technologies used in the treatment train (Tchobanoglous et al., 2015). Some representative data are provided in Table 6.2 of the water quality produced from different treatment trains. Additional guidance on pathogen and chemical performance for potential treatment trains can be found in Chapter 5 of TWDB (2015). The final water quality may need post-processing to stabilize the water to prevent corrosion and related issues.

Table 6.2. Typical Range of Effluent Quality after Various Levels of Conventional Wastewater and Advanced Water Treatment

Constituent	Unit	Untreated Wastewater	Range of Effluent Quality after Indicated Treatment			
			Conventional Activated Sludge with Filtration	Activated Sludge with O_3/BAF	Activated Sludge with MF and RO	Activated Sludge with MF, RO, and UV-AOP
Total suspended solids	mg/L	130–389	2–8	1–2	≤1	≤1
Turbidity	NTU	80–150	1–10	≤1	≤0.1	≤0.1
Biochemical oxygen demand	mg/L	133–400	<5–20	≤1	≤1	≤1
Chemical oxygen demand	mg/L	339–1016	30–70	≤10–30	≤2–10	≤2–10
Total organic carbon	mg/L	109–328	15–30	2–5	0.1–1	0.1–1
Ammonia nitrogen	mg N/L	14–41	1–6	≤1	≤1	≤1
Nitrate nitrogen	mg N/L	0–trace	5–30	5–30	≤1	≤1
Nitrite nitrogen	mg N/L	0–trace	0–trace	≤0.001	≤0.001	≤0.001
Total nitrogen	mg N/L	23–69	15–35	≤1	≤1	≤1
Total phosphorus	mg P/L	3.7–11	2–6	2–6	≤0.5	≤0.5
Volatile organic compounds	µg/L	<100–>400	10–40	≤1	≤1	≤1
Iron and manganese	mg/L	1–2.5	1–1.4	≤0.3	≤0.1	≤0.1
Surfactants	mg/L	4–10	0.5–1.5	≤0.5	≤0.1	≤0.1

Constituent	Unit	Untreated Wastewater	Range of Effluent Quality after Indicated Treatment			
			Conventional Activated Sludge with Filtration	Activated Sludge with O_3/BAF	Activated Sludge with MF and RO	Activated Sludge with MF, RO, and UV-AOP
Totals dissolved solids	mg/L	374–1121	374–1121	374–1121	≤5–40	≤5–40
Trace constituents[a]	μg/L	10–50	5–30	≤0.1	≤0.1	≤0.1
Total coliform	No./ 100 mL	10^6–10^{10}	10^3–10^5	350	<1	<1
Protozoan cysts and oocysts	No./ 100 mL	10^1–10^5	0–10	≤0.002	≤0.002	≤0.002
Viruses	PFU/ 100 mL	10^1–10^8	10^1–10^4	≤0.03	≤0.03	≤0.03

Notes: [a]For example, fire retardants, personal care products, and prescription and nonprescription drugs.
Source: Adapted from Tchobanoglous et al. (2015).

6.4 Pilot Testing/Demonstration Studies

Pilot testing/demonstration studies can be used for the following purposes:

- Make decisions about the selection of specific AWT processes for the DPR project.
- Verify AWT performance and gain regulatory approval for the treatment train.
- Evaluate the effectiveness of different types of treatment processes or different vendors of the same treatment processes.
- Inform the design of the full-scale DPR system.

Pilot tests and/or demonstration studies should have treatment study goals guided by test plans, which includes a framework for monitoring (i.e., performance, critical control points [CCPs], and water quality).

6.5 Panel Recommendations for NMED: Advanced Water Treatment Technologies

- AWTFs will employ different treatment trains using different treatment technologies, based on specific water quality goals, operational objectives, regulatory requirements, available research, and technological advancements. The proposed treatment train must meet pathogen log reduction criteria and chemical criteria. No one specific treatment train is recommended for potable water reuse; however, typical treatment trains are provided in this section as examples.

- AWTF treatment trains should be designed to eliminate acute risks (i.e., pathogens) and minimize potential chronic risks (i.e., chemical constituents).
- Final water quality will vary depending upon the treatment technologies used in the treatment train, but all treatment processes should be selected with the aim of ensuring the protection of public health.
- A bypass from the outlet of the AWTF into the sewer system (if available) or recycled back to the start of the treatment process should be included in all potable reuse projects.
- Pilot testing or – preferably – demonstration studies are recommended for DPR projects.
- Research and experience in the field are continuously contributing to the enhancement of current treatment technologies and development of new ones. NMED should allow the consideration of alternatives treatment processes to accommodate future progress and evolution in DPR treatment technology and processes.

CHAPTER 7: PROCESS CONTROL AND MONITORING

Process monitoring for DPR systems involves the following two key components: (1) documentation and review of system performance in accordance with design intent and manufacturer recommendations to ensure water-quality specifications are met; and (2) the ability of the control system to accurately measure chemical and pathogen reduction performance to meet specified criteria.

7.1 Acute and Chronic Risks

The goal of advanced water treatment is to minimize the risk to public health through the destruction and removal of health-significant microbial and chemical constituents. DPR treatment trains should be designed to eliminate acute risks (i.e., pathogens) and minimize potential chronic risks (i.e., chemical constituents) (Salveson et al., 2014).

7.2 System Control for Pathogen Credits

CCPs are points in advanced water treatment where control can be applied to individual unit processes to reduce, prevent, or eliminate process failure and where monitoring is conducted to confirm that the CCPs are functioning correctly. The goal is to reduce the risk from pathogen and chemical constituents. For each treatment process, the goal is to establish a surrogate used to assess whether the treatment process is functioning as expected or has been compromised based on measured data. CCP monitoring would include a set of alarms, alerts, and critical limits, as well as appropriate follow-up actions.

For DPR, the CCP concept has been detailed in Halliwell et al. (2014), Salveson et al. (2015), Walker et al. (in press), and Tchobanoglous et al. (2015).

The application of the CCP approach can be used to determine log reduction credits for pathogens. This concept is illustrated in Figure 7.1 and Table 7.1 for an example AWTF treatment train. In this example, the California IPR approach (see Section 3.1.2.4) is used for pathogen targets; specifically, 12-log reduction of virus, 10-log reduction of *Giardia*, and 10-log reduction of *Cryptosporidium*. These log reductions are intended to protect public health (NWRI, 2013; CDPH, 2014).

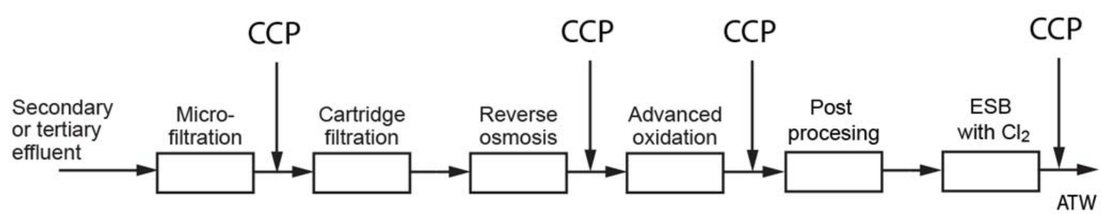

Figure 7.1. Example AWTF process flow diagram with critical control points identified for the individual treatment processes for both process control and establishing log reduction credits. Figure courtesy of Tchobanoglous et al. (2015).

Table 7.1. Pathogen Log Reduction Credits Based on the Example Monitoring Scheme Shown in Figure 7.1 (Tchobanoglous et al., 2015)

Process	Critical Control Point Monitoring	Log Reduction Credits			Notes
		V	G	C	
Secondary treatment	None sufficiently proven	0 - 1.9[b]	0 - 0.8[b]	0 - 1.2[b]	No clear correlation between rapid water quality measurements of secondary effluent and log reduction of pathogens, so "0" is the default. Site-specific performance information should be generated to demonstrate log reductions.
MF or UF	Daily PDT	0[a]	4.0	4.0	Pressure decay test (PDT) should be done daily to verify proper performance.
RO	Online EC	1.5	1.5	1.5	Electrical conductivity (EC) should be monitored in RO influent and effluent. Log reduction in system control must be based upon measured values.
UV-AOP	Intensity sensors	6	6	6	UV sensors should be calibrated per U.S. EPA (2006).
ESB with free chlorine, CL_2, residual ($\geq$0.4 mg/L)	Online Cl_2	6	3	0	The size of the ESB is dictated by the FRT of the UF system, which is the interval between the UF membrane integrity tests (about 24 hours). System control is based on maintaining a minimum free residual of 0.4 mg/L over a 24-hour storage time.
Total		13.5	14.5	11.5	

Notes: V=virus, G=*Giardia*, and C=*Cryptosporidium;* [a] Virus credit could be awarded on a case-by-case basis for UF; [b]Secondary treatment log-removals based on lower 10th percentile; however, site-specific performance information would need to be generated.

7.2.1 Automated System Control – Direct Potable Reuse Treatment Train

The treatment process control system (i.e., the Supervisory Control and Data Acquisition [SCADA] system) should continuously record the CCP data and calculate the total pathogen log reduction credits in real time, with automated warning systems and, if needed, system shutdown and diversion. Pathogen credit alarm values are proposed below using the 12/10/10 log reduction targets for virus/*Cryptosporidium/Giardia*. Similar alarms could be set based upon the anticipated removal of salts, TOC, and so on, depending upon the treatment processes and their respective treatment performance. For instance:

- **Pathogen credits drop below 13-log reduction of virus and 11-log reduction of both *Giardia* and *Cryptosporidium*.** Higher log reduction credits (i.e., 13 and 11) are targeted for this example to allow for some measured reduction in performance before diverting flow. High-level alarms require a prompt analysis of subject treatment process monitoring equipment and treatment equipment. The alarm may be the result of a failure in the CCP monitoring system or the treatment process, or a combination of the two.

- **Pathogen credits drop below 12-log reduction of virus and 10-log reduction of both *Giardia* and *Cryptosporidium*.** High-level alarm sounds and the system shuts down until proper repairs or recalibrations are completed. Having the water stored in an ESB may allow for system troubleshooting or adjustment rather than immediate diversion of flow. For example, a decrease in pathogen log reduction may be able to be corrected immediately by increasing the level of disinfection.

7.2.2 Automated System Control – Drinking Water Treatment Facility

The DWTF component of the treatment train must operate as part of the combined DPR system and also can operate independently as a DWTF with its own treatment goals and monitoring approaches. The SWTR and its amendments require a DWTF to provide a minimum of 3-log reduction of *Giardia* cysts, 4-log reduction of viruses, and a 2-log up to 5.5-log reduction of *Cryptosporidium* (depending on the utility's Bin number as defined by LT2 ESWTR).

7.2.3 Flow Diversion

In the event the entire treatment train cannot attain the target pathogen goals (e.g., 12-log reduction of virus and 10-log reduction of protozoa), effluent from the AWTF may need to be diverted or the system may need to be shut down unless the DWTF process can be shown to provide adequate treatment.

7.3 Start-Up/Documentation of Baseline Performance

At startup and prior to system operation, water quality monitoring is recommended for each major treatment process and for final product water quality (an example of startup testing is provided in Table 7.2 for one example treatment train). This monitoring is intended to: (1) document that system performance results in a finished water protective of public health; and (2) provide a baseline of system performance for future comparison and analysis. This baseline performance ideally would establish a normal distribution of performance and monitoring data. Future deviations from the normal distribution would be flagged for a more detailed evaluation and potentially equipment repair.

The State of New Mexico enforces U.S. EPA requirements and includes additional state-specific requirements for potable water quality (NMED, 2015). Recommended sampling for compounds with MCLs and secondary MCLs, as well as specific compounds with Drinking Water Health Advisory (DWHA) values, can be found in U.S. EPA (2012).

At start up, monitoring should be conducted for the chemicals listed in Chapter 3 for both unregulated and regulated constituents, including CECs.

Table 7.2. Example Startup Testing for the AWTF Flow Diagram Shown in Figure 7.1 (Tchobanoglous et al., 2015)

Process	Test	Sample Type and Frequency	Notes
Secondary effluent	Effluent turbidity, biochemical oxygen demand (BOD), and total suspended solids (TSS) microbial indicators	Online (continuous) and grab (daily) for 30 days	Sets baseline water quality.
	Effluent MCLs, secondary MCLs, and health advisory values	2 grab samples over 30 days	Provides a preliminary understanding of trace constituents ahead of advanced treatment.
MF or UF	PDT	Offline testing (daily)	None.
RO	Influent and effluent TOC	Online (continuous) and grab (daily) for 30 days	TOC reduction to <0.5 mg/L is expected with well-functioning RO membranes.
	Influent and effluent EC	Online (continuous) and grab (daily) for 30 days	EC monitoring is required for long-term operation.
	Influent and effluent CECs	2 grab samples over 30 days	Demonstrates removal by key process for CEC reduction (RO).
UV-AOP	Influent and effluent NDMA and 1,4-dioxane (if present in source water)	2 grab samples over 30 days	Demonstrates UV and oxidant doses and removal of indicator constituents difficult to remove by other techniques. 1,4-dioxane is primarily removed by AOP; NDMA by UV photolysis.
	UV sensors	Online (continuous) and verification (weekly) monitoring	Comparisons to anticipated values from manufacturers required.
	Influent ultraviolet light transmittance (UVT)	Online (continuous) and grab (daily) monitoring	None.
	Effluent *E. coli* and total coliform	Grab (weekly) for 1 month	Total coliform is not an MCL, but a general bacteria performance check.
	Effluent MCLs, secondary MCLs, unregulated and CECs	2 grab samples over 30 days	Demonstrates quality of ATW ahead of blending.
	Influent and effluent chloramine	Grab (daily) for 30 days	UV-AOP performance correlates with chloramine destruction.
ESB with free chlorination	Effluent free chlorine residual	Online (continuous) and grab (daily) for 30 days	Demonstrates the ability to maintain minimum target residual and minimum CT.

7.4 Performance Monitoring

Performance monitoring is intended to demonstrate the continuous production of high-quality water protective of public health.

- Recommended continuous online sampling for all feasible control parameters and periodic bench-top calibration of online meters are summarized in Table 7.3 for one example treatment train.
- Frequent grab samples are recommended if online systems are not available.
- Recommended periodic sampling requirements for water quality monitoring are summarized in Table 7.4 for one example treatment train.

Table 7.3: Performance Monitoring: Example Online and Calibration Sampling for the Flow Diagram Shown in Figure 7.1 (Tchobanoglous et al., 2015)

Process	Test	Type and Frequency of Sampling during Operation
Secondary effluent	Turbidity and microbial indicators	Turbidity: online (continuous) and grab (weekly); microbial: grab (weekly)
	Ammonia, TSS, and BOD	Grab (weekly)
MF or UF	PDT	Offline testing (daily)
	Turbidity	Online (continuous) and grab (weekly)
RO	Influent and effluent EC and TOC	Online (continuous) and grab (weekly)
UV-AOP	UV sensors	Online (continuous) and verification (weekly)
	Influent UVT	Online (continuous) and grab (weekly)
	Influent and effluent chloramine	Online (continuous) and grab (weekly)
ESB with free chlorination	Effluent free chlorine residual	Online (continuous) and grab (weekly)

Table 7.4. Example Performance Monitoring (Only by Grab Samples) (Tchobanoglous et al., 2015)

Monitoring Parameters	Sample Locations	Regulatory Monitoring	Process Monitoring	Frequency
TOC, EC	ROF, ROP		✓	Monthly
MCLs, secondary MCLs	ATW	✓		Quarterly or as mandated by State
CECs and unregulated	UV-AOP		✓	Quarterly (initially)
Total coliform, *E. coli*	UV-AOP	✓		As mandated by State
NDMA	UV-AOP		✓	Quarterly

Notes: ROF=RO feed, ROP=RO permeate.

7.5 Panel Recommendations for NMED: Process Control and Monitoring

- Appropriate process monitoring for DPR systems using rapid surrogate measures is needed to measure pathogen reduction performance and to document and review system performance.
- Having redundant monitoring processes (e.g., TOC and EC for RO monitoring) and active CCPs may allow for some process or monitoring excursions, while still producing water that is protective of public health.
- Automated system control (e.g., turbidity and disinfectant residuals) for the DPR system will provide continuously recorded CCP data and calculate total pathogen log reduction credits in real time. Automated water systems can provide systems shutdown and diversion. Pathogen credit alarms and system shutdown values should be established.
- In the event the DPR system cannot attain target pathogen credits or other water quality excursion, a judgment needs to be made based upon all of the information available as to whether the facility should be shut down or out-of-specification water bypassed or diverted to another system (sewer). The use of an ESB allows for time to make such decisions.
- Startup performance monitoring should be reported to NMED for approval. Water quality monitoring is recommended for each major treatment process and final product water quality.
- Process monitoring, including continuous online sampling and periodic sampling, is needed to demonstrate the continued production of high-quality water.
- Periodic calibration of online meters is needed.

CHAPTER 8: OPERATION AND MAINTENANCE

The production of ATW involves the use of a number of advanced treatment processes. Aggressive operation and maintenance (O&M) is necessary to ensure that the ATW meets all public health objectives and the DPR system operates consistently and reliably. O&M activities begin with the design and construction of the DPR system and continue throughout its lifetime (Tchobanoglous et al., 2015).

8.1 Initial Startup

Initial startup and system performance testing will demonstrate the DPR system works properly. An initial startup plan will identify the steps necessary to complete performance testing for the equipment for water treatment, monitoring, and pumping. Startup monitoring was addressed previously in Section 7.3.

8.2 Annual or Seasonal Startup (Where Needed)

An annual startup may be needed for systems that are operated intermittently or seasonally. The annual startup plan should include:

- Information identified in the initial startup plan.
- Information on periodic maintenance or cleaning and equipment rehabilitation or replacement.
- A checklist of tasks for each treatment process and the system as a whole, as performed by certified operators who have been trained on the overall operation of the DPR system.
- A schedule for completing these tasks.

8.3 Shutdown Plan

The shutdown plan should provide the same level of detail as the startup plan, including provisions to drain piping and tanks where freezing or stagnant non-compliant water exists. Some systems after shutdown may need to stay “wet”; therefore, handling this stagnant water during the preparation for startup needs to be addressed.

8.4 Operation and Maintenance Plan

An O&M plan demonstrates system performance of the various treatment processes to provide the public and regulators assurance that the DPR system is performing as designed. The O&M plan must also include regulatory compliance sampling and monitoring, as required by NMED, as well as performance monitoring. Components of an O&M plan are listed in Table 8.1.

Table 8.1: Components of an O&M Plan for a DPR System

Component	Description
Staffing (i.e., for daily operations and emergencies)	• The DPR system will operate all day every day; therefore, appropriately trained staff will be needed to ensure it is operated properly and routine periodic maintenance is performed. • Water/wastewater operators are needed to manage day-to-day plant operations, allowing for the continuity of operation in the event of illness or vacation. • A wide range of skills and experience are required to operate the plant; therefore, it may be difficult to hire the required personnel. An alternative would be to use a contracted turnkey service provider to operate the plant with appropriately trained personnel. • Remote sensing capability is necessary to provide 24/7 surveillance. • A summary of the various tasks to be performed, along with the appropriate hours, can provide insight into the number of operators that would be needed to perform all of the required maintenance, sampling, and monitoring.
Operator training and certification	• The lead operators of a DPR system will need the highest level of certifications (Level 4 for either water or wastewater). It would be useful if the operators had both water and wastewater certifications. • Operators must be trained in and demonstrate an understanding of advanced treatment system operations for potable reuse. • NMED should create a training program for each specific advanced treatment technology to be used for potable water reuse, as well as a general training program to define the broader picture of public health protection, pathogen and pollutant targets, etc. The training program could require a minimum of 16 hours per year to maintain a pool of higher level operators and advance the knowledge of advanced treatment systems throughout the State. • A separate DPR (advanced treatment) certification program could be developed, or an “endorsement” for DPR (advanced treatment) could be applied to a water or wastewater certificate.
Checklists for operations procedures (daily, weekly, and monthly)	• Use checklists developed with information provided by manufacturers to ensure routine procedures and duties are performed. • Checklists should include water quality sampling and monitoring to document treatment performance. • Incorporate monthly or other water quality sampling for compliance with NMED requirements.
Routine maintenance of equipment	• The most important aspect of operations is periodic maintenance of equipment and monitoring systems. • Identify routine maintenance as recommended by equipment manufacturers, and verify that online meters are properly integrated for each CCP. • Determine the amount of hours and type of work needed to perform periodic maintenance and incorporate this information into the annual startup and shutdown plans. • Regularly perform the monitoring and calibration of online instruments to ensure they are functioning properly.
Critical spare parts and failure training	• Identify a list of critical spare parts needed onsite in the event of system failure. • Recommend periodic "failure" drills to verify that staff is trained and parts are available to make rapid repairs to equipment.

Component	Description
Control system (e.g., SCADA, shutdown procedures, and alarms)	• Operators need to be connected to the SCADA system to constantly monitor system operations. • Program the SCADA system to alert operators when the system is not operating properly and to shut down the system if performance is compromised. • A phone, internet, or cloud-based messaging system could be used to notify operators during non-working hours if an alarm goes off. • The types of alarms that would generate these phone calls need to be determined to ensure operators respond swiftly to the situation. • System shutdown criteria need to be developed to automatically stop the system from allowing out-of-specification water to enter into the distribution system. These systems should be checked at least once per year.
Process monitoring and control	• Operators must know proper procedures for the calibration of online instruments, sampling and testing, and sensor testing. • Additional spare units may be needed to allow for easy change out if the instrument fails or calibration requires that the system be shut down for extended periods of time. • Develop process control during initial startup and verify with vendors, contractors, and operations staff.
Regulatory compliance	• Address regulatory compliance monitoring, including online instruments, daily sampling, monthly compliance sampling and testing, and others. • NMED will need to determine the number and types of sampling required with online monitoring. • NMED will need to determine the type and frequency of monitoring used to demonstrate compliance.
Frequency of monitoring	• Process monitoring is needed to monitor the performance of individual equipment or a collection of equipment. • Process monitoring should be based on manufacturer recommendations to ensure the proper operation and performance of equipment. • Process monitoring should be a combination of online instruments and water quality sampling. • Use the initial startup period to familiarize operators with equipment and various methods of process monitoring. • Employ the SCADA system as a means of monitoring online instruments and processes during non-working hours. • NMED will need to determine the frequency and types of monitoring used to demonstrate the protection of public health.
Distribution System	• Include periodic sampling of the distribution system during initial startup to determine chemical compatibility between existing drinking water supplies and the ATW. • Implement these tests prior to bringing the DPR project online and on a regular basis during operation. • Consider simple water quality testing comparing existing supplies to the ATW (or blend of the two), including pH, hardness, alkalinity, total ions and cations.
Response time to treatment failures or non-compliant water quality	• Operators should be available 24-hours a day, 7 days per week.

8.5 Operator Training and Certification

AWTFs are complex systems and must be operated and maintained by well-trained, highly skilled operations staff. These operators must be able to effectively respond to any issues or challenges that arise at the AWTF, as well as receive ongoing training or certification as new processes and techniques become available. Efforts are underway in the State of California to determine what is needed for DPR operator training and certification. For example, the State Water Resources Control Board collaborated with the California Urban Water Agencies and four other organizations to develop a framework for potable reuse operator training and certification in California (CUWA, 2016), which can serve as a reference for NMED and others interested in this process.

8.6 Reporting

The Panel recommends the following for reporting:

- Start-up monitoring should be reported to NMED for approval.
- Performance and compliance monitoring should be reported in the monthly operating report (MOR) consistent with State drinking water program reporting requirements.
- An annual report for DPR projects should be required and submitted to NMED. The report should detail trends in water quality and treatment over the year and list any significant operational or technical challenges. It should also verify that the required maintenance has been performed for the various systems.

8.6 Panel Recommendations for NMED: Operation and Maintenance

- The presence and availability of highly trained staff and access to expert support assistance are critical to the safe, successful functioning of DPR systems.
- The O&M requirements for a DPR system exceed the demands of a wastewater or drinking water supply, requiring special operator skills and experience. It is recommended that these operators have a high level of certification (such as Level 4) in either or both water and wastewater and be trained specifically for operating the DPR system. A contracted turnkey service provider may be an appropriate approach to obtain qualified O&M staff.
- Certified water/wastewater operators will be needed to run a DPR system. Staffing for a DPR system is required 24/7 unless an operational electronic remote sensing system is available to provide real-time data, appropriate alarms, and automatic response so that operators and other expert support personnel can be on call at all times.
- Utilities with DPR systems should develop plans for initial startup, annual startup, shutdown, asset management, and O&M. The O&M plan must include regulatory compliance sampling and monitoring, as required by NMED.

- NMED will need to determine (1) the number and types of sampling required with online monitoring; (2) the type and frequency of monitoring used to demonstrate compliance; and (3) the frequency and types of monitoring used to demonstrate the protection of public health.
- NMED staff will need to acquire the necessary knowledge to provide oversight for DPR systems.
- For DPR projects, NMED should require (1) start-up reporting, (2) additional reporting in the existing MOR, and (3) an annual report.

CHAPTER 9: TECHNICAL, MANAGERIAL, AND FINANCIAL CAPACITY

Technical, managerial and financial (TMF) capacity is the ability of a water utility to provide safe and dependable water to its customers. In general, it includes forms of financial support or assistance (i.e., grants and loans), regulatory enforcement, and operator certification activities, among others. NMED already has an existing capacity development program for public drinking water systems, per requirements in the 1996 SDWA, to assess the TMF capacities of water systems and assist those in need of developing or improving TMF capacity (NMED, 2014). This existing program may need to be modified or expanded upon to specifically address DPR.

9.1 Background on TMF

The 1996 SDWA requires states to incorporate TMF capacity into public water system operations. This requirement helps ensure that public water systems – including small drinking water systems – have long-term sustainability and are able to maintain compliance with all applicable drinking water laws and regulations. In particular, the Capacity Development Program was created under the SDWA Amendments of 1996 and includes the following three major components (U.S. EPA, 2015):

1. **Section 1420(a) New Systems**: States must have a program established to "ensure that all new community water systems and non-transient, non-community water systems commencing operations after October 1, 1999, demonstrate TMF capacity with respect to each national primary drinking water regulation in effect, or likely to be in effect, on the date of commencement of operations."

2. **Section 1420(c) State Capacity Development Strategies**: States must develop and implement a "strategy to assist public water systems in acquiring and maintaining TMF capacity."

3. **Section 1452(a)(3) Assessment of Capacity**: States may not provide Drinking Water State Revolving Fund (DWSRF) loan assistance to systems that lack the TMF capability to ensure compliance, or if the system is in significant noncompliance with any drinking water standard or variance; however, States may provide assistance if the use of such assistance will ensure compliance and the system has agreed to make the necessary changes in operation to ensure that it has the TMF capacity to comply over the long-term.

9.2 TMF Capacity for Direct Potable Reuse Projects

A utility will need to know if it has the TMF capacity to undertake a successful DPR project – that is, can it:

- Build, operate, manage, and sustain a DPR system for the long-term?
- Plan, achieve, and maintain regulatory compliance?
- Provide effective public health and environmental protection?

- Make efficient use of public funds and sustainable public investments?

Because wastewater is used as the source water, DPR should require a higher level of accountability by the utilities undertaking these projects; therefore, TMF capacity should also address issues such as (but not limited to) the quality of the source water, advanced treatment technologies in use at the AWTF, ability to take corrective action for a problem or failure within a shorter response time, and efforts to build and maintain public trust and confidence.

9.3 TMF Capacity Assessment

A list is included in Table 9.1 of possible areas to assess when evaluating the TMF capacity of an AWTF. The ultimate goal of a TMF capacity assessment should be to help AWTF administrators, employees, and operators identify potential or existing weaknesses and improve the AWTF's ability to provide safe and reliable ATW on a long-term basis.

Table 9.1: Potential Areas to Assess for the TMF Capacity of AWTFs

Capacity	Description	Potential Areas to Assess
Technical	Deals with the performance and operation of the AWTF.	• Feasibility of consolidation • Existing water sources (sufficient sources, source control, etc.) • Water system treatment capacity • Monitoring • Number of trained certified operators • O&M plan • Treatment, storage, and distribution facilities • Compliance records, violations of federal and state compliance standards, and plans to correct these violations
Managerial	Deals with governance (e.g., administrators must understand the responsibilities of overseeing the AWTF; employees and contractors must understand their roles; adequate time is needed to conduct all required tasks).	• Ownership • Management • Water rights • Operations (including training and technical competency, and the O&M plan) • Organization • Master planning (including an inventory of equipment and infrastructure) • Emergency response planning • System policies • Customer service
Financial	Deals with financial ability to operate and maintain existing infrastructure and financial planning for future needs. Assessed through budget statements, asset management, and financial audits.	• Capital costs • Lifecycle costs • Budgeting (and budget control) • User fees • Financial audits • Rate studies • Financial planning and management • Capital improvement plan (CIP)

9.4 Examples of TMF Capacity Development Components for AWTFs

Specific components to consider as part of a TMF capacity development program for AWTFs may include (but are not limited to):

- Adequate infrastructure
- Asset management
- Business plan or CIP
- Communication/outreach
- Construction
- Distribution
- Emergency response
- Energy efficiency and management
- Financing, revenue, and water rates
- Funding for small water systems
- Management
- Monitoring
- O&M
- Regulations
- Reserve fund
- Source control
- Source water quality
- Technical knowledge and implementation
- Training
- Treatment reliability
- Water security

9.5 Challenges Specific to New Mexico

The following challenges discussed in Sections 9.5.1 and 9.5.2 pertain specifically to water systems in New Mexico considering or implementing DPR programs.

9.5.1 Technical Assistance for Facility Operations

One of the concerns faced by most small water and wastewater utilities in New Mexico is their inability to operate their facilities due to both an inability to attract and retain qualified operators and a lack of adequate financial resources to pay for O&M costs and equipment repairs and replacement. NMED certifies water and wastewater personnel through its Utility Operator Certification Program, which is administratively located in the Surface Water Quality Bureau of NMED. In addition to certification, the Bureau organizes operator training events and provides a list of resources that operators can access for education and training. In the past, NMED has run a utility operator assistance program with funding from the U.S. EPA; however, at present, NMED does not have a formal program to provide technical assistance to assist with the O&M of water and wastewater treatment systems. The Technical Services Group in the NMED Construction Programs Bureau provides limited technical assistance during the construction of projects; however, its primary responsibility is to provide funding and oversight of water and wastewater construction projects.

The U.S. Department of Agriculture (USDA) funds the Rural Water Association, which provides limited technical assistance to operators of rural water and wastewater systems in the form of circuit riders. The New Mexico Environmental Finance Center is a U.S EPA-funded program that has provided a very limited amount of technical assistance in the past; however, this assistance was primarily offered only to utilities run by Native American tribes and pueblos in New Mexico. Several engineering firms in New Mexico offer utility O&M support on a contract basis.

As DPR projects are considered for implementation by small communities, it is clear that the complexity of the treatment processes will require technical support for O&M that is much more sophisticated than is currently available or has been provided in the past. For example, this support could be in the form of publicly funded circuit riders or possibly requiring that the utility establish a relationship with a commercial O&M provider for technical assistance and troubleshooting. NMED should also seek assistance from larger utility operations in the State that may be willing to have operators provide technical assistance and operational support.

9.5.2 Asset Management

One of the greatest challenges to water and wastewater utilities is planning for the rehabilitation and replacement of capital facilities as they age. In particular, few utilities set aside sufficient funds to replace aging infrastructure. The problem is exacerbated for small utilities in New Mexico by two factors. First, most small communities in New Mexico are poor and have very limited ability to finance water and wastewater infrastructure. New Mexico is among the poorest states in the country, with over 20-percent of its population living below the federal poverty level, as compared to the national level of 15-percent, according to the U.S. Census Bureau. The second reason is that there is an expectation in many small communities that funding for large infrastructure needs will be provided by state and/or federal grants.

Ideally, a well-run DPR utility will identify the costs associated with rehabilitation and replacement of its facilities and develop both an O&M program and a fiscal management strategy to ensure that the equipment and facilities reach their design lives and that funding is in place to replace the equipment and facilities as their useful lives are exceeded. Asset management is a formal program developed by the water utility industry that calls for a utility to identify all of its physical assets, determine their present conditions, and then plan for cost-effective O&M, rehabilitation, and eventual replacement and disposal.

The benefits of asset management have been formally recognized in New Mexico. In 2005, the New Mexico Legislature passed HJM86, which called for the State Engineer, in collaboration with NMED and other agencies, to "develop criteria for water system planning, performance, and conservation as a condition of funding." To ensure compliance with this guidance, the State Engineer and NMED require that all water projects receiving state funding develop and implement an asset management plan.

The five required components of an asset management plan (NMEFC, 2006) include:

- **Asset inventory**: The utility must identify all elements of its physical infrastructure, its condition, its remaining useful life, and its value.

- **Level of service**: The level of service defines the way in which the utility wants its system to perform over the long-term. For an AWTF, it would include the quality of water provided, system reliability, and the cost of providing the product.

- **Critical assets**: Not all physical assets are equally essential for providing water. The utility must identify the critical assets (i.e., those that have the most significant consequences if they fail). The utility must further determine how likely the asset is to fail.

- **Lifecycle costing**: Lifecycle costing involves determining the costs associated with the O&M of existing assets, repairing assets as they fail, rehabilitating assets to extend their lives, and replacing assets at the end of their useful lives.

- **Long-term funding strategy**: The final factor in the asset management strategy is to determine the best manner in which to fund O&M, repair, rehabilitation, and replacement of assets.

In principle, the information developed from an asset management plan would feed into the development of the long-term funding strategy. The NMEFC (2006) also identified four categories of funding that may be available to water utilities in New Mexico:

- Revenues generated by the system to include user fees, hook-up fees, stand-by fees, late fees, penalties, reconnect charges, and developer impact fees.

- System reserve funds, such as emergency reserves, capital improvement reserves, and debt reserves.

- System-generated replacement funds, which might include bonds and taxes.

- Non-system sources of revenue, such as state and/or federal grants and loans.

The preparation of a comprehensive asset management plan will provide information for utility managers to quantitatively evaluate the condition of the current physical infrastructure, as well as develop a financial plan to ensure proper O&M and replacement at the end of serviceable life. Often, a utility's asset management program includes the preparation of a lifecycle cost assessment in which the value of capital infrastructure and its O&M are analyzed and presented as net present value (NPV). It is recommended that utilities interested in DPR should consider conducting a lifecycle analysis of the entire DPR program (i.e., source control, wastewater collection and treatment, advanced water treatment and [if necessary] storage, and drinking water treatment and distribution).

9.6 Panel Recommendations for NMED: Technical, Managerial, and Financial Capacity

- To comply with requirements in the SDWA, NMED may need to modify or expand its existing TMF capacity development program for public drinking water systems to specifically address AWTFs.
- The goal of a TMF capacity assessment for AWTFs should be to help staff identify potential or existing weaknesses and improve the AWTF's ability to provide safe and reliable ATW.
- As DPR projects are considered for implementation by small communities in New Mexico, it is clear that the complexity of the treatment processes will require significant technical support for O&M (e.g., publicly funded circuit riders or requiring the utility to establish a relationship with a commercial O&M provider for technical assistance and troubleshooting). These communities should also seek assistance from larger utilities throughout the State.
- Utilities implementing DPR should identify the costs associated with rehabilitation and replacement of its DPR facilities and develop both an O&M program and a fiscal management strategy to ensure that equipment and facilities reach their design lives and funding is in place to replace equipment and facilities as their useful lives are exceeded.
- Utilities considering DPR as part of their future water supply should conduct a lifecycle analysis of the entire DPR program (i.e., source control, wastewater collection and treatment, advanced water treatment and [if necessary] storage, and drinking water treatment and distribution).

CHAPTER 10: PUBLIC ACCEPTANCE AND OUTREACH

In general, public confidence and support is critical to the successful implementation of potable reuse projects. According to research funded by WateReuse, public acceptance of potable reuse is equally as important as technical merit (TWDB, 2015; Macpherson and Slovic,). The public needs to trust that the use of recycled water as a source of supply is protective of public health; therefore, proponents of DPR (i.e., utilities and communities) should develop and launch public outreach programs within their service areas to allay public concerns, build public confidence, and garner public acceptance of potable reuse.

NMED is not expected to become involved with the outreach efforts of individual potable reuse projects within the State; however, NMED should be cognizant of how it can impact public perception of potable reuse.

10.1 DPR Public Perception Challenges

As with any water supply project, proponents of DPR could encounter a number of public perception challenges, such as public health concerns about chemical constituents in the water supply, perceptions about potable reuse (e.g., it may be viewed as a "last resort" among viable water supply options), and community opposition to the project (for example, opposition to raising water rates to fund the project) (Tchobanoglous et al., 2015). These challenges should be addressed through proactive and comprehensive public outreach.

10.2 Overview of DPR Public Outreach

The purpose of public outreach should be to build awareness, trust, confidence, support, and acceptance of the DPR project. To achieve this end, proponents of DPR should consider the following activities (Millan et al., 2015; Tchobanoglous et al., 2015; TWDB, 2015):

- Design the outreach program to be strategic, transparent, and thorough.
- Start outreach early and continue to engage the public throughout the lifetime of the project (i.e., planning and design, construction, operation, expansion, etc.).
- Use proven techniques and tools to listen to and communicate with the community, engage the media, and address public concerns.
- Provide useful, accurate information that builds awareness of potable reuse and builds confidence in the quality of recycled water.
- Develop consistent messages to communicate to the entire community, including different audiences in the community.
- Build relationships with opinion leaders, educators, and other influential community members.
- Create transparency in all aspects of the project, including costs, water quality, and safety.
- Prepare for tough questions and address misinformation.

10.3 Panel Recommendations for NMED: Public Acceptance and Outreach

Although it is not the role of NMED to perform DPR outreach or provide guidance to utilities on DPR outreach strategies, NMED could require utilities to develop and implement an outreach plan (beginning early on) for the DPR project. On a broader scale, NMED can engage in activities that impact public perception of potable reuse. In particular:

- The development of specific guidance for agencies interested in implementing DPR projects can help assure citizens of the State of New Mexico that potable water produced from wastewater through DPR is adequately protective of public health.

- Communicate openly and candidly with the public about the safety and challenges associated with implementing DPR. For instance, NMED could have a webpage that provides information about DPR and links to potable reuse projects within the State (when applicable) and outside the State (e.g., the Orange County Water District, City of San Diego, and Santa Clara Valley Water District in California and El Paso Water Utilities in Texas all have existing potable reuse programs or demonstration facilities). The WateReuse Association also has substantial educational material that can be found at www.watereuse.org/water-reuse-101/, such as the informational video "The Ways of Water" by WateReuse (www.watereuse.org/foundation/ways-of-water). The City of Wichita Falls in Texas also developed an outreach video for its DPR project that is accessible at https://www.youtube.com/watch?v=_MKrU1yi5Yc.

- Be thoughtful in how the State communicates with the public about water reuse in general and potable reuse in particular. Avoid sending mixed messages. For example, the general public is told to "do not drink" recycled water used for irrigation purposes – but they can drink advanced treated water produced at an advanced treatment water facility for potable reuse. This distinction can be confusing to a layperson lacking knowledge or understanding of the terms used and the differences between the treatment processes and product water quality.

- Appropriate terminology – not technical jargon – is needed when discussing potable reuse to the public. Efforts are being undertaken currently to develop consistent terminology for potable reuse within the water industry. The same is needed for the public (Tchobanoglous et al., 2015). As an early proponent of DPR, NMED should weigh in on these discussions to develop standard, "user-friendly" DPR terminology. Along these lines, this recommendation ties in with the recommendation from Chapter 2 in which NMED is encouraged to "adopt definitions for IPR and DPR to provide clarity to State agencies and utilities interested in implementing planned potable reuse projects in the State of New Mexico." These definitions will also be useful to the public and represent the first step in developing uniform terminology for both the State and water industry as a whole.

11. SMALL WATER SYSTEM CONSIDERATIONS

11.1 Overview of Small Water System Challenges

Small water systems, which can be defined as serving less than 10,000 people, will be of special interest to NMED because they.

- Generally have limited resources and a limited number of operators and other staff with technical expertise.
- Are often located in rural communities and low-income areas.
- Face the greatest challenges with SDWA compliance (for this reason, the 1996 SDWA Amendments include provisions that allow for additional flexibility in regulatory implementation and monitoring requirements for small water systems).

11.2 Preliminary Thoughts on DPR for Small Water Systems

The Panel has the following preliminary thoughts regarding the applicability of proposed DPR guidelines for small systems:

- **Water Quality Criteria.** The water quality criteria should be the same for all system sizes. That is, the pathogen and chemical criteria for DPR should apply equally to all utilities.
- **Source Control.** Small systems are often exempt from federal pretreatment programs; however, small systems considering DPR should adopt pretreatment and source control programs.
- **Wastewater Treatment.** Wastewater treatment for small systems can be enhanced for potable reuse.
- **Advanced Water Treatment Technologies.** Advanced water treatment technologies exist on a small-scale and are available to small systems, often in package plants that facilitate O&M.
- **Process Control and Monitoring.** Consistent with the 1996 SDWA Amendments provisions that allow for additional flexibility in regulatory implementation, modified monitoring requirements for small water systems proposing DPR may be possible. NMED could consider this on a case-by-case basis; however, the protection of public health still needs to be ensured.
- **O&M.** Appropriate O&M is necessary because AWTFs are complex systems that must be operated and maintained by well-trained, highly skilled operations staff. It is critical

that small system operators receive ongoing training and certification. The State will need to determine the appropriate level of O&M needed for small systems interested in implementing DPR.

- **TMF Capacity.** When possible, the State's TMF program should provide strategies for small systems to develop the capacity needed for DPR. The Panel made recommendations in Chapter 9 addressing the use of TMF capacity for assessing utilities considering DPR. This process will be critical for assessing small systems.

- **Public Acceptance and Outreach.** It is important for small systems to conduct public outreach to gain public acceptance of and confidence in a DPR project.

11.3 Panel Recommendations for NMED: Small Water System Considerations

- Small water systems present unique challenges for the State. The State will need to consider the preliminary thinking provided in Section 11.1 in the approval and permitting of DPR projects for small water systems. Of particular importance is the use of the TMF capacity process for assessing the ability of the small system to implement DPR.

12. References

Chapter 1: Introduction

CCR. *Water Recycling Criteria*, Title 22, Division 4, Chapter 3, California Code of Regulations: Sacramento, CA, 2015. https://govt.westlaw.com/calregs/Browse/Home/California/CaliforniaCodeofRegulations?guid=IE8ADB4F0D4B911DE8879F88E8B0DAAAE&originationContext=documenttoc&transitionType=Default&contextData=(sc.Default) (accessed 9/3/2015)

Chapter 2: Defining Direct Potable Reuse

NRC (2012). *Water Reuse: Potential for Expanding the Nation's Water Supply through Reuse of Municipal Wastewater.* National Research Council, National Academies Press: Washington, DC. http://www.nap.edu/catalog.php?record_id=13303 (accessed 9/3/2015)

Tchobanoglous, G., J. Cotruvo, J. Crook, E. McDonald, A. Olivieri, A. Salveson, and R.S. Trussell (2015). *Framework for Direct Potable Reuse*, WateReuse Association, Alexandria, VA.

Texas Water Development Board (2015). *Final Report: Direct Potable Reuse Resource Document*. Report prepared for the Texas Water Development Board by Alan Plummer Associates, Inc.: Fort Worth, TX. http://www.twdb.texas.gov/publications/reports/contracted_reports/doc/1248321508_Vol1.pdf (accessed 9/3/2015) http://www.twdb.texas.gov/publications/reports/contracted_reports/doc/1248321508_Vol2.pdf (accessed 9/3/2015)

Chapter 3: Water Quality Considerations

Baronti, C., R. Curini, G. D'Ascenzo, A. DiCoricia, A. Gentili, and R. Samper (2000). "Monitoring Natural and Synthetic Estrogens at Activated Sludge Sewage Treatment Plants and in a Receiving River Water." *Environmental Science and Technology*, 34(24): 5059-5066.

Bruce, G.M., Pleus, R.C., and Snyder, S.A. Toxicological Relevance of Pharmaceuticals in Drinking Water. *Environ. Sci. Technol.* 2010**,** *44*, 5619–5626.

Bull, R.; Crook, J.; Whittaker, M.; Cotruvo, J. Therapeutic Dose as the Point of Departure in Assessing Potential Health Hazards from Drugs in Recycled Municipal Wastewater. *Regul. Toxicol. Pharm.* 2011, *60* (1), 1–19.

CDPH (2014). *Groundwater Replenishment Reuse FINAL Regulations*. California Department of Public Health: Sacramento, CA.

Cotruvo, J.A., R.J. Bull, J. Crook, and M. Whittaker (2012). *Health Effects Concerns of Water Reuse with Research Recommendations*. Project Number WRF 06-004. WateReuse Foundation: Alexandria, VA.

Linden, K., A. Salveson, and J. Thurston (2012). *Innovative Treatment Technologies for Reclaimed Water.* Project Number WRRF-02-009. WateReuse Research Foundation: Alexandria, VA.

Lovins, W., J. Taylor, and S. Hong (2002). "Microorganism Rejection by Membrane Systems." *Environ. Eng. Sci.*, 19(2): 453-465.

MDH. *Human Health-Based Water Guidance Table*, webpage last updated by the Minnesota Department of Health on September 1, 2015. http://www.health.state.mn.us/divs/eh/risk/guidance/gw/table.html (accessed 9/3/2015)

National Water Research Institute (NWRI) (2013). *Examining the Criteria for Direct Potable Reuse*. Independent Advisory Panel Final Report prepared for Trussell Technologies, Inc., under WateReuse Research Foundation Project No. 11-02, National Water Research Institute: Fountain Valley, CA. https://www.watereuse.org/product/11-02-1 (accessed 9/4/2015)

NRC. *Water Reuse: Potential for Expanding the Nation's Water Supply through Reuse of Municipal Wastewater.* National Research Council, National Academies Press: Washington, DC, 2012. http://www.nap.edu/catalog.php?record_id=13303 (accessed 9/3/2015)

RxList. Prempro, Premphase, website last reviewed by the RxList on February 21, 2012. http://www.rxlist.com/prempro-drug/clinical-pharmacology.htm#CS (accessed 9/3/2015)

Salveson, A., J. Brown, Z. Zhou, and J. Lopez (2010). *Monitoring for Microconstituents in an Advanced Wastewater Treatment Facility and Modeling Discharge of Reclaimed Water to Surface Canals for Indirect Potable Reuse.* Project Number WRRF-06-019. WateReuse Research Foundation: Alexandria, VA.

Salveson, A., T. Rauch-Williams, E. Dickenson, J. Drewes, D. Drury, D. McAvoy, and S. Snyder (2012). *A Proposed Suite of Indicators for Assessing the Efficiency of Secondary Treatment for the Removal of Organic Trace Compounds.* Project Number CEC4R08. Water Environment Research Foundation: Alexandria, VA.

Schäfer, A.I., A.G. Fane, and T.D. Waite, Eds. (2005). *Nanofiltration, Principles and Applications.* Elsevier: New York, NY.

Sedlak, D.L., and M. Kavanaugh (2006). *Removal and Destruction of NDMA and NDMA Precursors during Wastewater Treatment.* Project Number WRRF-01-002. WateReuse Research Foundation: Alexandria, VA.

Snyder, S., G. Korshin, D. Gerrity, and E. Wert (2012). *Use of UV and Fluorescence Spectra as Surrogate Measures for Contaminant Oxidation and Disinfection in the Ozone/H_2O_2 Advanced Oxidation Process.* Project Number WRRF-09-10. WateReuse Research Foundation: Alexandria, VA.

Steinle-Darling, E., E. Litwiller, and M. Reinhard (2010). "Effects of Sorption on the Rejection of Trace Organic Contaminants during Nanofiltration." *Environmental Science and Technology*, 44(7): 2,592-2,598.

TAC (n.d.). Texas Administrative Code: Title 30, Part 1, Chapter 290, Subchapter D, Rule §290.42 on Water Treatment. Website of the Office of the Secretary of the State. http://texreg.sos.state.tx.us/public/readtac$ext.TacPage?sl=T&app=9&p_dir=F&p_rloc=163791&p_tloc=44408&p_ploc=29582&pg=4&p_tac=&ti=30&pt=1&ch=290&rl=42 (accessed 1/3/2016).

Tchobanoglous, G., J. Cotruvo, J. Crook, E. McDonald, A. Olivieri, A. Salveson, and R.S. Trussell (2015). *Framework for Direct Potable Reuse*, WateReuse Association, Alexandria, VA.

Texas Water Development Board (2015). *Final Report: Direct Potable Reuse Resource Document*. Report prepared for the Texas Water Development Board by Alan Plummer Associates, Inc.: Fort Worth, TX. http://www.twdb.texas.gov/publications/reports/contracted_reports/doc/1248321508_Vol1.pdf (accessed 9/3/2015) http://www.twdb.texas.gov/publications/reports/contracted_reports/doc/1248321508_Vol2.pdf (accessed 9/3/2015)

Trussell, R.R., A. Salveson, S.A. Snyder, R.S. Trussell, D. Gerrity, and B.M. Pecson (2013). *Potable Reuse: State of the Science Report and Equivalency Criteria for Treatment Trains*. WateReuse Research Foundation: Alexandria, VA.

U.S. EPA (1998). Stage 1 Disinfectant and Disinfection Byproduct Rule, 63 CFR page 69,390 *Federal Register,* December 16.

U.S. EPA (2005). *Membrane Filtration Guidance Manual for the Final Long Term 2 Enhanced Surface Water Treatment Rule*. EPA 815-R-06-007, Office of Water, U.S. Environmental Agency, Washington, DC.

U.S. EPA (2006a). *Ultraviolet Disinfection Guidance Manual for the Final Long Term 2 Enhanced Surface Water Treatment Rule*. EPA 815-R-06-009, Office of Water, U.S. Environmental Agency, Washington, DC.

U.S. EPA (2006b). Stage 2 Disinfectant and Disinfection Byproduct Rule 71 CFR page 388, *Federal Register,* January 4.

U.S. EPA (2012). *2012 Edition of Drinking Water Standards and Health Advisories*, EPA 822-S-12-001. Office of Water, U.S. Environmental Protection Agency: Washington, DC. http://water.epa.gov/action/advisories/drinking/upload/dwstandards2012.pdf (accessed 9/4/2015)

US EPA (2013). Long Term 2 Enhanced Surface Water Treatment Rule: Basic Information, webpage last updated February 11, 2013 http://water.epa.gov/lawsregs/rulesregs/sdwa/lt2/basicinformation.cfm (accessed 9/4/2015)

U.S. EPA (2015a). Drinking Water Science and Regulatory Support, web page last updated August 24, 2015 http://water.epa.gov/drink/standards/hascience.cfm (accessed 9/4/2015)

U.S. EPA (2015b). Human Health Benchmarks for Pesticides, webpage last updated September 4, 2015. http://iaspub.epa.gov/apex/pesticides/f?p=HHBP:home (accessed 9/4/2015)

Water Replenishment District (WRD). *Amended Title 22 Engineering Report for the Leo. J. Vander Lans Water Treatment Facility Expansion: Alamitos Barrier Recycled Water Project. Final Report*. CDM Smith: Boston, MA, 2013.

WHO (2011). *Guidelines for Drinking Water Quality*, fourth edition. World Health Organization: Geneva, Switzerland. http://www.who.int/water_sanitation_health/publications/dwq_guidelines/en/ (accessed 9/4/2015)

Chapter 4: Source Control for DPR

Tchobanoglous, G., J. Cotruvo, J. Crook, E. McDonald, A. Olivieri, A. Salveson, and R.S. Trussell (2015). *Framework for Direct Potable Reuse*, WateReuse Association, Alexandria, VA.

Texas Water Development Board (2015). *Final Report: Direct Potable Reuse Resource Document*. Report prepared for the Texas Water Development Board by Alan Plummer Associates, Inc.: Fort Worth, TX. http://www.twdb.texas.gov/publications/reports/contracted_reports/doc/1248321508_Vol1.pdf (accessed 9/3/2015) http://www.twdb.texas.gov/publications/reports/contracted_reports/doc/1248321508_Vol2.pdf (accessed 9/3/2015)

U.S. EPA (2011). *Introduction to the National Pretreatment Program*, (EPA-833-B-11-001). Office of Wastewater Management: U.S. Environmental Protection Agency: Washington, DC, 2011. http://water.epa.gov/polwaste/npdes/pretreatment/upload/pretreatment_program_intro_2011.pdf (accessed 9/3/2015)

U.S. EPA (2014). Pretreatment Frequently Asked Questions, webpage last updated by the U.S. Environmental Protection Agency on June 30, 2014. http://water.epa.gov/polwaste/npdes/pretreatment/Pretreatment-FAQs.cfm (accessed 9/10/2015)

Chapter 5: Enhanced Wastewater Treatment

Salveson, A.; Rauch-Williams, T.; Dickenson, E.; Drewes, J.; Drury, D.; McAvoy, D.; Snyder, S. *Trace Organic Compound Indicator Removal during Conventional Wastewater Treatment*. Water Environment Research Foundation: Alexandria, VA, 2012.

Salveson, A.; Salveson, M.; Mackey, E.; Flynn, M. *Application of Risk Reduction Principles to Direct Potable Reuse.* Project Number WRRF-11-10. WateReuse Research Foundation: Alexandria, VA, 2014.

Tchobanoglous, G., J. Cotruvo, J. Crook, E. McDonald, A. Olivieri, A. Salveson, and R.S. Trussell (2015). *Framework for Direct Potable Reuse*, WateReuse Association, Alexandria, VA.

Tchobanoglous, G.; Stensel, H. D.; Tsuchihashi, R.; Burton, F. L. *Wastewater Engineering: Treatment and Resource Recovery*, 5th ed. Metcalf & Eddy/AECOM, McGraw-Hill: New York, 2014.

Tchobanoglous, G.; Leverenz, H.; Nellor, M. H.; Crook, J. *Direct Potable Reuse: A Path Forward.* WateReuse Research Foundation: Alexandria, VA, 2011.

Texas Water Development Board (2015). *Final Report: Direct Potable Reuse Resource Document*. Report prepared for the Texas Water Development Board by Alan Plummer Associates, Inc.: Fort Worth, TX. http://www.twdb.texas.gov/publications/reports/contracted_reports/doc/1248321508_Vol1.pdf (accessed 9/3/2015) http://www.twdb.texas.gov/publications/reports/contracted_reports/doc/1248321508_Vol2.pdf (accessed 9/3/2015)

Trussell, R. S.; Jang, N.; Merlo, R.; Kim, I. S.; Hermanowicz, S. W.; Jenkins, D. Changes in Mixed Liquor and Organic Foulant Properties Affect Membrane Fouling for Non-Nitrifying and Nitrifying Biological Conditions. *Water Environ. Res.* 2009, *81*, 255–264.

Chapter 6: Advanced Water Treatment Technologies

Salveson, A.; Salveson, M.; Mackey, E.; Flynn, M. *Application of Risk Reduction Principles to Direct Potable Reuse*. WateReuse Research Foundation Project 11-10, Final Report. WateReuse Research Foundation: Alexandria, VA, 2014.

Tchobanoglous, G.; Stensel, H. D.; Tsuchihashi, R.; Burton, F. L. *Wastewater Engineering: Treatment and Resource Recovery*, 5th ed. Metcalf & Eddy/AECOM, McGraw-Hill: New York, 2014.

Tchobanoglous, G., J. Cotruvo, J. Crook, E. McDonald, A. Olivieri, A. Salveson, and R.S. Trussell (2015). *Framework for Direct Potable Reuse*, WateReuse Association, Alexandria, VA.

Texas Water Development Board (2015). *Final Report: Direct Potable Reuse Resource Document*. Report prepared for the Texas Water Development Board by Alan Plummer Associates, Inc.: Fort Worth, TX. http://www.twdb.texas.gov/publications/reports/contracted_reports/doc/1248321508_Vol1.pdf (accessed 9/3/2015) http://www.twdb.texas.gov/publications/reports/contracted_reports/doc/1248321508_Vol2.pdf (accessed 9/3/2015)

Chapter 7: Process Control and Monitoring

CDPH (2014). *Groundwater Replenishment Reuse FINAL Regulations*. California Department of Public Health: Sacramento, CA.

Halliwell, D., D. Burris, D. Deere, G. Leslie, J. Rose, and J. Blackbeard (2014). *Utilization of Hazard Analysis and Critical Control Points Approach for Evaluating Integrity of Treatment Barriers for Reuse*. Project Number WRRF-09-03, WateReuse Research Foundation: Alexandria, VA.

National Water Research Institute (NWRI) (2013). *Examining the Criteria for Direct Potable Reuse*. Independent Advisory Panel Final Report prepared for Trussell Technologies, Inc., under WateReuse Research Foundation Project No. 11-02, National Water Research Institute: Fountain Valley, CA. https://www.watereuse.org/product/11-02-1 (accessed 9/4/2015)

New Mexico Environment Department (NMED) (2015). Drinking Water Bureau: Laws & Regulations, webpage last updated September 4, 2015. https://www.env.nm.gov/dwb/regulations (accessed 9/4/2015)

Salveson, A., M. Salveson, E. Mackey, and M. Flynn (2014). *Application of Risk Reduction Principles to Direct Potable Reuse.* Project Number WRRF-11-10. WateReuse Research Foundation: Alexandria, VA.

State Water Resources Control Board (SWRCB) (2010). *Final Report: Monitoring Strategies for Chemicals of Emerging Concern (CECs) in Recycled Water—Recommendations of a Science Advisory Panel*. State Water Resources Control Board: Sacramento, CA. http://www.waterboards.ca.gov/water_issues/programs/water_recycling_policy/docs/cec_monitoring_rpt.pdf (accessed 9/3/2015)

Tchobanoglous, G., J. Cotruvo, J. Crook, E. McDonald, A. Olivieri, A. Salveson, and R.S. Trussell (2015). *Framework for Direct Potable Reuse*, WateReuse Association, Alexandria, VA.

U.S. EPA (2006). *Ultraviolet Disinfection Guidance Manual for the Final Long Term 2 Enhanced Surface Water Treatment Rule*, EPA 815-R-06-007. Office of Water, U.S. Environmental Protection Agency, Cincinnati, OH.

U.S. EPA (2012). *2012 Edition of Drinking Water Standards and Health Advisories*, EPA 822-S-12-001. Office of Water, U.S. Environmental Protection Agency: Washington, DC. http://water.epa.gov/action/advisories/drinking/upload/dwstandards2012.pdf (accessed 9/4/2015)

Walker, T., B.D. Stanford, C. Robillot, S. Snyder, S. Khan, and J. Vickers (in press). *Critical Control Point Assessment to Quantify the Robustness and Reliability of Multiple Treatment Barriers of a DPR Scheme.* Project Number WRRF-13-03. WateReuse Research Foundation: Alexandria, VA.

Chapter 8: Operation and Maintenance

CUWA (2016). *Draft White Paper: Potable Reuse Operator Training and Certification Framework*, California Urban Water Agencies: Walnut Creek, CA. http://www.cuwa.org/index.html (accessed 1/20/2016)

Tchobanoglous, G., J. Cotruvo, J. Crook, E. McDonald, A. Olivieri, A. Salveson, and R.S. Trussell (2015). *Framework for Direct Potable Reuse*, WateReuse Association, Alexandria, VA.

Chapter 9: Technical, Managerial, and Financial Capacity

NMED (2014). *State Of New Mexico Triennial Capacity Development Report to the Governor State Fiscal Years 2012-2014: Capacity Development Annual Report State Fiscal Year 2014*. New Mexico Environment Department Drinking Water Bureau. https://www.env.nm.gov/dwb/assistance/documents/SFY12-14CapDevGovernorsReport.pdf (accessed 12/29/2015).

NMEFC (2006). *Asset Management: A Guide for Water and Wastewater Systems*. New Mexico Environmental Center, New Mexico Institute of Mining and Technology, Socorro, New Mexico. https://southwestefc.unm.edu/main.php (accessed 12/29/2015)

U.S. EPA (2003). *Small Systems Guide to Safe Drinking Water Act Regulations: The First STEP to Providing Safe and Reliable Drinking Water*. U.S. Environmental Protection Agency, Office of Ground Water and Drinking Water (4606M), EPA 816-R-03-017. http://nepis.epa.gov/Exe/ZyPDF.cgi/1000478A.PDF?Dockey=1000478A.PDF (accessed 12/28/2015).

U.S. EPA (2015). *Information for States about Building the Capacity of Drinking Water Systems*. Webpage last updated October 15, 2015, by the U.S. Environmental Protection Agency. http://www.epa.gov/dwcapacity/information-states-about-building-capacity-drinking-water-systems (accessed 12/28/2015)

Chapter 10: Public Acceptance and Outreach

Macpherson, L. and Slovic, P. (2011). *Talking about Water: Vocabulary and Images that Support Informed Decisions about Water Recycling and Desalination* (WRF Project 07-003-1). WateReuse Research Foundation: Alexandria, VA.

Millan, M., P.A. Tennyson, and S. Snyder (2015). *Model Communication Plans for Increasing Awareness and Fostering Acceptance of Potable Reuse*. Project Number WRRF-13-02. WateReuse Research Foundation: Alexandria, VA.

Tchobanoglous, G., J. Cotruvo, J. Crook, E. McDonald, A. Olivieri, A. Salveson, and R.S. Trussell (2015). *Framework for Direct Potable Reuse*, WateReuse Association, Alexandria, VA.

Texas Water Development Board (2015). *Final Report: Direct Potable Reuse Resource Document*. Report prepared for the Texas Water Development Board by Alan Plummer Associates, Inc.: Fort Worth, TX. http://www.twdb.texas.gov/publications/reports/contracted_reports/doc/1248321508_Vol1.pdf (accessed 9/3/2015) http://www.twdb.texas.gov/publications/reports/contracted_reports/doc/1248321508_Vol2.pdf (accessed 9/3/2015)

APPENDIX A: NWRI PANEL BACKGROUND

About NWRI

For over 20 years, NWRI – a science-based 501c3 nonprofit located in Fountain Valley, California – has sponsored projects and programs to improve water quality, protect public health and the environment, and create safe, new sources of water. NWRI specializes in working with researchers across the country, such as laboratories at universities and water agencies, and are guided by a Research Advisory Board (representing national expertise in water, wastewater, and water reuse) and a six-member Board of Directors (representing water and wastewater agencies in Southern California).

Through NWRI's research program, NWRI supports multi-disciplinary research projects with partners and collaborators that pertain to treatment and monitoring, water quality assessment, knowledge management, and exploratory research. Altogether, NWRI's research program has produced over 300 publications and conference presentations.

NWRI also promotes better science and technology through extensive outreach and educational activities, which includes facilitating workshops and conferences and publishing White Papers, guidance manuals, and other informational material.

More information on NWRI can be found online at www.nwri-usa.org.

About NWRI Panels

NWRI also specializes in facilitating Independent Advisory Panels on behalf of water and wastewater utilities, as well as local, county, and state government agencies, to provide credible, objective review of scientific studies and projects in the water industry. NWRI Panels consist of academics, industry professionals, government representatives, and independent consultants who are experts in their fields.

The NWRI Panel process provides numerous benefits, including:

- Third-party review and evaluation.
- Scientific and technical advice by leading experts.
- Assistance with challenging scientific questions and regulatory requirements.
- Validation of proposed project objectives.
- Increased credibility with stakeholders and the public.
- Support of sound public-policy decisions.

NWRI has extensive experience in developing, coordinating, facilitating, and managing expert Panels. Efforts include:

- Selecting individuals with the appropriate expertise, background, credibility, and level of commitment to serve as Panel members.
- Facilitating hands-on Panel meetings held at the project's site or location.
- Providing written report(s) prepared by the Panel that focus on findings and comments of various technical, scientific, and public health aspects of the project or study.

Over the past 5 years, NWRI has coordinated the efforts of over 20 Panels for water and wastewater utilities, city and state agencies, and consulting firms. Many of these Panels have dealt with projects or policies involving groundwater replenishment and potable (indirect and direct) reuse. Specifically, these Panels have provided peer review of a wide range of scientific and technical areas related water quality and monitoring, constituents of emerging concern, treatment technologies and operations, public health, hydrogeology, water reuse criteria and regulatory requirements, and outreach, among others.

More information about the NWRI Independent Advisory Panel Program can be found on the NWRI website at http://nwri-usa.org/Panels.htm.

Appendix B: Biographies of the Independent Advisory Panel Members and Editors

B.1 Independent Advisory Panel

Chair: James Crook, Ph.D., P.E., BCEE. Jim Crook is an environmental engineering consultant (Boston, MA) with more than 40 years of experience in state government and consulting engineering arenas, serving public and private sectors in the U.S. and abroad. He has authored more than 100 publications and is an internationally recognized expert in water reclamation and reuse. He has been involved in numerous projects and research activities involving public health, regulations and permitting, water quality, risk assessment, treatment technology, and water reuse. Crook spent 15 years directing the California Department of Health Services' water reuse program, during which time he developed California's first comprehensive water reuse criteria. He also spent 15 years with consulting firms overseeing water reuse activities and is now an independent consultant specializing in water reuse. He currently serves on a number of advisory panels and committees, including serving as co-chair of an NWRI Expert Panel for the State of California on developing water recycling criteria for indirect potable reuse through surface water augmentation and determining the feasibility of developing criteria for direct potable reuse. Examples of other panels that he chairs include the long-term review of the Orange County Water District's Groundwater Replenishment System and the development of operational criteria for direct potable reuse for the State of New Mexico. He also served on a panel to develop a *Direct Potable Reuse Framework* document (2015) for the WateReuse Association, NWRI, and other sponsors. Among his honors, Crook was elected as a Water Environment Federation Fellow in 2014 and selected as the American Academy of Environmental Engineers' 2002 Kappe Lecturer and the WateReuse Association's 2005 Person of the Year. He received a B.S. in Civil Engineering from the University of Massachusetts and both an M.S. and Ph.D. in Environmental Engineering from the University of Cincinnati.

Joseph A. Cotruvo, Ph.D., BCES. Joe Cotruvo is President of Joseph Cotruvo & Associates, an environmental and public health consulting firm in Washington, DC, and is active in the World Health Organization (WHO)/NSF International Collaborating Centre for Drinking Water Safety and Treatment. Previously, he served as Director of the Criteria and Standards Division of the U.S. Environmental Protection Agency Office of Drinking Water, where his organization developed the *Drinking Water Health Advisory System* and numerous *National Drinking Water-Quality Standards and Guidelines*. He was also Director of the EPA's Risk Assessment Division and a former Vice President for Environmental Health Sciences at NSF International. He is a member of WHO Drinking Water Guidelines development committees and he has led the recently published monograph on *Desalination Technology: Health and Environmental Impacts*. He also led studies on bromate metabolism through the American Water Works Association Research Foundation and on recycled water contaminants for the WateReuse Foundation. Cotruvo served as Chair of the Water Quality and Water Services Committee of the Board of Directors of the District of Columbia Water and Sewer Authority. He is also Chair of the WateReuse Association National Regulatory Committee and a member of a number of expert panels, such as panels for the Orange County Water District, Los Angeles Department of Water and Power, and New Mexico Environment Department. He also served on a panel to develop a *Direct Potable Reuse Framework* document (2015) for the WateReuse Association, NWRI, and other sponsors.   Cotruvo received a B.S. in Chemistry from the University of Toledo and a Ph.D. in Physical Organic Chemistry from Ohio State University.

Andrew Salveson, P.E. Andy Salveson is Vice President and Water Reuse Chief Technologist at the national engineering firm of Carollo Engineers, Inc., where he leads advanced technology research and development and oversees Carollo's advanced wastewater treatment designs. He leads the planning, permitting, and design of direct and indirect potable reuse facilities across the Southwestern United States. He has led more than $6 million in advanced treatment research, including numerous projects for the California Direct Potable Reuse Initiative. In addition, he serves on an NWRI Independent Advisory Panel for the development of potable reuse regulatory guidance in New Mexico, as well as serves on the World Health Organization's team to develop international guidelines for direct and indirect potable reuse. He also served on a panel to develop a *Direct Potable Reuse Framework* document (2015) for the WateReuse Association, NWRI, and other sponsors. Salveson received a BS in Civil Engineering from San Jose State University and an M.S. in Environmental Engineering Technology/Environmental Technology from the University of California, Davis.

John Stomp, P.E. John Stomp is the Chief Operating Officer for the Albuquerque Bernalillo County Water Utility Authority, where he manages the operations to provide service to over 650,000 residents and businesses in the metropolitan area. Before becoming Chief Operating Officer in 2010, Stomp was the Water Resources Manager for over 13 years and was the Project Manager for the San Juan-Chama Drinking Water Project, providing up to 90 million gallons per day of purified surface water. He has been involved with western water issues for more than 25 years and is currently serving on the Bureau of Reclamation's Municipal and Industrial Water Conservation group, which is part of the Colorado River Basin wide study. Stomp received both his B.S. and M.S. in Civil Engineering from the University of New Mexico. He is also a registered professional Engineer in New Mexico and is certified as a Level IV Water and Wastewater Operator.

Bruce M. Thomson, Ph.D., P.E. Bruce Thomson has taught at the University of New Mexico since 1978. Currently the Regents Professor of Civil Engineering, he teaches a wide range of courses in environmental engineering, including physical-chemical water treatment, biological wastewater treatment, aquatic chemistry, groundwater and contaminant transport modeling, and radioactive waste management. His research interests focus on the chemical behavior and treatment of radioactive and inorganic water contaminants in both surface water and groundwater systems. Current projects include work on the remediation of contamination from uranium mining and milling activities, development of tensiometric or dry barriers to prevent contaminant migration through the vadose zone, and evaluation of groundwater contamination from onsite wastewater disposal systems. Thomson has consulted nationally and internationally on the management of wastes from the mining industry, radioactive and mixed wastes, and domestic wastes. He received a B.S. in Civil Engineering from the University of California, Davis, and both an M.S. and Ph.D. in Environmental Science and Engineering from Rice University.

B.2 Editors

Jeffrey J. Mosher. Jeff Mosher has extensive experience in water supply and water resources, including water reuse with an emphasis on indirect and direct potable reuse. For the past 10 years, he has served as executive director of NWRI, a 501c3 nonprofit focused on improving water quality and protecting public health. In this capacity, he oversees project management, strategic planning, financial management, and conference and meeting planning. Under his leadership, NWRI has supported projects, publications, and events focused on potable reuse, desalination, and other areas of advanced water treatment. He also has led more than 30 NWRI independent advisory panels for water, wastewater, and state agencies addressing water quality, treatment options, and the implementation of complex projects and policies; this effort includes administering an expert panel on evaluating the feasibility of developing water recycling criteria for direct potable reuse for the state of California. In addition, he administered a panel to develop a *Direct Potable Reuse Framework* document (2015) for the WateReuse Association, NWRI, and other sponsors; he served as one of the documents editors. Through NWRI, Mosher serves as administrative director for the Southern California Salinity Coalition. His extensive background in association and research foundation management includes previous positions for the WateReuse Association, WateReuse Research Foundation, and Association of Metropolitan Water Agencies. Mosher received a BS in Chemistry from the College of William and Mary and an MS in Environmental Engineering from George Washington University.

Gina Melin Vartanian. Gina Vartanian is an experienced writer and editor, specializing in water resources and technology. Since 1998, she has served as an editor, writer, and project manager for NWRI, a 501c3 nonprofit focused on improving water quality and protecting public health. As communications and outreach manager, she focuses on publications, website and social media development, grant proposals, and program development for conferences, workshops, and others. She has edited hundreds of technical documents for the water industry, including NWRI's *Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse* and the textbook *Riverbank Filtration: Improving Source-Water Quality*. Vartanian also provides editorial support for NWRI's Independent Advisory Panel program, attending panel meetings and assisting with panel reports. These efforts include panels to review potable reuse projects for agencies like the Orange County Water District (CA), Village of Cloudcroft (NM), and El Paso Water Utilities (TX), as well as an expert panel on evaluating the feasibility of developing water recycling criteria for direct potable reuse for the state of California. She also edited the document, *Direct Potable Reuse Framework* (2015), developed by an expert panel for the WateReuse Association, NWRI, and other sponsors. Vartanian received a BA in English Literature and a Master of Professional Writing from the University of Southern California.