Produced Water Treatment Pilot Testing:
Water Quality Report

April 17, 2026

Table of Contents

List of Tables

List of Figures

List of Appendices (see separate spreadsheet file)

Appendix A.1	TxPWC Piloting Water Quality Data, 2024-2025
Appendix A.2	Pivot Table Summary
Appendix B.	FracFocus Chemicals Listed for 203 Permian Basin Wells, 2020-2024
Appendix C.	Analytes NOT Detected in TxPWC Piloting Samples
Appendix D.	Analytes Detected in TxPWC Piloting Samples
Appendix E.	Analytes Detected in PW, TPW, or DPW, but NOT Detected in PDPW
Appendix F.	Analytes Detected in PDPW
Appendix G.	PDPW Water Quality Comparison to TCEQ Drinking Water Limits
Appendix H.	Whole Effluent Toxicity (WET) Testing Results

List of Abbreviations

CB	clean brine
DAF	dissolved air floatation
DPW	desalinated produced water
ED	electrodialysis
GAC	granular activated carbon
MCL	maximum contaminant limit
MD	membrane distillation
MDL	method detection limit
MF	microfiltration
NORM	naturally occurring radioactive material
NOEC	no observable effect concentration
ORP	oxidation-reduction potential
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PDPW	polished desalinated produced water
PW	produced water
REE	rare earth elements
RO	reverse osmosis
TDS	total dissolved solids
TOC	total organic carbon
TOX	total organic halides
TPH	total petroleum hydrocarbons
TPW	treated produced water
TxPWC	Texas Produced Water Consortium
UF	ultrafiltration
WET	whole effluent toxicity

Acknowledgements

The Texas Produced Water Consortium (TxPWC) was established at Texas Tech University in 2021 by Senate Bill 601 of the 87th Regular Session of the Texas Legislature to study the beneficial reuse of produced water. TxPWC is constituted by a wide and diverse spectrum of members representing all facets of water in industry, the environment, and society, and TxPWC would not exist without the support, feedback, and expertise of our members and advisory boards. As such, this report is a synthesis from a diverse group and does not necessarily represent the views of any individual or entity. TxPWC would also like to thank the leadership of the State of Texas for their continued dedication to future energy and water resource planning for our State.

TxPWC Staff

Dr. Shane Walker, Director
Wrye Mauldin, Project Mgr.
Lana Kirkland, Business Mgr.
Tim Neuman, Unit Mgr.

Stakeholder Advisory Council

Steve Appleyard, ConocoPhillips
Kegan Boyer, Chevron
Laura Capper, Energy Makers
Rajendra Ghimire, Badwater Alchemy/PWS
Ryan Hall, NGL
Adrianne Lopez, Texas Pacific Water
Rick McCurdy, Select Water
Vrajesh Mehta, Occidental Petroleum
Dan Mueller, Environmental Defense Fund
Tulsi Oberbeck, TXOGA
Paul Porcaro, Bechtel
Aaron Redman, ExxonMobil
Cyrus Reed, Sierra Club
Chad Unrau, Western Midstream
Steven Walden, Texas Desal/TAWWA
Cole Walker, CRMWD
Jeff White, University Lands
Ira Yates, Friends of the Pecos

TxPWC Faculty

Dr. Todd Anderson, Envr. Toxicology
Dr. Matthew Barnes, Plant & Soil Sciences
Dr. Chau-Chyun Chen, Chemical Engr.
Dr. Scott Collins, Natural Resources Mgmt.
Dr. Caitlyn Cooper-Norris, Nat. Rec. Mgmt.
Dr. Jordan Crago, Envr. Toxicology
Dr. Amrika Deonarine, Civil, Envr., & Constr. Engr.
Dr. Laura Fischer, Ag. Ed. & Communications
Dr. Evan Gray, Civil, Envr., & Constr. Engr.
Dr. Amy Hardberger, School of Law
Dr. Krishna Jagadish, Plant & Soil Sciences
Dr. Mahdi Malmali, Chemical Engr.
Dr. Hadis Matinpour, Civil, Envr., & Constr. Engr.
Dr. Courtney Meyers, Ag. Ed. & Communications
Dr. Kay Millerick, Civil, Envr., & Constr. Engr.
Dr. Aaron Norris, Natural Resources Mgmt.
Dr. Michelle Pantoya, Mechanical Engr.
Dr. Seonggyu Park, Civil, Envr., & Constr. Engr.
Dr. Balaji Rao, Civil, Envr., & Constr. Engr.
Dr. Danny Reible, Civil, Envr., & Constr. Engr.
Dr. Matthew Siebecker, Plant & Soil Sciences
Dr. Catherine Simpson, Plant & Soil Sciences
Dr. Lindsey Slaughter, Plant & Soil Sciences
Dr. Shane Walker, Civil, Envr., & Constr. Engr.
Dr. Marshall Watson, Petroleum Engr.
Dr. Ryan Williams, Veterinary Medicine

Executive Summary

With over 20 million barrels per day (*i.e.*,~1M acre-feet/year or ~1B gal/day) of produced water (PW) disposal in the Permian Basin, there is a great opportunity for beneficial reuse of treated produced water, and the Texas Produced Water Consortium (TxPWC) has collaborated with a diverse membership of stakeholders from the upstream industry, midstream industry, technology developers, landowners, agriculturalists, environmental defense, groundwater conservation districts, industrial water users, river authorities, municipal water suppliers, public health professionals, economists, academicians, and regulators to study technical aspects of the treatment of produced water for beneficial reuse such as stream discharge or land application (*e.g.*, crop irrigation or rangeland rehabilitation). The goal of this effort is to study water quality improvements through the three general stages of pilot tested treatment systems on real produced water (pretreatment, desalination [including distillation, pressure-driven membrane, and hybrid], and polishing/post-treatment) and the corresponding four general water types. This report highlights observations from the analyses of 60 samples from five pilot testing projects conducted in 2024-2025, including 17 raw produced water (PW), 13 clean brine (CB) or pre-treated PW (TPW), 12 desalinated produced water (DPW), and 18 polished DPW (PDPW). These samples were analyzed by Eurofins' laboratories (NELAP-certified). To our knowledge, this is the most extensive water quality analysis of PDPW to date. Overall, the pilot treatment systems were effective at removing >99% of salinity, organics, and radioactivity.

For these samples, 582 of the 765 analytes (*i.e.*, 76%) were not detected in concentrations above the method detection limits (MDLs), including chemical classes not expected to be present (*e.g.*, PCBs, PFAS, most herbicides and pesticides, *etc.*).

Generally, with average PW and TPW salinities of approximately 120,000 mg/L total dissolved solids (TDS), the thermal and membrane-based desalination pilot tests successfully removed bulk salinity to yield an average DPW salinity of 317 mg/L TDS, which is suitable for most beneficial reuse applications (*e.g.*, streamflow augmentation, rangeland rehabilitation, and crop irrigation). With respect to trace constituents, pilot testing of post-desalination polishing demonstrated effective removal of key indicators such as benzene, glutaraldehyde, gross alpha, methanol, naphthalene, and xylenes to below detection limits. At the time of this writing, TCEQ has not yet released draft permits for Surface Discharge or Land Application, so for the sake of performing an evaluation of water quality, PDPW quality was compared with drinking water limits. Of the 101 TCEQ drinking water limits, 76 were comparable with the PDPW water quality data, and >98% of these parameters complied with TCEQ drinking water limits.

With respect to whole effluent toxicity (WET) testing of water samples from the pilot testing projects, for two DPW samples, three of the 16 (*i.e.*, 19%) testing endpoints showed no toxicity, which confirms the importance of post-desalination polishing steps to remove trace constituents. For 16 PDPW samples, 85 of the 95 endpoints (*i.e.*, 89%) showed no toxicity for the undiluted sample, which is very promising. As industry continues to scale-up and automate treatment

systems, post-treatment/polishing unit processes are a critical step for robust removal of trace organics, trace metals, and toxicity (*e.g.*, ammonia removal for surface water discharge or boron removal for rangeland rehabilitation and crop irrigation).

Several large-scale pilot and full-scale produced water treatment systems are expected to come online in 2026. The opportunity for the beneficial reuse of polished desalinated produced water will be advanced through ongoing collaboration on water quality analyses, treatment technology development and optimization, basin-scale ecological, and field-scale land application studies.

1 Introduction

1.1 Produced water treatment processes and water types

Generally, as illustrated in **Figure 1**, the first water type, raw produced water (PW), can be treated to yield the second water type, *treated produced water* (TPW), also referred to as *clean brine* (CB), which can be reused in the oil and gas industry (*e.g.*, hydraulic fracturing). Similarly, produced water might also be pre-treated in preparation for desalination, so while the terms clean brine and *pre-treated produced water* have nuanced distinctions, for the purposes of this study, the second water type included both *clean brine* and *pre-treated PW*. Desalination processes are used to remove most of the salinity to yield the third water type, *desalinated PW* (DPW). Post-treatment or polishing treatments such as ammonia stripping, granular activated carbon (GAC) filtration, and adsorption processes can be used to yield the fourth water type, *polished DPW* (PDPW).

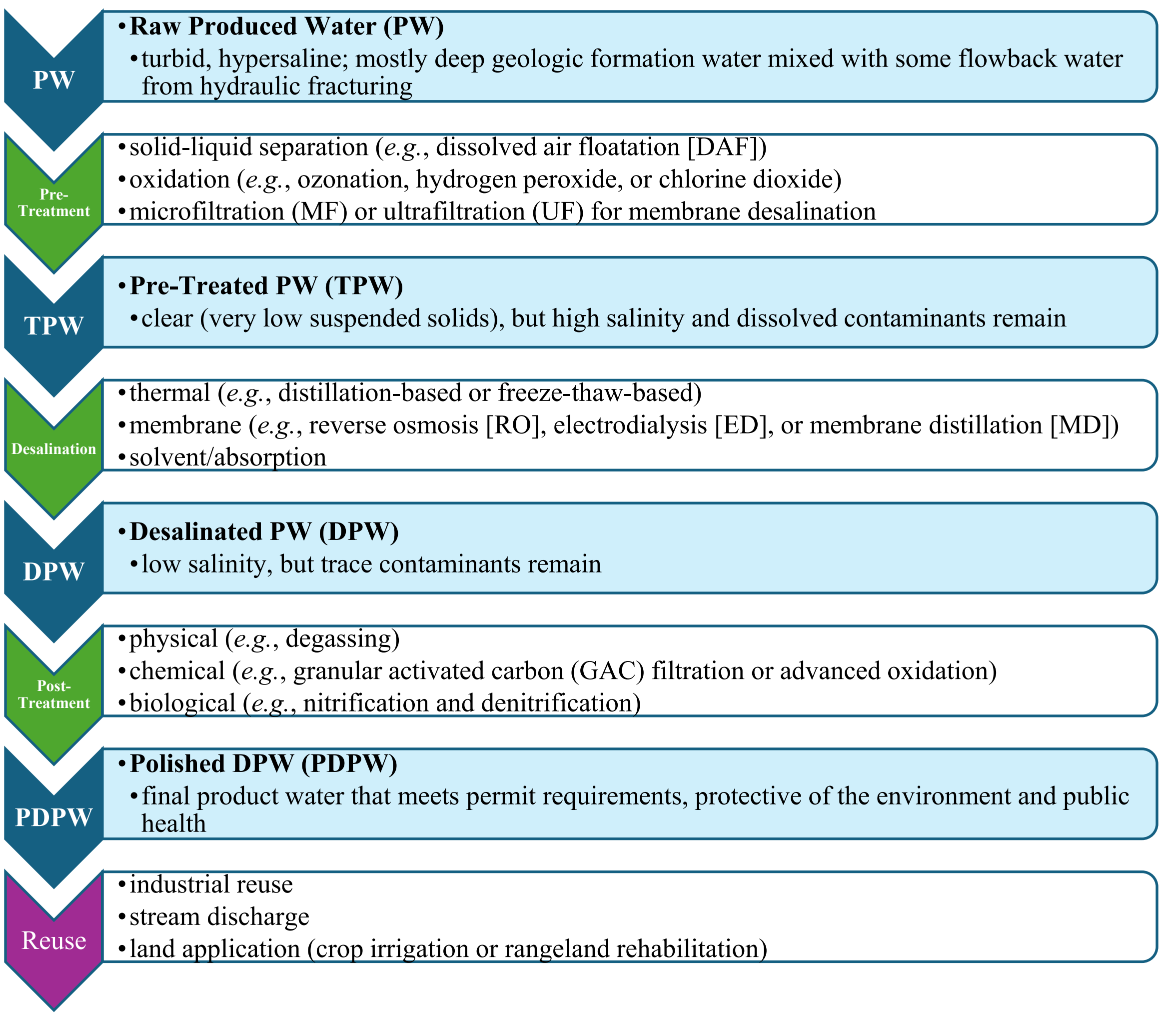

Figure 1. Four water types: raw produced water (PW), pre-treated PW (TPW), desalinated PW (DPW), and polished DPW (PDPW)

1.2 Pilot testing in the Permian Basin (2024-2025)

Five produced water treatment pilot testing projects that included pretreatment, desalination (including distillation, pressure-driven membrane, and hybrid), and polishing/post-treatment are summarized in **Table 1**, from which water quality data were collected. While some piloting systems were more advanced than others, all five were grouped together in this study to make observations across the breadth of treatment approaches, rather than differentiating (*e.g.*, thermal distillation versus pressure-driven membrane desalination). Some of the pilot treatment systems had extensive post-treatment polishing downstream of desalination, whereas some did not. Future research will compare performance between different types of treatment.

Table 1. Summary of Permian Basin pilot testing projects collaborating with TxPWC

Sub-Basin	Nominal Feed Flow Rate (bbl/day)	Number of Months of Testing
Delaware	100	18
Midland	300	6
Delaware	500	3
Delaware & Midland	20	18
Midland	800	2

2 Methodology

2.1 Collection of water samples and water quality data

From August 2024 to June 2025, in collaboration with the TxPWC, 45 water samples were collected from produced water treatment pilot testing in the Permian Basin for third-party water quality analyses by Eurofins, and TxPWC received the water quality results directly from Eurofins. Water quality data from Eurofins for an additional 15 samples were provided directly from a TxPWC member that had performed pilot testing in the Permian Basin. The number of each type of the 60 water samples are summarized in **Table 2**, and the 17,172 rows of water quality data are tabulated in **Appendix A.1** in a separate spreadsheet.

Table 2. Summary of water samples analyzed for water quality in pilot testing of treatment of produced water

Water Type	Number of Samples
Raw PW (PW)	17
Pre-Treated PW (TPW)	13
Desalinated PW (DPW)	12
Polished DPW (PDPW)	18
Total	60

The most abundant constituents in produced water from the Permian Basin are naturally occurring dissolved minerals, sodium and chloride, along with other dissolved minerals (*e.g.*, aluminum, bicarbonate, calcium, magnesium, potassium, sulfate, *etc.*). Produced water contains naturally occurring dissolved metals (*e.g.*, arsenic, barium, chromium, iron, lithium, manganese, strontium, *etc*.), naturally occurring radioactive material (NORM, *e.g.*, actinium-228, bismuth-214, lead-214, potassium-40, radium-226, radium-228, *etc.*), and naturally occurring reduced forms of nitrogen and sulfur (*e.g.*, ammonia and hydrogen sulfide). Obviously, produced water is expected to contain some naturally occurring organic compounds, especially petroleum hydrocarbons such as:

- aliphatics (containing straight or branched chains of carbon atoms)
  - alkanes (paraffins), containing only single bonds (*e.g.*, n-hexane, n-decane)
  - cycloalkanes (naphthenes), with carbon atoms arranged in ring structures (*e.g.*, cyclohexane)
- aromatics (containing one or more benzene rings)
  - single-ring aromatics (*e.g.*, benzene, toluene, ethylbenzene, xylene ("BTEX")
  - polycyclic aromatic hydrocarbons (PAHs), compounds with two or more bonded benzene rings (*e.g.*, naphthalene, anthracene)

Produced water may also contain chemicals (*e.g.*, formaldehyde, methanol, silicon dioxide [sand], *etc*.) used in well completion processes (*e.g.*, hydraulic fracturing).

To support thorough and robust research characterization of the potential contaminants in PW, some subcategories of contaminants were included in the analyses even though they would not be expected to be present in raw produced water or any derivative thereof. For example, herbicides, pesticides, polychlorinated biphenyls (PCBs), dioxin/furan, *etc.* are not expected to be present in produced water. In total, 765 distinct analytes were analyzed across the 60 samples, but not all samples were analyzed for all 765 analytes due to either matrix complexity (*e.g.*, high salinity, suspended solids, and oil/grease in raw produced water or high salinity of the clean brine) or some pilot plant operators wanted to analyze for additional parameters. A pivot table (**Appendix A.2**, see separate spreadsheet) was developed to summarize the results by water quality parameters (analytes) with number of detections, number of analyses, the range of method detection limits (MDLs), and the range of detected values.

2.2 Chemicals used in hydraulic fracturing

Generally, several types of chemicals listed in **Table 3** are used in hydraulic fracturing and subsequent conveyance, treatment, and disposal of produced water, and a detailed list from an analysis of FracFocus data from 203 wells in the Permian Basin from 2020-2024 is provided in **Appendix B** (see separate spreadsheet). Of the 130 Chemical Abstracts Service (CAS) Registry Numbers (RNs) listed in Appendix B, 54 were either analyzed directly or one or more of their constituents (*e.g.*, minerals with ions that dissociate when dissolved in water) were analyzed and are included in the 765 analytes in Appendix A. Example chemicals such as acetophenone, acrylamide, citric acid, ethanol, isopropanol, and methanol were not detected in the PDPW. Most of the constituents listed in Appendix B were also measured by aggregate analyses performed in this study, such as total suspended solids (TSS) for proppants, total dissolved solids (TDS) analyses for inorganic constituents, total organic carbon (TOC) for organic constituents, total petroleum hydrocarbon (TPH) for 6- to 35-carbon aliphatic and aromatic compounds, pH for acids and bases, and oxidation-reduction potential (ORP) for oxidizing and reducing agents.

Table 3. Purposes and examples of chemicals used in hydraulic fracturing and produced water management

Chemical Purpose	**Example Chemicals**
Antifreezing agent	ethylene glycol, methanol
Bacteria control, biocide	peracetic acid, glutaraldehyde, quaternary amines (benzalkonium), isothiazolinones
Clay stabilizer	quaternary ammonium salts, sodium chloride, potassium chloride
Coagulant	polyaluminum chloride
Corrosion inhibitor	amines, petroleum distillates
Crosslinker	borate salts and potassium hydroxide
Demulsifier (emulsion breaker)	ethyl-oxalated compounds, peroxydisulfate salts, nonylphenol ethoxylates, ammonium persulfate
Emulsifier	isopropyl alcohol
Enhanced oil recovery	terpenes from orange peel
Friction reducer	polyacrylamides, acrylamide copolymers, and AMPS copolymers
Gel breaker	strong oxidizers, ammonium persulfate, sodium bromate
Gelling agent	guar gum, sodium borate, cellulose-based polymers
Iron control	citric acid
Non-emulsifier	methanol, ethanol, petroleum distillates, naphtha, isopropanol
Oxidizer	hydrogen peroxide, sodium hypochlorite (bleach), chlorine dioxide
pH control	acids (acetic, hydrochloric, sulfuric) or bases (hydroxide, carbonate)
Proppant	silica sand, (specialty: glass beads)
Scale inhibitor	polyphosphonate (polyDADMAC) or polycarboxylic acid
Solvent	xylene
Surfactant	polyethylene glycol alkylphenyl ether, nonylphenol polyoxyethylene ether, ammonium sulfate

3 Results and Discussion

3.1 Undetected water quality analytes

For the 60 water samples analyzed in this study, 582 of the 765 analytes (*i.e.*, 76%) were not detected[1] in concentrations greater than method detection limits (MDLs) in any of the samples; these undetected analytes are listed in **Appendix C** (see separate spreadsheet) with minimum and maximum values of MDLs. Select subcategories of undetected analytes are summarized in **Table 4** by analytical method and analysis; the chemical classes (*e.g.*, PCBs, PFAS, herbicides and pesticides, rare earth elements [REEs], *etc.*) listed in Table 4 account for 300 of the 582 analytes not detected in any of the samples for which they were analyzed. These results indicate that further analysis of these chemical classes in PW, TPW, DPW, or PDPW is unlikely to contribute substantive new information, and future analyses are not justified.

Table 4. Select analytical methods from which there were no detected values in any samples for which they were analyzed

Analytical Method	**Analysis**	**Samples**	**Number of Analytes**
EPA 1668A	Chlorinated Biphenyl Congeners (PCBs) by HRGC/HRMS	3 (3 PW)	168
EPA 1633*	Per- and Polyfluoroalkyl Substances (PFAS) by LC/MS/MS	7 (2 PW; 1 PT; 1 DPW; 3 PDPW)	40
EPA 8141B*	Organophosphorous Compounds (Pesticides) by GC, Capillary Column Technique	6 (1 DPW; 5 PDPW)	26
EPA 8081B	Organochlorine Pesticides (GC)	26 (6 PW; 3 PT; 1 DPW; 16 PDPW)	24
EPA 6020B_REE	Rare Earth Metals (ICP/MS)	36 (17 PW; 3 PT; 16 PDPW)	19
EPA 8321B_Herb	Herbicides (LC/MS)	15 (1 PW; 1 PT; 2 DPW; 11 PDPW)	11
EPA 8082A	Polychlorinated Biphenyls (PCBs) by GC	26 (6 PW; 3 PT; 1 DPW; 16 PDPW)	7
EPA 504.1*	EDB, DBCP and 1,2,3-TCP (soil fumigants) by GC	10 (10 PDPW)	2
EPA 547	Glyphosate (DAI HPLC)	9 (9 PDPW)	1
EPA 6850	Perchlorate by LC/MS or LC/MS/MS	24 (11 PW; 1 PT; 1 DPW; 11 PDPW)	1
SM 4500SO3_B	Sulfite	19 (10 PW; 9 PDPW)	1
Total	-	-	*300*

Notes: * and variants; DIA – direct aqueous injection; GC – gas chromatography; HP – high performance; HR – high resolution; ICP – inductively coupled plasma; LC – liquid chromatography; MS – mass spectrometry

[1] The term "not detected" indicates that the analytical result of the analysis was less than the method detection limit (MDL) and does not guarantee that the constituent was not present.

3.2 Detected water quality analytes and general treatment efficacy

The 183 water quality analytes that had detected values are listed in **Appendix D** (see separate spreadsheet), along with minimum and maximum MDLs. Overall, across all five pilot treatment systems, the combination of three distinct treatment steps (pre-treatment, desalination, and polishing) was effective at removing >99% of salinity, organics, and radioactivity. A select set of analytes are listed in Error! Reference source not found. to highlight a range of key water quality indicators:

- aggregate parameters, including both inorganic and organic (*e.g.*, specific conductance [also called electrical conductivity], total dissolved solids [TDS], total organic carbon [TOC], total organic halides [TOX] total petroleum hydrocarbons [TPH], and ultraviolet absorption)
- metals (*e.g.*, arsenic, barium, chromium, and uranium)
- inorganic constituents (*e.g.*, ammonia and boron)
- volatile organic compounds (*e.g.*, acetone, benzene, and naphthalene)
- semi-volatile organic compounds (*e.g.*, benzyl alcohol and phenols)
- carbonyl compounds (*e.g.*, glutaraldehyde)
- non-halogenated organic compounds (*e.g.*, methanol)
- radioactivity (*e.g.*, gross alpha and gross beta)

Analytes such as benzene, glutaraldehyde, gross alpha, methanol, naphthalene, and xylenes are examples in **Error! Reference source not found.** of analytes not detected in the PDPW; of the 183 detected analytes listed in Appendix D, the 72 analytes NOT detected in the Polished DPW are listed in **Appendix E**. Finally, the 116 analytes detected in the polished DPW (PDPW) are listed in **Appendix F** with minimum and maximum MDLs, as well as minimum, average, and maximum detected values.

With respect to desalination performance, the average cumulative removal ratio from raw PW to Desalinated PW was 99.73%, 99.76%, and 99.86% for TDS, sodium, and chloride, respectively. Including the final post-treatment polishing steps downstream of desalination, most of the TOC and TPH analyses of polished DPW (PDPW) were below detection limits, representing average cumulative removal ratios of >99.3% and >99.4%, respectively. While the average detected concentration of ammonia in PDPW was 6.46 mg/L, the average concentration was less than 1 mg/L for pilot treatment systems with more robust ammonia polishing.

Table 5. Select detected constituents and averages of detected concentrations for the four PW water types

Analyte	Units	Raw PW (PW)		Pretreated PW (TPW)		Desalinated PW (DPW)		Polished DPW (PDPW)	
		detects/ analyses	avg. of det. conc.	detects/ analyses	avg. of det. conc.	detects/ analyses	avg. of det. conc.	detects/ analyses	avg. of det. conc.
Acetone	mg/L	3/11	0.652	9/11	0.264	11/11	0.169	0/10	<0.00307
Aluminum†	mg/L	0/11	ND	1/11	0.006	0/1	ND	8/11	0.107
Ammonia	mg/L	19/19	620	3/3	419	13/13	21.9	16/23	6.46
Arsenic†	mg/L	1/17	0.00246	0/3	<0.0345	0/1	<0.00138	8/17	0.00155
Barium†	mg/L	17/17	10.3	3/3	9.47	0/1	<0.00268	13/17	0.00925
Benzene	mg/L	17/17	6.32	3/13	0.2	7/12	0.00226	0/17	<0.00046
Benzyl alcohol	mg/L	1/6	0.00205	1/2	0.0277	NA	NA	5/6	0.00789
Boron†	mg/L	17/17	58.0	3/3	55.9	11/11	5.14	14/17	5.32
Chloride	mg/L	17/17	77,005	3/3	59,233	10/11	37.6	17/17	80.5
Chromium†	mg/L	3/17	0.342	0/3	<0.028	1/1	0.0284	7/17	0.00222
Ethylbenzene*	mg/L	17/17	0.229	1/13	0.0275	0/12	<0.00039	0/17	<0.00039
Formaldehyde*	mg/L	6/6	0.768	1/3	0.115	0/2	<0.00066	2/16	0.0352
Glutaraldehyde*	mg/L	1/1	0.557	1/1	0.0527	0/2	<0.03	0/11	<0.03
Gross alpha	pCi/L	13/16	1394	1/1	1370	1/1	1.63	0/15	<12.1
Gross beta	pCi/L	16/16	1014	1/1	598	1/1	1.75	8/15	1.73
Methanol*	mg/L	2/6	4.43	1/3	98.1	3/7	6.1	0/16	<2.27
Naphthalene	mg/L	7/18	0.0582	1/14	0.0043	0/14	<0.00135	0/28	<0.00135
Phenols, total	mg/L	NA	NA	NA	NA	1/1	0.0066	3/9	0.0112
Sodium†	mg/L	17/17	33,470	3/3	31,033	8/8	48.9	17/17	80.53
Specific Conductance‡	µS/cm	10/11	176,000	1/1	179,000	11/11	396	10/11	314
Toluene	mg/L	17/17	5.03	1/13	0.541	5/12	0.000755	4/17	0.00446
Total Dissolved Solids (TDS)	mg/L	17/17	131,117	3/3	124,333	11/11	317	15/15	352
Total Organic Carbon (TOC) †	mg/L	17/17	84.3	13/13	44.3	10/10	1.83	3/16	1.04
Total Organic Halogens (TOX)	mg/L	NA	NA	NA	NA	1/2	0.124	4/5	0.174
Total Petroleum Hydrocarbons (TPH) (C6-C35)	mg/L	10/11	158	0/1	<0.912	0/2	<0.876	3/11	1.13
Ultraviolet absorption	1/cm	9/9	0.206	9/9	0.165	1/1	0.066	10/10	0.0268
Uranium†	mg/L	0/16	<0.0105	0/3	<0.0105	0/1	<0.00042	1/16	0.00102
Xylenes, total*	mg/L	17/17	2.13	1/13	0.195	1/12	0.00234	0/17	<0.00124

* listed in Frac Focus; † unfiltered/total basis; ‡ electrical conductivity, µmho/cm = µS/cm = 0.001 mS/cm = 0.001 dS/m; “NA” not analyzed

3.3 Water quality comparison to regulatory water quality standards

At the time of this writing, TCEQ has not yet released draft permits for Surface Discharge or Land Application, which are two key beneficial reuse options for polished desalinated produced water (PDPW). While Surface Discharge and Land Application permits fall under the Clean Water Act framework, and while PDPW has not yet been proposed to be used for drinking water, some stakeholders have requested a comparison of the water quality of PDPW to drinking water limits because surface discharge to the Pecos River could influence the water quality of downstream drinking water intakes. Of the 101 chemical, radionuclide, and aesthetic drinking water quality parameters regulated by TCEQ[2], there are 86 primary limits and 16 secondary limits with two parameters (Cu and F) having both primary and secondary limits, tabulated in **Appendix G**. Of the 101 TCEQ drinking water limits, 76 were comparable with the TxPWC water quality data summarized in Sections 3.1 and 3.2, and the minimum value of Eurofins' minimum detection limits (MDLs) was less than the TCEQ maximum contaminant levels (MCLs) for all 76 parameters. Of the 76 parameters, 53 were not detected, and of the 23 parameters with detected values, 22 had average values that satisfied the TCEQ drinking water limits. Thus, >98% of the comparable analytes complied with TCEQ drinking water limits; the only few minor excursions were with respect to secondary limits: high total dissolved solids (TDS, 1 of 15 analyses), aluminum (8 of 11 analyses), and hydrogen sulfide (1 of 11 analyses), as well as low pH (1 of 16 analyses). There are known treatment methods for all of these parameters, and they could be controlled within safe limits. Certain pilot operations that were designed to be more robust showed no excursions.

3.4 Whole effluent toxicity (WET) testing

While other chemical constituents may be present in the water for which analyses were not performed, whole effluent toxicity (WET) testing can be helpful in reducing the uncertainty of the presence of hazardous chemicals. Thus, in addition to chemical analyses, acute and chronic toxicity analyses were also performed on 18 samples from the pilot treatment systems: two desalinated produced water (DPW) samples and 16 polished DPW (PDPW). WET tests were performed with organisms representing three trophic levels in aquatic ecosystems (*i.e.*, algae, microcrustaceans, and fish, representing primary producers, primary consumers, and secondary consumers, respectively). Two of the chronic tests had two toxicity endpoints for a total of 111 toxicity test results, tabulated in **Appendix H**. Undiluted sample water was tested along with serial dilutions with control water (*i.e.*, 100% [undiluted sample water], 50%, 25%, 12.5%, 6.25% [*i.e.*, 6.25% sample water with 93.75% control water]), and the no observable effect concentration (NOEC) is the highest concentration of sample water that yields no statistical

[2] Texas Administrative Code (TAC), Title 30, Part 1, Chapter 290, Subchapter F. Drinking Water Standards Governing Drinking Water Quality And Reporting Requirements For Public Water Systems, available at https://texas-sos.appianportalsgov.com/rules-and-meetings?chapter=290&interface=VIEW_TAC&part=1&subchapter=F&title=30#, accessed 2026 APR 11

difference in toxicity compared with the organism's response to the control water. Some PDPW samples were remineralized with calcium to avoid false toxicity due to nutrient deficiency.

Overall, for the two desalinated produced water (DPW) samples, three of the 16 (*i.e.*, 19%) endpoints listed in **Table 6** showed no toxicity, which confirms the necessity of post-desalination polishing steps to remove trace constituents. When post-treatment is added, the 16 polished desalinated produced water (PDPW) samples, 85 of the 95 endpoints showed no toxicity for the undiluted sample, and the weighted-average NOEC was 92.7%. These results are promising considering that most of these pilot treatment systems did not have fully-optimized polishing unit processes throughout the entirety of the piloting duration.

Table 6. Whole effluent toxicity (WET) test results

Test	**Endpoint**	**Desalinated PW (DPW)**		**Polished DPW (PDPW)**	
		Not Toxic/ Total	Avg NOEC	Not Toxic/ Total	Avg NOEC
Common Water Flea, Acute 48 or 96-hr (*Daphnia pulex*), EPA 2021	Survival	0/2	50%	2/2	100%
Fathead Minnow, Acute 48 or 96-hr (*Pimephales promelas*), EPA 2000	Survival	0/2	38%	16/16	100%
Fathead Minnow, Chronic (*Pimephales promelas*), EPA 1000	Growth	0/2	31%	10/14	80%
	Survival	1/2	56%	13/14	96%
Green Algae, Chronic 7-day (*Selenastrum capricornutum*), EPA 1003	Growth	0/2	27%	1/3	54%
Water Flea, Acute 48-hr (*Ceriodaphnia dubia*), EPA 2002	Survival	0/2	50%	15/18	88%
Water Flea, Chronic 7-day (*Ceriodaphnia dubia*), EPA 1002	Reproduction	0/2	38%	14/14	100%
	Survival	2/2	100%	14/14	100%

Note: "Not Toxic" refers to no observable effect at 100% concentration (*i.e.*, no dilution required); NOEC – no observable effect concentration (*e.g.*, 88% means 88% sample water with 12% control water to yield no statistical difference from 100% control water)

For these 18 DPW and PDPW samples, the *Ceriodaphnia* Chronic-survival was the least sensitive test (*e.g.*, no observed effects for undiluted DPW), while the Green Algae Chronic-growth was the most sensitive test (*e.g.*, average NOEC of 54% for PDPW). However, Green Algae tests generally exhibit higher interlaboratory variability compared to the Fathead Minnow and Water Flea tests and are not typically used in discharge permit standards. In acute toxicity tests, the organisms are not supplied with food, so they experience a different type of stress than chronic toxicity tests (typically 7 days with food). The acute toxicity tests in this dataset include tests performed at either 48-hr or 96-hr durations; some WET testing lab managers prefer the 48-hr test because the 96-hr test may be vulnerable to false-positive indications of toxicity due to the stress that the organisms experience from lack of food.

4 Conclusion

Water quality analyses were performed on 60 water samples from pilot testing produced water (PW) treatment in the Permian Basin in 2024-2025, and overall, the pilot treatment systems were effective at removing >99% of salinity, radioactivity, and organics. With average raw PW and pre-treated PW salinities over 120,000 mg/L total dissolved solids (TDS), the thermal and membrane-based desalination methods successfully removed bulk salinity to yield an average desalinated produced water (DPW) salinity of 317 mg/L TDS, which is a salinity suitable for most beneficial reuse applications (*e.g.*, streamflow augmentation, rangeland rehabilitation, and crop irrigation). With respect to trace constituents, desalination and post-treatment/polishing effectively removed key indicators such as benzene, glutaraldehyde, gross alpha, methanol, naphthalene, and xylenes to below analytical method detection limits (MDLs).

At the time of this writing, TCEQ has not yet released draft permits for Surface Discharge or Land Application, so PDPW quality was compared with drinking water limits: 75 of 76 comparable polished desalinated produced water (PDPW) water quality parameters (>98%) complied with TCEQ drinking water limits. With respect to whole effluent toxicity (WET) testing, 85 of 95 toxicity endpoints showed no toxicity in undiluted PDPW samples. These results are promising.

At the time of this writing, several larger pilot-scale and full-scale produced water treatment systems are under construction to be operational mid-2026 and will include robust post-treatment/polishing unit processes for ample removal of trace organics, trace metals, and toxicity (*e.g.*, ammonia removal for surface water discharge and boron removal for land application such as rangeland restoration and crop irrigation).

Ongoing and future work is investigating correlations among water chemistry and toxicity results, as well as best management practices on treatment plant operator training, online monitoring, and consistent laboratory water quality analyses. A related point of future work is the recovery of potentially valuable chemicals from the produced water or treatment residuals (*e.g.*, desalination concentrate).

Ultimately, the safe and beneficial reuse of polished desalinated produced water will be advanced through ongoing collaboration on water quality, water treatment optimization, basin-scale ecological and hydrologic studies, and field-scale land application studies.