

# U.S. Produced Water Volumes and Management Practices in 2021

Prepared for:



Prepared by:



November 2022

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## Acronyms and Abbreviations

|        |   |
|--------|---|
| ADEQ   | Arizona Department of Environmental Quality                           |
| AOGC   | Arkansas Oil and Gas Commission                                       |
| AOGCC  | Alaska Oil and Gas Conservation Commission                            |
| AOGCM  | Arizona Oil and Gas Commission  |
| bbls   | barrels   |
| BLM    | Bureau of Land Management   |
| BOE    | barrels of oil equivalent   |
| BOEM   | Bureau of Ocean Energy Management                                     |
| BOGC   | Montana Board of Oil and Gas Conservation                             |
| BSSE   | Bureau of Safety and Environmental Enforcement                        |
| CalGEM | California Geologic Energy Management Division                        |
| CBM    | Coalbed Methane   |
| CDOC   | California Department of Conservation                                 |
| COGCC  | Colorado Oil and Gas Conservation Commission                          |
| DENR   | South Dakota Department of Environment and Natural Resources          |
| DII    | U.S. Department of the Interior                                       |
| DMME   | Virginia Department of Mines, Minerals, and Energy                    |
| DOE    | U.S. Department of Energy   |
| DOGM   | Utah Department of Natural Resources Division of Oil, Gas, and Mining |
| DOGRM  | Ohio Division of Oil and Gas Resources Management                     |
| EDMS   | Electronic Document Management System                                 |
| EIA    | Energy Information Administration                                     |
| EOR    | Enhanced Oil Recovery   |
| ER     | Enhanced Recovery   |
| FDEP   | Florida Department of Environmental Protection                        |
| FS     | Forest Service  |
| GWPC   | Ground Water Protection Councils                                      |
| HF     | Hydraulic Fracturing  |
| IDNR   | Indiana Department of Natural Resources                               |
| IOGCC  | Idaho Oil and Gas Conservation Commission                             |
| KCC    | Kansas Corporation Commission   |
| KDNR   | Kentucky Department of Natural Resources                              |
| LOC    | Louisiana Office of Conservation                                      |
| MDNR   | Missouri Department of Natural Resources                              |
| MGS    | Missouri Geological Survey  |
| Mmcf   | million standard cubic feet   |
| MOGB   | Mississippi State Oil and Gas Board                                   |
| NDIC   | North Dakota Industrial Commission                                    |
| NDOM   | Nevada Division of Minerals   |
| NMOCD  | New Mexico Oil Conservation Division                                  |
| NOGCC  | Nebraska Oil and Gas Conservation Commission's                        |
| NPDES  | National Pollutant Discharge Elimination System                       |
| NYDEC  | New York State Department of Environmental Conservation               |
| OCC    | Oklahoma Corporation Commission                                       |
| ODNR   | Ohio Department of Natural Resources                                  |

|        |   |
|--------|---|
| OGBA   | Oil and Gas Board of Alabama                          |
| ONRR   | Office of Natural Resources Revenue                   |
| OOGRM  | Office of Oil and Gas Resource Management             |
| OTC    | Oklahoma Tax Commission                               |
| PADEP  | Pennsylvania Department of Environment Protection     |
| RBDMS  | Risk-Based Data Management System                     |
| RCC    | Railroad Commission of Texas                          |
| SONRIS | Strategic Online Natural Resources Information System |
| SWD    | saltwater disposal wells                              |
| TDEC   | Tennessee Department of Environment and Conservation  |
| TDS    | total dissolved solids                                |
| UIC    | underground injection control                         |
| USDA   | U.S. Department of Agriculture                        |
| WGR    | water-to-gas ratio                                    |
| WOGCC  | Wyoming Oil and Gas Conservation Commission           |
| WOR    | water-to-oil ratio (WOR)                              |
| WVDEP  | West Virginia Department of Environmental Protection  |

## Executive Summary

### Background

Withdrawal of oil and gas from reservoirs underground is typically escorted by “saltwater” or “brine,” which is described as produced water. Produced water can begin as ground water within the hydrocarbon bearing formations, however as the extraction matures or in the case of shale or tight formations where hydraulic fracturing is necessary to liberate the hydrocarbon, produced water can also contain fluids that were previously injected. When secondary or tertiary recovery methods are used, or with longer lateral wellbores when hydraulically fractured, the quantity of water collected at the surface usually increases and normally exceeds the amount of the hydrocarbons generated. The main take away is that produced water arrives at the surface accompanied by oil and gas or as flowback water from hydraulic fracturing operations and is not pure water.

The chemical complexity of produced water varies from reservoir to reservoir and with the hydrocarbon accompanying its production. The production and processing of produced water alters the pressure and temperature which in turn affects the fracturing and natural chemicals present. These changes coupled with the occurrence of hydrocarbons and solids, influence the produced-water behavior and properties.

Environmental concerns have increased the importance of produced water. Produced waters were historically viewed as a by-produce waste stream that required disposal. The consequence of produced water disposal and the volumes involved was not always considered vital but with the increase in hydraulic fracturing (HF) and repetitive droughts has heighten the status of this available resource. The vast majority (>90%) of produced water from onshore operations has been reinjected. Injection of produced waters serves several purposes: it generates additional hydrocarbons through secondary or tertiary recovery, it reuses a potential waste product, it permanently separates a pollutant from underground sources of drinking water, and in some areas, it controls land subsidence.

Secondary and tertiary enhanced recovery operations result in the production of more water with the hydrocarbon. To employ these waters for enhanced recovery, suspended solids and oil are removed to a suitable level to avoid blocking or clogging pathways. Offshore platforms generally discharge their produced waters directly into the ocean however progressively more rigorous environmental rules have to be met regarding the constituents present in the produced water. Offshore operators are now contemplating produced-water reinjection to prevent having to meet these discharge regulations.

### Data Collection and Approach

The 2021 study effort followed the same approach with email requests for participation being sent to 36 state agency directors or other senior managers and online research conducted to obtain data from federal agencies that oversee onshore and offshore lands and tribal assets. The emails included an introductory letter from the GWPC Executive Director explaining the process and means of replying, a questionnaire with further explanation of the desired data and two tables with instructions for completing, as well as a spreadsheet version of the two tables with summary and conversion formulas embedded. A copy of the introduction letter, questionnaire, and spreadsheets are available in **Appendix A**.

The majority of states (26) provided responses to the questionnaire coupled with populated spreadsheet tables. Four states reported no production, so did not return questionnaires and six states provided alternative instructions for obtaining their data from online sources or other state agencies. The information obtained via replies to the questionnaire generally accounted for what was asked and



met the desired data needs, however some responses included caveats. In those cases, we followed-up via email or phone call and obtained clarification. In the cases where states did not have or were unable to provide the data, we consulted the Energy Information Administration (EIA) website to fill hydrocarbon production blanks, as for produced water volumes in these cases they were left blank as no other agency solicits or collects such data. **Chapter 5** presents state-by-state accounts of the data collection, estimation, and compilation.

## Produced Water Volume

This report documents the fourth effort to assess national produced water volumes and management practices employed by operators across various states and regions. The production of crude oil, natural gas, and produced water all increased between 2017 and 2021. The percentage increases from 2017 to 2021 as compared to the percentage increases from 2012 to 2017 are as follows:

- **Crude Oil:** 20.18% (2021 vs. 2017) – 50.41% (2017 vs. 2012)
- **Natural Gas:** 17.21% (2021 vs. 2017) – 17.73% (2017 vs. 2012)
- **Produced Water:** 6.02% (2021 vs. 2017) – 15.16% (2017 vs. 2012)

Natural gas increased at about the same rate for this four-year period versus the early five-year period. Both crude oil and produced water each slowed down their rate of increase, however the percentage increase in produced water as compared to the increase in crude oil appears to have remained consistent with a near 3.3 fold relationship in their percent increases.

The produced water, crude oil plus condensate, and natural gas rounded total volumes for each of the study years is presented in **Figures ES-1, ES-2, and ES-3**. Over this 15-year period (2007-2021) the U.S. crude oil production increased by 133.8%, U.S. natural gas production increased by 70.4% and U.S. produced water production increased by 23.2%.

Of the 25,860,854,000 barrels (bbls) of produced water generated in 2021, onshore wells (both oil and gas and both conventional and unconventional wells) generated 25,458,257,000 bbl (98.4%), offshore wells added another 402,597,000 bbl (1.6%). Eight states reported over 1 billion bbls of produced water in 2021 (TX, IL, CA, OK, NM, WY, AK, KS) Texas retained the top spot with roughly 8.1 billion bbls produced for the year, however this was a decline of ~1.9 billion bbls compared to 2017, the difference most likely was unaccounted reuse water for hydraulic fracturing operations.

Texas again produced the highest volumes of oil and gas to go along with their number one ranking for produced water. The remaining billion bbl/year water-producing states were not all represented in the top ten for oil and gas production, although Alaska, Oklahoma, New Mexico, and Wyoming appeared in the top ten for both crude oil and natural gas.

The aggregate produced water volume for 2021 increased by 6.02% over the total volume generated in 2017. This growth should be looked at through a lens that acknowledges the parallel increases in oil (20.18%) and gas (17.21%) volumes from 2017 to 2021. This same pattern of oil and gas volumes increasing faster than water volumes was observed in 2017 and 2012, albeit at a slower rate from 2017 to 2021 than the prior study period. Since the types of wells and formations used to produce hydrocarbons remained consistent, between 2017 and 2021, i.e., unconventional, the explanation must lie with the increased number of wells and the amount of produced water initially generated from fracturing.

Water-to-oil (WOR) and water-to-gas (WGR) ratios were calculated for ~20 states and conventional and unconventional WOR and WGRs were computed for <10 states. These values are presented in **Chapter 4** however, these values should not be cited as accurate national values.

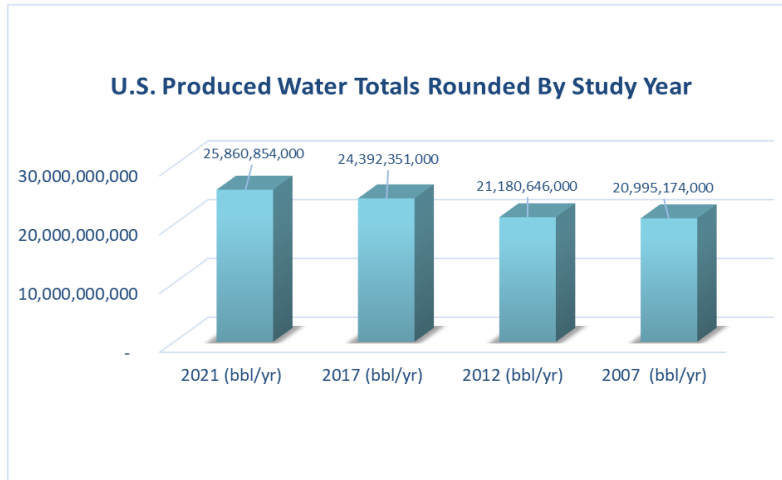


Figure ES-1 — Produced Water Totals (2007, 2012, 2017 & 2021)

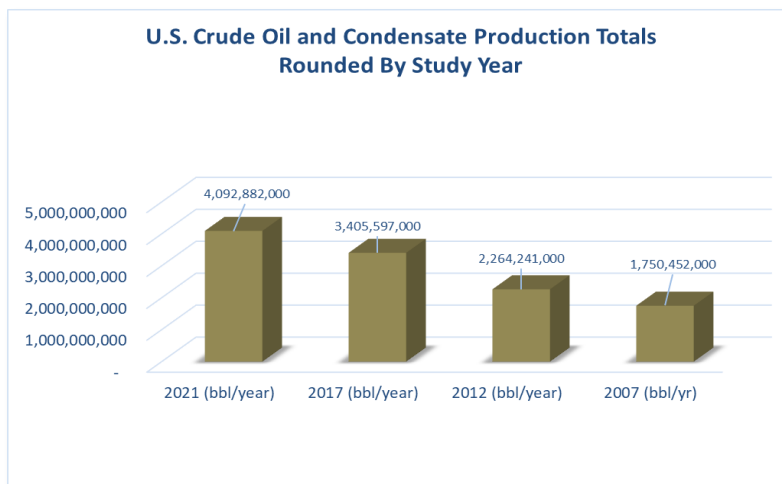


Figure ES-2 — Crude Oil and Condensate Production Totals (2007, 2012, 2017, 2021)

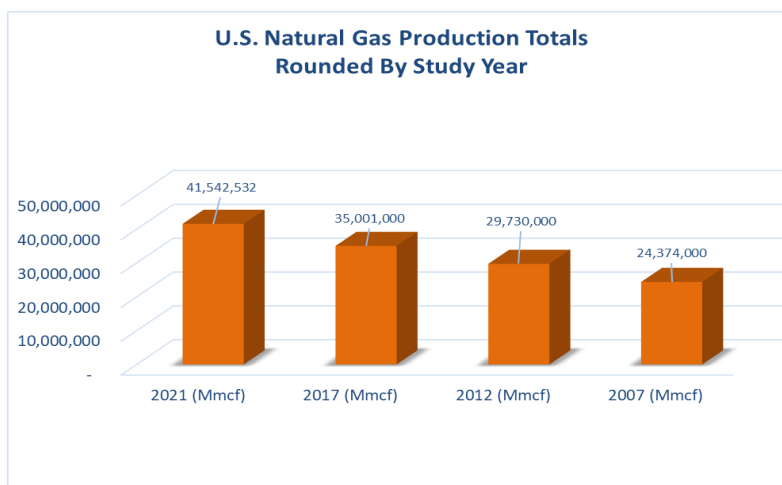


Figure ES-3 — Natural Gas Production Totals (2007, 2012, 2017, & 2021)

## Produced Water Management

The questionnaire included a request and expanded spreadsheet table for state agencies to provide detailed data regarding the produced water disposition or reuse in 2021. As with previous years, some agencies provided comprehensive data, while others could provide only limited data, only a couple of producing states were unable to share any information.

The total volume of estimated produced water (24,902,774,000 bbl) managed in 2021, pairs tightly with the reported volume of produced water generated (25,860,854,000 bbl). This is expected, since several agencies reported the volumes injected for enhanced oil recovery (EOR) or disposal as the total volumes produced as they do not require the quantities of produced water to be reported by operators. **Chapter 4** provides a table depicting produced water volumes per management practice for each state and in federal waters were available. Observation of produced water management categories for 2021 are as follows:

- ~95.74% (23,841,387,000 bbl) of the produced water was injected:
  - ~48.3% (12,038,534,000 bbl) was injected for EOR,
  - ~37.3% (9,284,329,000 bbl) was injected for disposal by operators,
  - ~10.1% (2,518,524,000 bbl) was injected for disposal by commercial operations.
- ~1.2% (291,036,000 bbl) was discharged as reported by seven states and the federal offshore assets:
  - ~1.15% (287,099,000 bbl) to water bodies,
  - ~0.02% (3,937,000 bbl) to land surfaces.
- ~0.2% (39,537,000 bbl) was evaporated mainly by several western states (CA, CO, ID, MT, NE, NM) as commercial disposal facilities have moved toward this method to augment injection near seismic sensitive areas:
  - ~0.06% (14,834,000 bbl) in lined Impoundments,
  - ~0.1% (24,703,000 bbl) in unlined Impoundments.
- ~1.2% (296,506,000 bbl) was sold or transferred for reuse in California as they were the only state to report this management method:
  - ~1.1% (265,760,000 bbl) for domestic reuse,
  - ~0.1% (30,746,000 bbl) to other oil and gas operators.
- ~1.4% was beneficially reused within and outside of the oil and gas industry as reported by eight states:
  - ~1.3% (331,268,000 bbl) for reuse in the oil field by seven states,
  - ~0.05% (12,821,000 bbl) for reuse outside the oil field by four states.
- ~0.4% (90,219,000 bbl) was reportedly in the “other” column by four states. It was mentioned by these states that these amounts represent spilled, unaccounted, record errors, or differences in produced versus managed volumes, but none was identified as being handled in a manner commensurate with reuse or disposal.

The water management categories for 2021 with some consolidated (Surface Discharge, Evaporation, Beneficial Reuse) for comparison are shown graphically in **Figures ES-4** versus the previous year’s study data as a percentage for similar categories. Note, as best practices and management strategies have evolved to accommodate changing priorities more categories have been included on the questionnaires over time, hence fewer management options were surveyed in 2007 and 2012.

An examination of the percentages across the years reveals that injection, be it for EOR or disposal, remains the primary management method employed. Note that in 2007 commercial injection for

disposal was not segregated and may have been represented in the operator injection for disposal category. A graph of just produced water injected over time is presented in **Figure ES-5**.

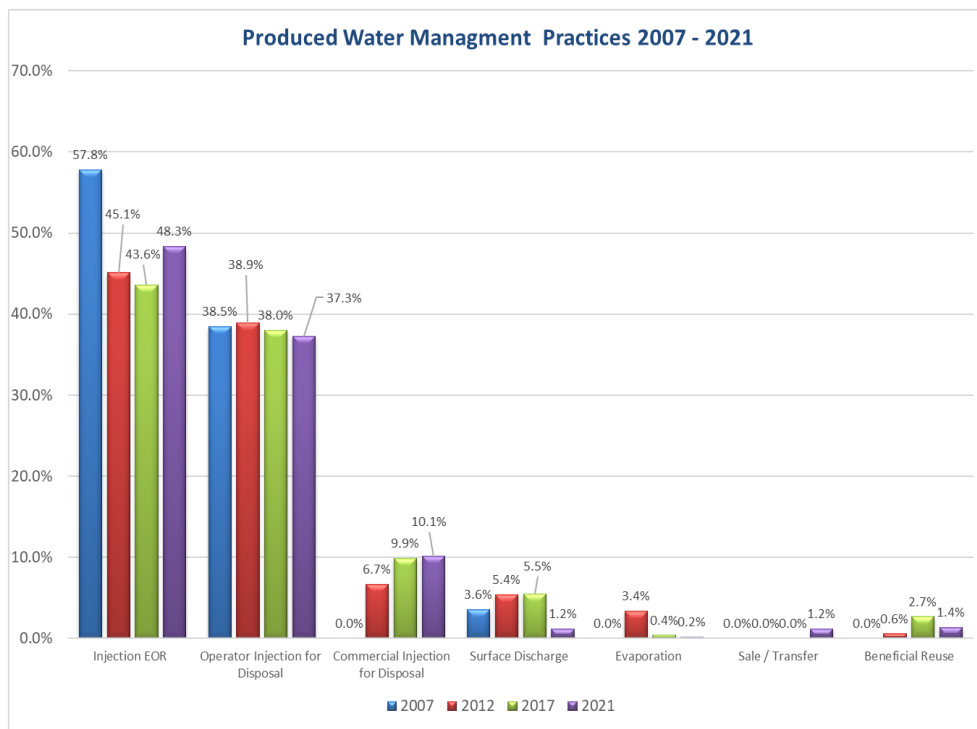


Figure ES-4 — Water Management Practices by Percentage 2007 - 2021

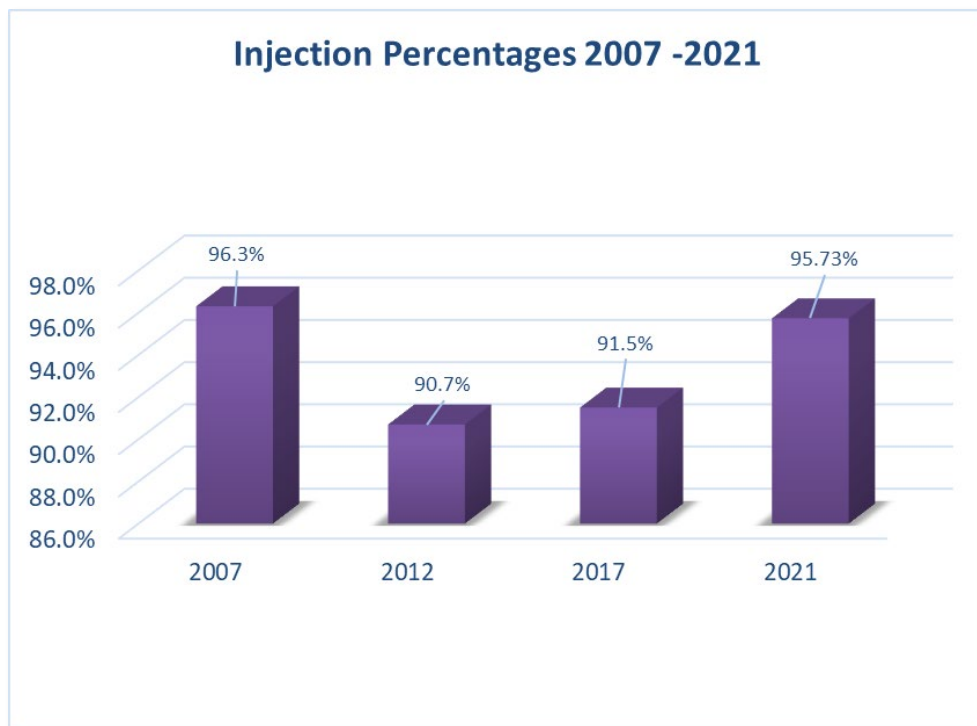


Figure ES-5 — Consolidated Injection Percentages 2007 – 2021

One can see that the percentage of water injected has remained above 90% over this 15-year period. This minor variation across the datasets could be explained as state or agency reporting discrepancies or unique assumptions made while assembling the data, in any case injection remains the leading practice.

## Data Availability and Quality

As noted in prior iterations of this study produced water volumes are not reported or documented in a consistent or regular manner from state to state. The rules and regulations vary from state to state and can cover monitoring and reporting produced water volumes from each well or make no mention of it at all, hence we are left with a mixed bag of information. However, most states responses to the questionnaire and provided insights to their data reliability and completeness.

Unlike past efforts, most states (26) had data on water production and injection for EOR or disposal and provided that information via responses to the questionnaire, it was the other management or reuse categories that were left blank or only a hand full by states which had data to complete those classifications. In only a few cases did we need to make assumptions or extrapolate volumes based on partial data provided. One of the other more common limitation was that the injection volume represented the total amount injected as many states do not track commercial disposal versus operator disposal.

In the cases where states did not have or were unable to provide the data, we consulted the Energy Information Administration (EIA) website to fill hydrocarbon production blanks, as for produced water volumes in these cases they were left blank as no other agency solicits or collects such data. The assumptions, data sets, and analyses used to develop the estimates are described separately for each state in **Chapter 5**.

Almost all states provided water volume data to the individual bbl. For consistency the amounts in the summary tables in **Chapter 4** depict rounded total volumes – these are the national totals that should be cited. There are functional issues prominent to ambiguities and imprecision of the agency supplied data (see discussion in **Chapter 4**).

## 1 Introduction

This report is the fourth edition of this study which estimates the volume of produced water generated by oil and gas producers throughout the United States. This edition has gathered data for 2021, from over 33 states and several federal agencies. Besides volumetric analyses this report also addresses the primary ways in which produced water was managed and describes the trends for recycling and reuse as reported. Copies of previous reports can be found at the Ground Water Protection Council (GWPC) website under Publications (2012 & 2017 editions - <https://www.gwpc.org/research>) and at the Office of Scientific and Technical Information website (2009 edition - <https://osti.gov/biblio/1007397>).

For this report, produced water means any water (brine) brought to the surface during the development or extraction of oil and gas, and includes natural formation water, flow-back water, injection water, enhanced-recovery water, as well as any chemicals added downhole or during the oil/water separation process. With regards to the background and characteristics of produced water very little has changed, as it is still the largest waste stream from oil and gas extraction, however its treatment for reuse is now important from both an environmental and economic perspective. Hence, the types of water management practices employed, and the produced water volumes are the only focus of this report. The report does not speak to source water, treatment technologies, or storage and transportation practices. These are integral to the industry but are beyond this report's scope.

This report addresses the 2021 produced water data compiled from various state and federal agencies. The methods used to collect data are the same as were used in the previous studies. The data's availability and quality vary between jurisdictions and has somewhat improved for 2021 with the introduction of statutes requiring the reporting of produced water disposition and the development of electronic reporting capabilities by some states. The main difference between the 2021 data and previous years is the quantity of oil and gas and produced water and the emphasis on recycling and reuse by the industry. The findings and observations are provided in the following chapters.

**Chapter 4** provides a summary tables of production volumes, hydrocarbon ratios, and management practices as well as figures depicting comparison between top producing states or jurisdictions and findings from previous reports. This chapter also includes data caveats and provides some analysis and interpretation of the data.

**Chapters 5 and 6** examine how data was reported or obtained from each state or federal agency, respectively and describes the analysis of that data, as well as any assumptions or augmentation applied. In **Chapter 5**, the State-by-State summaries each contain two tables as provided in the questionnaire, the first table reveals the quantities of oil, gas, and produced water reported for 2021, while the second table depicts the produced water's disposition by volume in each management category. **Chapter 6** provides similar data and discussion for produced water associated with federal wells onshore in tribal lands and offshore in federal waters.

## 1.1 Previous Produced Water Volume Estimates

The previous national estimates of produced water volumes have demonstrated a steady increase associated with a corresponding increase in production of hydrocarbons. The production results as previously reported are as follows:<sup>1,2,3</sup>

- 2007:
  - ~21.0 billion barrels (bbl) produced water
  - ~1.75 billion bbls crude oil
  - ~24,374,000 million standard cubic feet (Mmcf) natural gas
- 2012:
  - ~21.2 billion bbl produced water,
  - ~2.26 billion bbls crude oil
  - ~29,730,000 Mmcf natural gas
- 2017:
  - ~24.4 billion bbl produced water,
  - ~3.41 billion bbls crude oil
  - ~35,000,000 Mmcf natural gas

One oil field barrel = 42 gallons, hence the volume of produced water per study year are equivalent to just under 900 billion gallons per year or about 2.4 billion gallons per day for 2007 and 2012 respectively, but 2017 exceeded a trillion gallons at close to 2.8 billion gallon per day.

The question is, was there more produced water generated in 2021, and if so, how does that parallel to the volumes of oil and gas produced?

## 1.2 Produced Water Management

This report includes information on the disposition of produced water as managed after it comes to the surface and is separated from the hydrocarbon. Produced water was reported by the various agencies as being managed by one of the following methods:

- Injection to a hydrocarbon-bearing formation to help produce more hydrocarbon (enhanced recovery)
- Injection to a non-hydrocarbon-bearing formation for disposal by the operator or by a third party (commercially)
- Discharge to surface water bodies or to land surface
- Evaporation in lined or unlined impoundments
- Sale or transfer for domestic use or to another oil and gas operator
- Reuse for oil and gas operations (e.g., drilling fluids, frac fluids)
- Beneficial reuse outside the oil field (e.g., cooling water, dust suppression, domestic sewer).

A few states require operators to track produced water management practices and report the volume monthly or quarterly; however, the majority of states have not implemented such systems and

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<sup>1</sup> Clark, C.E., and J.A. Veil, 2009, Produced Water Volumes and Management Practices in the United States, ANL/EVS/R-09/1, prepared for the U.S. Department of Energy, National Energy Technology Laboratory, September 2009.

<sup>2</sup> Veil, J., 2015, "U.S. Produced Water Volumes and Management Practices in 2012," prepared for the Ground Water Protection Council, April 2015.

<sup>3</sup> Veil, J., 2020, "U.S. Produced Water Volumes and Management Practices in 2017," prepared for the Ground Water Protection Council, February 2020.

therefore do not have information on how the water is handled or managed beyond the volumes injected for disposal or enhanced recovery.

### 1.3 Current Perspective on Produced Water

The development of unconventional oil and gas resources has made access to relatively inexpensive and readily available energy and chemical feedstock more reliable and helped boost energy independence, however, the potential widespread application has raised concerns with environmental impacts on water resources. The environmental management challenges confronted by the oil and gas industry evolve from local water availability and lack of public infrastructure for treating and disposing of produced water. Although these are significant challenges, they create opportunities for innovation in the industry resulting in freshwater conservation.

The vast majority of produced water is reused within the oil and gas industry for enhanced recovery efforts (~49%), to augment drilling fluids, and hydraulic fracturing operations. The use of produced water in applications outside the oil and gas industry does not represent a significant amount, but the trends in certain fields/states e.g., Texas, seem to be on an upward trajectory. Hindering these applications are the large amounts of salt and other residual chemical constituents present in produced water, as well as the economic constraints of treatment required to make the water suitable for an alternative use.

The variability of produced water is renowned as the chemical and physical properties differ substantially between basins, geologic formations, the hydrocarbon being produced, and the duration of production. It is this variability coupled with the end use that mandates which tailored treatment methodologies are developed per location.

On the other hand, the costs of managing produced water are typically spent on local and regional services as development activities are spread out over more than 30 states at hundreds of thousands of individual sites. These efforts provide job opportunities for services, equipment providers, trucking companies, and have initiated the development of a more water-centric midstream industry over the past 5 years.

Produced water is a constant by-product of oil and gas development and will only grow in importance as the industry faces more energy source competition and environmental constraints.



## 2 Produced Water

### 2.1 Produced Water

Withdrawal of oil and gas from reservoirs underground is typically escorted by “saltwater” or “brine,” which is described as produced water. Produced water can begin as ground water within the hydrocarbon bearing formations, however as the extraction matures or in the case of shale or tight formations where hydraulic fracturing is necessary to liberate the hydrocarbon, produced water can also contain fluids that were previously injected. When secondary or tertiary recovery methods are used, or with longer lateral wellbores when hydraulically fractured, the quantity of water collected at the surface usually increases and normally exceeds the amount of the hydrocarbons generated. The main take away is that produced water arrives at the surface accompanied by oil and gas or as flowback water from hydraulic fracturing operations and is not pure water.

The chemical complexity of produced water varies from reservoir to reservoir and with the hydrocarbon accompanying its production. The production and processing of produced water alters the pressure and temperature which in turn affects the fracturing and natural chemicals present. These changes, coupled with the occurrence of hydrocarbons and solids, influence the produced-water behavior and properties.

Environmental concerns have increased the importance of produced water. Produced waters were historically viewed as a by-product waste stream that required disposal. The consequence of produced water disposal and the volumes involved was not always considered vital but with the increase in hydraulic fracturing (HF) and repetitive droughts has heightened the status of this available resource. The vast majority (>90%) of produced water from onshore operations has been reinjected.<sup>4</sup> Injection of produced waters serves several purposes: it generates additional hydrocarbons through secondary or tertiary recovery, it reuses a potential waste product, it permanently separates a pollutant from underground sources of drinking water, and in some areas, it controls land subsidence.

Secondary and tertiary enhanced recovery operations result in the production of more water with the hydrocarbon removal. To employ these waters for enhanced recovery, suspended solids and oil are removed to a suitable level to avoid blocking or clogging pathways. Offshore platforms generally discharge their produced waters directly into the ocean however progressively more rigorous environmental rules have to be met regarding the constituents present in the produced water. Offshore operators are now contemplating produced-water reinjection to prevent having to meet these discharge regulations.

### 2.2 Water Plays a Role in Oil and Gas Production

This subsection addresses the important role water plays in the production of oil and gas and was retained from the previous 2017 report.

**Figure 2-1** shows a water life cycle for unconventional oil and gas production. The box on the left called Makeup Water includes different types of source water, such as ground water, surface water, municipal water, or other. Companies need to plan well in advance to obtain a sufficient volume of source water to meet the needs and schedules of the drilling and hydraulic fracturing activities. The source water must be stored and transported to the well site.

Water is used to make up drilling fluids, frac fluids, and for general clean up during these processes. Following a frac job, produced water flows to the surface. It must be separated from the oil and gas, stored, and managed. Some forms of produced water management require treatment ranging from

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<sup>4</sup> *ibid*, 1,2,3

simple to complex, depending on whether the water is disposed or reused. In other cases, water may be taken directly to injection wells or evaporated. When treatment is required, the treatment process generates cleaner water and sludges, brines, or other residuals that must be managed.

Some produced water is intended for reuse within the oil and gas process (the Recycled Water box on the figure). It may be treated as needed then blended with other water sources to be used for a subsequent well.

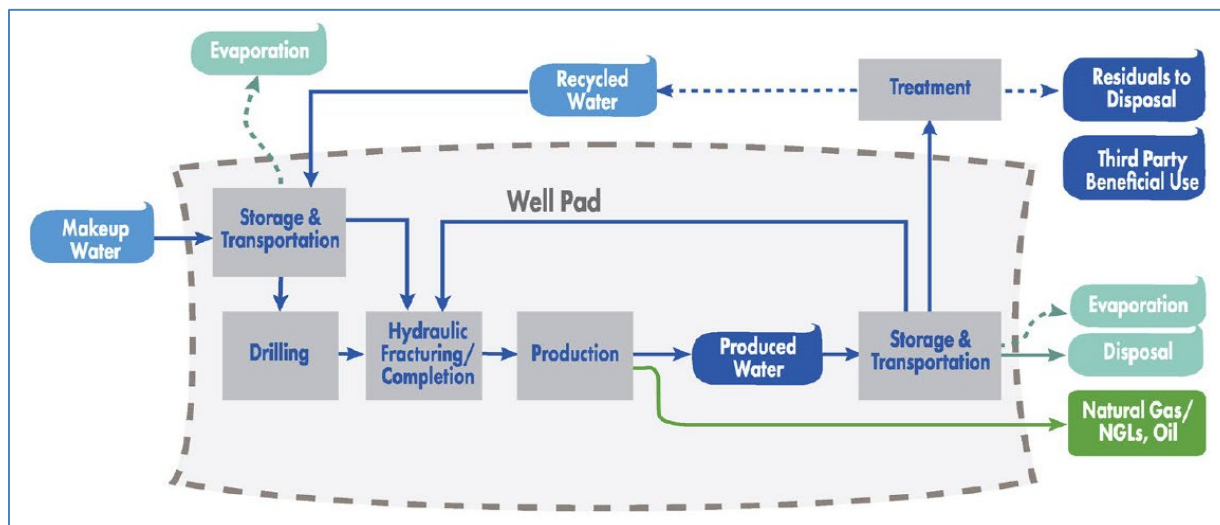


Figure 2-1 – Water Lifecycle for Unconventional Oil and Gas Production

Source: This figure is based on a graphic prepared by the Energy Water Initiative, a collaborative group of U.S. oil and gas companies. The figure was previously published in the Ground Water Protection Council (GWPC) 2019 Produced Water Report (GWPC 2019), a report focusing on produced water and the opportunities for reusing it.

This report focuses solely on produced water volumes and the types of water management practices that are used. It does not look at source water, the types of treatment used, storage practices, or transportation practices. These are very important for the industry but are outside the scope of this report.

## 2.3 Produced Water Management

The questionnaire used for this study was expanded beyond previous year's efforts to reflect additional management practices available as expressed by some of the state agencies that responded in 2017 with comments explaining the practices in their states. Produced water characteristics fluctuate over time and differ from geographical and geological location. These variations coupled with different regulatory requirements, economic constraints, climates, and infrastructure affect which management practices are used.

### 2.3.1 Injection

Three types of injection were provided in the questionnaire, enhanced recovery (ER), operator disposal (non-commercial) and commercial disposal (third-party).

- **Enhanced Recovery:** Injecting water into conventional hydrocarbon bearing formations in a regulated approach typically yields an additional 20-40% over primary recovery.<sup>5</sup> These

<sup>5</sup> Office of Fossil and Carbon Management, Enhanced Oil Recovery, accessed September 13, 2022, at <https://www.energy.gov/fecm/science-innovation/oil-gas-research/enhanced-oil-recovery>

secondary recovery techniques include water flooding, thermal injection (steam) for heavy crudes, and gas or chemical injection.<sup>6</sup>

- **Operator Disposal:** Injection of produced water into a Class II disposal wells by the operator who generated water. Injected into underground permeable rock formations with no oil or gas production, and sealed above and below by continuous, impervious strata. Most operators maintain their own saltwater disposal wells (SWD) as they are one of the most economical means of disposal and are recognized by oversight agencies as safe.
- **Commercial Disposal:** Injection of produced water into a Class II disposal wells by a third-party being paid to dispose of the water.

### 2.3.2 Surface Discharge

Discharges of produced water by the oil and gas industry are regulated by the EPA. Generally, discharges are permitted offshore provided certain water quality standards are met; however, onshore discharges are limited geographically. Onshore wells west of the 98<sup>th</sup> meridian (a north south boundary from approximately the state line between the Dakotas and Minnesota through eastern Nebraska, Kansas, Oklahoma, and Texas) are allowed to discharge to surface waters provided the produced water is treated and meets National Pollutant Discharge Elimination System (NPDES) quality standards and is beneficially reused for wildlife or agricultural purposes. Only a few western states issue NPDES permits for produced water discharge under specific circumstances and in unique locations. Onshore wells east of the 98<sup>th</sup> meridian are not permitted to discharge produced water with the exception of one location, the coalbed methane wells in the Black Warrior Basin of Alabama.<sup>7</sup> The questionnaire included surface discharge options for water bodies and land surfaces.

### 2.3.3 Evaporation

Use of evaporation systems in the oil and gas industry has grown rapidly in recent years. Evaporation ponds are large impoundments that require a relatively large space to efficiently evaporate water by sunlight. They are designed either to prevent subsurface infiltration of water or the downward migration of water depending on produced water quality. It is a positive technique that is often used to augment injection for disposal in the warm dry climates of several western states. Evaporation ponds have become a means to offset injection volumes in seismic sensitive areas. The questionnaire included evaporation in lined and unlined impoundments.

### 2.3.4 Sale / Transfer

This category was added this year because California previously reported that they collect data on sales and transfers of produced water for domestic use and between oil and gas operators.<sup>8</sup> Water transfers are voluntary actions proposed by willing buyers and sellers, they are not initiated by State agencies. Water transfers that require the use of State, regional, or a local public agency's conveyance facilities require the owner of the conveyance facilities to determine that the transfers will not harm any other

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<sup>6</sup> Vladimir Vishnyakov, Baghir Suleimanov, Ahmad Salmanovm, Eldar Zeynalov, 2020. Primer on Enhanced Oil Recovery, Gulf Professional Publishing.

<sup>7</sup> Mueller, D., 2015. Treatment and Permitting of Produced Water for Discharge to Surface Water, Society of Petroleum Engineers, 2015 SPE Hydraulic Fracturing Technology Conference, DOI 10.2118/173366-MS.

<sup>8</sup> California Department of Water Resources and Bureau of Reclamation, Mid-Pacific Region, DRAFT Technical Information for Preparing Water Transfer Proposals (Water Transfer White Paper) Information for Parties Preparing Proposals for Water Transfers Requiring Department of Water Resources or Bureau of Reclamation Approval, December 2019 accessed at <https://water.ca.gov/Programs/State-Water-Project/Management/Water-Transfers> August 2022.

legal user of water, will not unreasonably affect fish and wildlife, and will not unreasonably affect the overall economy of the county from which the water is transferred.

### 2.3.5 Beneficial Reuse

Water treatment technology innovations coupled with restrictions on produced water disposal in certain areas have encouraged the beneficial reuse of treated produced water. The complex nature of produced water and the rural aspect of oil and gas operations limit the application of many of these potential opportunities. Additionally, the beneficial reuse of produced water necessitates standard laboratory testing methods for identifying the constituents of concern and their potential impacts with regards to their environmental fate. The sole breakthrough in recent time has been the development of frac-fluids capable of using water with higher total dissolved solids (TDS) that let produced water be reused for fracking jobs.<sup>9</sup> The beneficial reuse of produced water, either treated or untreated, is trending “upward” as more operators are collecting their produced water and reusing it as source water to augment fresh water for frac jobs or for drilling. Other purposes outside industry include limited agricultural irrigation in California during drought seasons, and dust and ice control on roads, but more fit-for-purpose research is needed to expand the use of treated produced water.

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<sup>9</sup> CS EST Engg. 2022, 2, 3, 347–366, Publication Date: December 13, 2021, <https://doi.org/10.1021/acsestengg.1c00248> Copyright © 2021 American Chemical Society

### 3 Approach and Methods

As with the previous iterations of this report, state oil and gas agencies and some state environmental agencies that oversee oil and gas development were contacted to elicit information on hydrocarbon and produced water volumes as well as the primary ways in which produced water is managed. A total of 36 states were contacted; a list of the various agencies by state and the means in which they responded is included in **Appendix A**. Additional information was gathered from a few state and federal databases where we were directed to download datasets or were aware of the data's availability and how to obtain it.

#### 3.1 Initial Data Collection

The 2021 research effort followed the same approach with email requests for participation being sent to the state agency directors or other senior managers. The emails included an introductory letter from the GWPC Executive Director explaining the process and means of replying; a questionnaire with further explanation of the desired data and two tables with instructions for completing, as well as a spreadsheet version of the two tables with summary and conversion formulas embedded. A copy of the introduction letter, questionnaire, and spreadsheets are available in **Appendix A**.

The information obtained via replies to the questionnaire generally accounted for what was asked and met the desired data needs, however some responses included caveats that were confusing, inconsistent, or unclear, or just had cells blank with no explanation. In those cases, we contacted the person who submitted the questionnaire via email or phone call and obtained clarification.

In the cases where states did not have or were unable to provide the data, we consulted the Energy Information Administration (EIA) website to fill in hydrocarbon production blanks, as for produced water volumes in these cases they were left blank as no other agency solicits or collects such data. Michigan was the only state that was unable to respond completely due to lack of staff during the pandemic to collate and enter the data, but their hydrocarbon production numbers were populated from EIA sources.

The majority of states (26) provided responses to the questionnaire coupled with populated spreadsheet tables. Four states, (Georgia, North Carolina, South Carolina, and Washington) reported no production in their states, so did not return questionnaires. The six states that did not submit replies or complete replies to the questionnaire but rather provided alternative instructions for obtaining their data are as follows:

- **Arizona:** We received instructions from the Program Administrator for the Arizona Oil and Gas Conservation Commission that a request to the Arizona Department of Environmental Quality - Record Management Center for Forms 14 (Report of Injection Project) and Form 16 (Monthly Producer's Report) was necessary to gather their data. We received Adobe pdf copies of the requested forms and tallied the reported monthly volumes for 2021 to populate the tables.
- **Arkansas:** The Oil and Gas Commission Director explained that Arkansas has old wells not covered by current production reporting regulations and it is difficult to sort this data out. Therefore, their staff used the old table format from the 2017 questionnaire to report their hydrocarbon production and produced water disposition.
- **Florida:** The Deputy Director of the Division of Water Resource Management provided access to their Electronic Document Management System (OCULUS) so that monthly data for each operating field was available for download.
- **Louisiana:** The Department of Natural Resources, Office of Conservation's Commissioner provided access to their online databases, SONRIS, via a data portal. Oil and gas volumes and produced water injection volumes were extracted from the portal.

- **Oklahoma:** The Oklahoma Corporation Commission replied to the questionnaire with hydrocarbon production data from January through June 2022 and with produced water production and disposition data for calendar year 2021. To avoid comparison issues, we reached out to the Oklahoma Tax Commission and obtained the crude oil and natural gas production totals for calendar year 2021, and it is these values that have been incorporated into Oklahoma's production dataset.
- **Utah:** The Service Manager for the Department of Nature Resources – Division of Oil, Gas and Mining replied to the questionnaire with both hydrocarbon and produced water numbers but omitted the well counts. We accessed the Utah DOGM Data Explore via their website interface and determined the number of crude oil and natural gas producing wells and then confirmed them with the Service Manager.

### 3.2 Data Collection for Wells on Federal Lands

With regards to the federal offshore and tribal onshore data, direct inquiries to agencies were not made as the responsible agency websites contained the desired information. Data obtained came from the U.S. Department of the Interior agencies Office of Natural Resources Revenue (ONRR), Bureau of Safety and Environmental Enforcement (BSEE), and the Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE) websites. These websites contained oil, and gas production volumes for federal offshore assets in the Gulf of Mexico, Pacific, and Alaska, as well as onshore production on tribal lands. Although, oil and gas volume estimates were obtained for onshore tribal lands, it is routine for these volumes to be reported to the state and are therefore already accounted for in the individual state totals. Also, a few states have some offshore production in state waters, but again these values have been accounted for in the state totals. We understand that this is not an exact accounting, but it does represent all United States production and is a rational means of presenting the data.

With regards to the water production, only injection volumes were available for the Gulf of Mexico and Pacific assets. Similarly in the 2017 report, the volumes discharged from the offshore platforms were a piece of information missing from the inquiry. As only produced water injection volumes were ascertained via the BSEE website, it can be assumed that the difference between total offshore produced water volume and the offshore amount injected represents the quantities discharged from the platforms. This inference aligns with the findings in the 2017 report and are consistent with the information obtained from the EPA regarding platform discharges.

### 3.3 U.S. Energy Information Administration Comparison

The 2021 oil and gas production estimates as reported by the state agencies and the federal resources as identified electronically were compared with available production data from the EIA to identify any major inconsistencies. A few anomalies were identified with the crude oil data; however, several discrepancies were identified with the Natural Gas data that could not be explained. The irregularities are identified in **Tables 3-1** and **3-2** which show the comparison and calculated percentage difference for each state's reported crude oil and condensate combined or natural gas volume, respectively versus the EIA's gathered data.<sup>10</sup>

In an effort to understand the differences, we reached out to the states with percent differences greater than 10% and although we didn't hear back from all of them it seems the general explanation may be the EIA totals are based on *Gross Withdrawals* versus some states totals which may or may not have

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<sup>10</sup> U.S. Energy Information Administration, Petroleum & Other Liquids – Crude Reserves and Production, and Natural Gas – Gross Withdrawals and Production, Series History Downloaded, [https://www.eia.gov/dnav/pet/pet\\_crd\\_crpdn\\_adc\\_mbbbl\\_m.htm](https://www.eia.gov/dnav/pet/pet_crd_crpdn_adc_mbbbl_m.htm), [https://www.eia.gov/dnav/ng/ng\\_prod\\_sum\\_a\\_EPG0\\_FGW\\_mmmcf\\_m.htm](https://www.eia.gov/dnav/ng/ng_prod_sum_a_EPG0_FGW_mmmcf_m.htm) September 22, 2022.

include gas that is marketed, returns from high pressure air injection enhanced recovery projects, gas that is flared at the well site, and gas that is used on lease. In the case of South Dakota, they replied that the difference was Market Gas versus Total Gas. With Utah it appears the EIA is not accounting for Coalbed Methane (CBM) as the difference is also identical to their CBM production quantity. For California it appears the offshore natural gas production was included in EIA's total and not in the states reply to the questionnaire.

**Table 3-1: Crude Oil and Condensate Production Comparison**

| Reported for 2021       | Crude Oil<br>(bbl/year) | Condensate<br>(bbl/yr) | Combined<br>(bbl/yr) | EIA<br>(bbl/yr)      | Difference<br>(bbl/yr) | Percent<br>Difference |
|-------------------------|-------------------------|------------------------|----------------------|----------------------|------------------------|-----------------------|
| Alabama                 | 3,544,505               | 719,838                | 4,264,343            | 4,289,000            | (24,657)               | -0.575%               |
| Alaska                  | 159,622,902             | -                      | 159,622,902          | 159,161,000          | 461,902                | 0.290%                |
| Arizona                 | 6,379                   | -                      | 6,379                | 6,000                | 379                    | 6.317%                |
| Arkansas                | 4,211,260               | -                      | 4,211,260            | 4,211,000            | 260                    | 0.006%                |
| California              | 137,117,236             | -                      | 137,117,236          | 134,612,000          | 2,505,236              | 1.861%                |
| Colorado                | 153,495,589             | -                      | 153,495,589          | 153,423,000          | 72,589                 | 0.047%                |
| Florida                 | 1,490,492               | -                      | 1,490,492            | 1,490,000            | 492                    | 0.033%                |
| Idaho                   | -                       | 25,500                 | 25,500               | 25,000               | 500                    | 2.000%                |
| Illinois                | 7,390,000               | -                      | 7,390,000            | 7,057,000            | 333,000                | 4.719%                |
| Indiana                 | 1,521,075               | -                      | 1,521,075            | 1,523,000            | (1,925)                | -0.126%               |
| Kansas                  | 27,908,720              | -                      | 27,908,720           | 27,905,000           | 3,720                  | 0.013%                |
| Kentucky                | 1,429,277               | -                      | 1,429,277            | 2,464,000            | (1,034,723)            | <b>-41.994%</b>       |
| Louisiana               | 34,724,485              | -                      | 34,724,485           | 34,719,000           | 5,485                  | 0.016%                |
| Maryland                | -                       | -                      | -                    | -                    | -                      |                       |
| Michigan <sup>1</sup>   | 4,338,000               | -                      | 4,338,000            | 4,339,000            | (1,000)                | -0.023%               |
| Mississippi             | 12,931,012              | -                      | 12,931,012           | 13,434,000           | (502,988)              | -3.744%               |
| Missouri                | 59,579                  | -                      | 59,579               | 60,000               | (421)                  | -0.701%               |
| Montana                 | 18,920,372              | -                      | 18,920,372           | 18,994,000           | (73,628)               | -0.388%               |
| Nebraska                | 1,705,559               | -                      | 1,705,559            | 1,706,000            | (441)                  | -0.026%               |
| Nevada                  | 223,233                 | -                      | 223,233              | 218,000              | 5,233                  | 2.400%                |
| New Mexico              | 451,085,590             | -                      | 451,085,590          | 457,200,000          | (6,114,410)            | -1.337%               |
| New York                | 265,592                 | -                      | 265,592              | 147,000              | 118,592                | <b>80.675%</b>        |
| North Dakota            | 405,127,827             | -                      | 405,127,827          | 405,128,000          | (173)                  | 0.000%                |
| Ohio                    | 18,777,412              | -                      | 18,777,412           | 18,688,000           | 89,412                 | 0.478%                |
| Oklahoma                | 148,337,394             | -                      | 148,337,394          | 143,052,000          | 5,285,394              | 3.695%                |
| Pennsylvania            | 863,098                 | 5,396,909              | 6,260,007            | 6,253,000            | 7,007                  | 0.112%                |
| South Dakota            | 1,028,395               | -                      | 1,028,395            | 1,028,000            | 395                    | 0.038%                |
| Tennessee <sup>2</sup>  | 151,633                 | -                      | 151,633              | 152,000              | (367)                  | -0.242%               |
| Texas                   | 1,459,827,134           | 264,574,972            | 1,724,402,106        | 1,739,660,000        | (15,257,894)           | -0.877%               |
| Utah                    | 35,513,708              | -                      | 35,513,708           | 35,488,000           | 25,708                 | 0.072%                |
| Virginia                | 4,097                   | -                      | 4,097                | 5,000                | (903)                  | <b>-18.060%</b>       |
| West Virginia           | 17,961,149              | -                      | 17,961,149           | 18,241,000           | (279,851)              | -1.534%               |
| Wyoming                 | 78,900,632              | 6,389,501              | 85,290,133           | 85,429,000           | (138,867)              | -0.163%               |
| <b>State Total</b>      | <b>3,188,483,335</b>    | <b>277,106,720</b>     | <b>3,465,590,055</b> | <b>3,480,107,000</b> | <b>(14,516,945)</b>    | <b>-0.417%</b>        |
| <b>Federal Offshore</b> |                         |                        | -                    |                      | -                      |                       |
| Gulf of Mexico          | 600,488,445             | 22,362,040             | 622,850,485          | 623,018,000          | (167,515)              | -0.027%               |
| Pacific                 | 3,991,793               | -                      | 3,991,793            | 3,992,000            | (207)                  | -0.005%               |
| Alaska                  | 449,679                 | -                      | 449,679              | -                    | 449,679                |                       |
| Tribal Lands            | 79,052,393              | -                      | 79,052,393           | -                    | 79,052,393             |                       |
| <b>Federal Total</b>    | <b>683,982,310</b>      | <b>22,362,040</b>      | <b>706,344,350</b>   |                      | <b>706,344,350</b>     |                       |
| <b>U.S. Total</b>       | <b>3,872,465,645</b>    | <b>299,468,760</b>     | <b>4,092,882,012</b> | <b>4,107,585,000</b> | <b>(14,702,988)</b>    | <b>-0.358%</b>        |

**Notes:**

1 - Value obtained from EIA monthly production summary

2 - Data is from 2020



Table 3-2: Natural Gas Production Comparison

| Reported for 2021       | Natural Gas (Mmcf) | EIA Tally (Mmcf)  | Difference (Mmcf) | Percent Difference |
|-------------------------|--------------------|-------------------|-------------------|--------------------|
| Alabama                 | 107,818            | 107,234           | 584               | 0.54%              |
| Alaska                  | 3,505,248          | 3,486,055         | 19,193            | 0.55%              |
| Arizona                 | 78                 | 229               | (151)             | <b>-66.08%</b>     |
| Arkansas                | 447,881            | 448,188           | (307)             | -0.07%             |
| California              | 121,534            | 142,109           | (20,575)          | <b>-14.48%</b>     |
| Colorado                | 1,956,843          | 1,881,108         | 75,735            | 4.03%              |
| Florida                 | 14,957             | 8,995             | 5,962             | <b>66.28%</b>      |
| Idaho                   | 1,359              | 1,329             | 30                | 2.28%              |
| Illinois <sup>1</sup>   | 1,843              | 1,843             | -                 | 0.00%              |
| Indiana                 | 4,136              | 4,064             | 72                | 1.76%              |
| Kansas                  | 167,849            | 152,985           | 14,864            | 9.72%              |
| Kentucky                | 63,578             | 75,372            | (11,794)          | <b>-15.65%</b>     |
| Louisiana               | 3,379,390          | 3,436,216         | (56,826)          | -1.65%             |
| Maryland                | 5                  | 3                 | 2                 | <b>63.53%</b>      |
| Michigan - EIA          | 72,301             | 72,301            | -                 | 0.00%              |
| Mississippi             | 27,028             | 27,568            | (540)             | -1.96%             |
| Missouri                | 493                | -                 | 493               | N/A                |
| Montana                 | 41,823             | 41,828            | (5)               | -0.01%             |
| Nebraska                | 321                | 326               | (5)               | -1.55%             |
| Nevada                  | 4                  | -                 | 4                 | N/A                |
| New Mexico              | 2,421,424          | 2,277,035         | 144,389           | 6.34%              |
| New York                | 9,735              | 9,705             | 30                | 0.31%              |
| North Dakota            | 1,075,358          | 1,075,358         | -                 | 0.00%              |
| Ohio                    | 2,256,484          | 2,281,195         | (24,711)          | -1.08%             |
| Oklahoma                | 2,544,913          | 2,571,883         | (26,970)          | -1.05%             |
| Pennsylvania            | 7,656,814          | 7,626,505         | 30,309            | 0.40%              |
| South Dakota            | 3,353              | 163               | 3,190             | <b>1956.80%</b>    |
| Tennessee               | 3,602              | 3,602             | 0                 | 0.00%              |
| Texas                   | 10,741,016         | 10,669,341        | 71,675            | 0.67%              |
| Utah                    | 265,882            | 239,944           | 25,938            | <b>10.81%</b>      |
| Virginia                | 96,044             | 96,043            | 1                 | 0.00%              |
| West Virginia           | 2,675,208          | 2,760,429         | (85,221)          | -3.09%             |
| Wyoming                 | 1,081,393          | 1,374,731         | (293,338)         | <b>-21.34%</b>     |
| <b>State Total</b>      | <b>40,745,716</b>  | <b>40,873,687</b> | <b>(127,971)</b>  | <b>-0.31%</b>      |
| <b>Federal Offshore</b> |                    |                   | -                 |                    |
| Gulf of Mexico          | 791,913            | 791,982           | (69)              | -0.01%             |
| Pacific                 | 2,455              | No Data           |                   |                    |
| Alaska                  | 2,784              | No Data           |                   |                    |
| Tribal Lands            | 339,352            | No Data           |                   |                    |
| <b>Federal Total</b>    | <b>1,136,503</b>   | <b>791,982</b>    | <b>344,521</b>    | <b>43.50%</b>      |
| <b>U.S. Total</b>       | <b>41,542,868</b>  | <b>41,665,669</b> | <b>(122,801)</b>  | <b>-0.29%</b>      |

## Notes:

1 - Valued provided from Illinois based on 2020 EIA data



## 4 Analysis and Results

### 4.1 Data Availability and Completeness

As noted in prior iterations of this study, produced water volumes are not reported or documented in a consistent or regular manner from state to state. The rules and regulations vary from state to state and can cover monitoring and reporting produced water volumes from each well or make no mention of it at all, hence we are left with a mixed bag of information. However, most state's responses to the questionnaire provided insights to their data reliability and completeness. With regards to hydrocarbon production, only 14 states differentiated between conventional or unconventional, the remaining 19 reported their total production without categorizing the source, some of which stated they do not track it, while others explained they do not have any unconventional development.

As with the previous versions, the most difficult challenge was combining the produced water data in a coherent manner to create usable estimates representative of national production. Unlike past efforts, most states had data on water production and injection for EOR or disposal. It was the other management or reuse categories that were left blank or only a handful of states had data to complete those classifications. In only a few cases did we need to make assumptions or extrapolate volumes based on partial data provided. One of the other more common limitation was that the injection volume represented the total as many states do not track commercial disposal versus operator disposal.

With regards to the state and federal agency databases on produced water volumes and management methods, the factors affecting the amount of information available and how readily it can be extracted have not changed from the previous studies. The main factors include:

- **Data Collection Requirements:** Does the agency mandate the information be collected? This varies widely between states and at the federal level there is not a consistent gathering of produced water disposition data.
- **Data Elements:** What information are required to be reported? Companies generally only submit data that are requested, therefore requiring reporting does not always ensure consistent information.
- **Category Relevance:** Agency reporting forms may require data for specified water management categories that do not match the study's focus. Consequently, we were attempting to gather more information on reuse and recycling efforts by operators, but this information was not uniformly required by the agencies.
- **Accessibility:** The majority of oil and gas producing states have large, sophisticated databases that contain data elements regarding oil, gas, and water volumes for each well. In fact, the GWPC was instrumental in establishing the Risk-Based Data Management System (RBDMS) for oil and gas data that is used by most states. However, one requires a trained IT specialist to query the databases and provide subsets of information, and not all agencies had the staff during this period, in light of the pandemic, to support this effort. A few states make their production data publicly available on websites, while others publish annual reports. As previously mentioned, we accessed the datasets available online as appropriate.

This study intended to deliver reliable data illustrating distinctions concerning produced water generation and disposition from conventional and unconventional production. As cited, 14 states were able to differentiate the source and share this type of information, but several of the larger oil and gas producing states were unable to separate the generated water volume by production type. Without the complete dataset from these larger producing states, a representative nationwide analysis could not be completed.

## 4.2 Data Accuracy and Quality

The data received from the various state and federal agencies regarding produced water quantities depends on the information they collect from diverse sources, including operators and sister agencies. It should be recognized that when gathering this data from hundreds of operators who administer close to one million wells, there is a chance that the data was not entered accurately or that some information could have been supplied erroneously.

The probable mistakes evolve from the method used to measure the raw water volumes, frequency of estimates, and quality control measures, if any, used as the data comes from the field to the forms or screen, and ultimately to the database.

Water volumes are typically not measured carefully, but rather by comparing tank heights, pump rate and duration, or by truckload counts, none of which are accurate, but are a fair estimate. As stated previously, except when an agency requires quantified water volumes the data is most likely just good rough calculation.

The estimated water volumes are normally composed on field log sheets that are summed and then entered via agency websites or hard copy forms. Both methods provide openings for errors that can be carried over or compounded when transferred to the agencies' databases. It is also common to find various units employed (gallons, bbl, acre feet, etc.) which present possible conversion errors.

The production data provided by the agencies showed volumes in bbls/year or Mmcfs/year which the accuracy is accepted at face value but cannot be validated for this report. The production volumes estimated in **Chapter 5** are shown in **Tables 4-1, 4-2, 4-3** for crude oil, natural gas, and produced water respectively, as compared with prior study data (2007, 2012, 2017); however, the totals are rounded to the nearest hundred thousand bbl, or thousand Mmcfs as appropriate. **Table 4-4** portrays the produced water volumes for each management practice as reported by the agencies for 2021 and again, the totals have been rounded in the bottom row. *The rounded totals are the integers that should be cited.*

Many of the states included exceptions or caveats associated with the numbers they reported for individual cells on the questionnaire. That information has been carried over through **Chapter 5** in the state-by-state summaries for clarification.

In a hand full of cases, the volume of water managed greatly differed from the volume of water generated. It is understood that the differences can be accounted for from additional sources of makeup or fresh water used for enhanced recovery operations or the lack of required reporting for a particular management practice. No assumptions to add or subtract from the reported volumes in these instances were made.

All of the issues described in Sections 4.1 and 4.2 impacted the scale and accuracy of the final data presented in this report. Unavoidably the amounts displayed in the tables are estimates with a degree of error. Error bars or standard deviations were not calculated for the data as the characteristic ambiguity of the data sources would not permit such detailed comparisons.

## 4.3 Results of Produced Water Volume Analysis

In 2021, the combined U.S. onshore and offshore oil and gas responsible agencies reported 4,092,882,000 bbl of crude oil including condensate, 41,543,000 Mmcfs of natural gas and 25,860,854,000 bbl of produced water. **Tables 4-1, 4-2, and 4-3** provide crude oil, natural gas, and produced water production quantities for each state or federal administered area lands for 2021, respectively. The comparable data for 2017, 2012, and 2007 are also shown in the tables. **Figure 4-1** is a map of the U.S. with 2021 produced water volumes. As noted in Section 3.2, production from federal onshore wells and offshore wells in state waters, as well as tribal wells onshore were included in the state totals.

Table 4-1: Crude Oil &amp; Condensate Production Overview (2021, 2017, 2012, 2007)

| State / Federal                 | 2021 (bbl/year)      | 2017 (bbl/year)      | 2012 (bbl/year)      | 2007 (bbl/yr)        |
|---------------------------------|----------------------|----------------------|----------------------|----------------------|
| Alabama                         | 4,264,343            | 6,827,900            | 11,310,000           | 5,028,000            |
| Alaska                          | 159,622,902          | 180,546,058          | 192,368,000          | 263,595,000          |
| Arizona                         | 6,379                | 12,829               | 51,900               | 43,000               |
| Arkansas                        | 4,211,260            | 5,288,375            | 6,568,000            | 6,103,000            |
| California                      | 137,117,236          | 172,293,268          | 197,749,000          | 244,000,000          |
| Colorado                        | 153,495,589          | 132,846,403          | 49,361,000           | 2,375,000            |
| Florida                         | 1,490,492            | 1,923,238            | 2,171,000            | 2,078,000            |
| Idaho                           | 25,500               | -                    | -                    | -                    |
| Illinois                        | 7,390,000            | 8,314,000            | 8,908,000            | 3,202,000            |
| Indiana                         | 1,521,075            | 1,780,016            | 2,350,000            | 1,727,000            |
| Kansas                          | 27,908,720           | 35,822,288           | 43,743,000           | 36,612,000           |
| Kentucky                        | 1,429,277            | 2,477,000            | 3,198,000            | 3,572,000            |
| Louisiana                       | 34,724,485           | 52,282,199           | 82,781,000           | 52,495,000           |
| Maryland                        | -                    | No Data              | No Data              | No Data              |
| Michigan <sup>1</sup>           | 4,338,000            | 5,800,000            | 7,400,000            | 5,180,000            |
| Mississippi                     | 12,931,012           | 17,037,830           | 24,146,000           | 20,027,000           |
| Missouri                        | 59,579               | 116,808              | 175,000              | 80,000               |
| Montana                         | 18,920,372           | 20,707,078           | 26,495,000           | 34,749,000           |
| Nebraska                        | 1,705,559            | 2,092,816            | 2,514,000            | 2,335,000            |
| Nevada                          | 223,233              | 284,954              | 368,000              | 408,000              |
| New Mexico                      | 451,085,590          | 172,587,378          | 85,340,000           | 59,138,000           |
| New York                        | 265,592              | 214,821              | 360,000              | 378,000              |
| North Dakota                    | 405,127,827          | 390,730,886          | 243,272,000          | 44,543,000           |
| Ohio                            | 18,777,412           | 19,802,406           | 5,063,000            | 5,422,000            |
| Oklahoma                        | 148,337,394          | 159,207,164          | 92,988,000           | 60,760,000           |
| Pennsylvania                    | 6,260,007            | 6,454,010            | 4,300,000            | 1,537,000            |
| South Dakota                    | 1,028,395            | 1,304,321            | 1,754,000            | 1,665,000            |
| Tennessee <sup>2</sup>          | 151,633              | 275,316              | 372,000              | 350,000              |
| Texas                           | 1,724,402,106        | 1,271,143,548        | 608,213,000          | 342,087,000          |
| Utah                            | 35,513,708           | 34,438,271           | 30,195,000           | 19,520,000           |
| Virginia                        | 4,097                | 795                  | 9,700                | 19,000               |
| West Virginia                   | 17,961,149           | 7,570,204            | 2,561,000            | 679,000              |
| Wyoming                         | 85,290,133           | 75,717,834           | 45,382,000           | 54,052,000           |
| <b>State Total</b>              | <b>3,465,590,055</b> | <b>2,785,900,014</b> | <b>1,781,466,600</b> | <b>1,273,759,000</b> |
| <b>Federal Offshore</b>         | 627,291,957          | 619,697,287          | 482,774,000          | 467,180,000          |
| <b>Tribal Lands<sup>3</sup></b> | 79,052,393           | no data              | no data              | 9,513,000            |
| <b>Federal Total</b>            | <b>706,344,350</b>   | <b>619,697,287</b>   | <b>482,774,000</b>   | <b>476,693,000</b>   |
| <b>U.S. Total Rounded</b>       | <b>4,092,882,000</b> | <b>3,405,597,000</b> | <b>2,264,241,000</b> | <b>1,750,452,000</b> |

Notes:

1 - Obtained from EIA 2021

2 - 2020 Data

3 - Included in State Totals

Table 4-2: Natural Gas Production Overview (2021, 2017, 2012, 2007)

| State / Federal                 | 2021 (Mmcf)       | 2017 (Mmcf)       | 2012 (Mmcf)       | 2007 (Mmcf)       |
|---------------------------------|-------------------|-------------------|-------------------|-------------------|
| Alabama                         | 107,818           | 150,857           | 216,000           | 285,000           |
| Alaska                          | 3,505,248         | 3,268,520         | 3,182,000         | 3,498,000         |
| Arizona                         | 78                | 342               | 116               | 1,000             |
| Arkansas                        | 447,881           | 692,469           | 1,137,000         | 272,000           |
| California                      | 121,534           | 189,444           | 174,000           | 312,000           |
| Colorado                        | 1,956,843         | 2,174,415         | 1,709,000         | 1,288,000         |
| Florida                         | 14,957            | 23,132            | 19,000            | 2,000             |
| Idaho                           | 1,359             | 3,789.00          | -                 | 0                 |
| Illinois <sup>2</sup>           | 1,843             | 2,131             | 2,100             | No data           |
| Indiana                         | 4,136             | 5,914             | 8,800             | 4,000             |
| Kansas                          | 167,849           | 241,845           | 299,000           | 371,000           |
| Kentucky                        | 63,578            | 88,715            | 106,000           | 95,000            |
| Louisiana                       | 3,379,390         | 3,306,864         | 3,347,000         | 1,382,000         |
| Maryland                        | 5                 | No Data           | No Data           | No Data           |
| Michigan <sup>1</sup>           | 72,301            | 97,500            | 130,000           | 168,000           |
| Mississippi                     | 27,028            | 52,275            | 437,000           | 97,000            |
| Missouri                        | 493               | 0                 | 12,000            | No data           |
| Montana                         | 41,823            | 27,529            | 67,000            | 95,000            |
| Nebraska                        | 321               | 456               | 1,200             | 1,000             |
| Nevada                          | 4                 | 3                 | 4                 | 0                 |
| New Mexico                      | 2,421,424         | 1,296,990         | 1,252,000         | 1,526,000         |
| New York                        | 9,735             | 11,800            | 27,000            | 55,000            |
| North Dakota                    | 1,075,358         | 688,605           | 259,000           | 71,000            |
| Ohio                            | 2,256,484         | 1,770,454         | 86,000            | 86,000            |
| Oklahoma                        | 2,544,913         | 2,350,071         | 2,023,000         | 1,643,000         |
| Pennsylvania                    | 7,656,814         | 5,464,661         | 2,260,000         | 172,000           |
| South Dakota                    | 3,353             | 260               | 15,000            | 12,000            |
| Tennessee <sup>2</sup>          | 3,602             | 3,038             | 6,000             | 1,000             |
| Texas                           | 10,741,016        | 8,124,096         | 8,137,000         | 6,878,000         |
| Utah                            | 265,882           | 315,143           | 491,000           | 385,000           |
| Virginia                        | 96,044            | 115,492           | 146,000           | 112,000           |
| West Virginia                   | 2,675,208         | 1,611,100         | 539,000           | 225,000           |
| Wyoming                         | 1,081,393         | 1,808,429         | 2,079,000         | 2,253,000         |
| <b>State Total</b>              | <b>40,745,716</b> | <b>33,886,339</b> | <b>28,167,220</b> | <b>21,290,000</b> |
| <b>Federal Offshore</b>         | 797,152           | 1,114,880         | 1,563,000         | 2,787,000         |
| <b>Tribal Lands<sup>3</sup></b> | 339,352           | no data           | no data           | 297,000           |
| <b>Federal Total</b>            | <b>1,136,503</b>  | <b>1,114,880</b>  | <b>1,563,000</b>  | <b>3,084,000</b>  |
| <b>U.S. Total Rounded</b>       | <b>41,542,532</b> | <b>35,001,000</b> | <b>29,730,000</b> | <b>24,374,000</b> |

Notes:

1 - Obtained from EIA 2021

2 - 2020 Data

3 - Included in State Totals

Table 4-3: Produced Water Production Overview (2021, 2017, 2012, 2007)

| State / Federal           | 2021 (bbl/yr)         | 2017 (bbl/yr)         | 2012 (bbl/yr)         | 2007 (bbl/yr)         |
|---------------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Alabama                   | 48,956,492            | 63,870,227            | 106,619,000           | 119,004,000           |
| Alaska                    | 1,039,555,842         | 828,067,983           | 769,153,000           | 801,336,000           |
| Arizona                   | 10,715                | 38,786                | 81,000                | 68,000                |
| Arkansas                  | 357,375,154           | 315,958,569           | 184,867,000           | 166,011,000           |
| California                | 3,083,959,386         | 3,134,503,023         | 3,074,585,000         | 2,552,194,000         |
| Colorado                  | 280,460,737           | 310,650,278           | 358,389,000           | 383,846,000           |
| Florida                   | 41,393,747            | 58,673,032            | 62,641,000            | 50,296,000            |
| Idaho                     | 7,314                 | 91,566.00             | -                     | -                     |
| Illinois <sup>1</sup>     | 4,591,349,632         | 282,599,989           | 99,142,000            | 136,872,000           |
| Indiana                   | 53,494,095            | 50,797,713            | 57,566,000            | 40,200,000            |
| Kansas                    | 1,016,408,380         | 1,205,091,949         | 1,061,019,000         | 1,244,329,000         |
| Kentucky                  | 5,642,263             | 13,913,894            | 19,689,000            | 24,607,000            |
| Louisiana                 | 796,655,259           | 998,519,062           | 927,635,000           | 1,149,643,000         |
| Maryland                  | No Data               | No Data               | No Data               | No Data               |
| Michigan                  | No Data               | 80,500,000            | 117,000,000           | 114,580,000           |
| Mississippi               | 15,712,999            | 171,145,175           | 231,236,000           | 330,730,000           |
| Missouri                  | 1,156,481             | 2,763,613             | 2,103,000             | 1,613,000             |
| Montana                   | 147,897,041           | 141,733,134           | 182,833,000           | 182,266,000           |
| Nebraska                  | 42,968,415            | 50,069,495            | 58,641,000            | 49,312,000            |
| Nevada                    | 4,779,403             | 6,510,029             | 5,865,000             | 6,785,000             |
| New Mexico                | 1,600,878,600         | 879,740,841           | 775,930,000           | 665,685,000           |
| New York                  | 186,637               | 189,746               | 510,000               | 649,000               |
| North Dakota              | 643,154,596           | 505,828,554           | 291,147,000           | 134,991,000           |
| Ohio                      | 32,332,672            | 24,142,988            | 5,542,000             | 6,940,000             |
| Oklahoma                  | 1,744,894,591         | 2,844,485,617         | 2,325,153,000         | 2,195,180,000         |
| Pennsylvania              | 36,779,077            | 55,321,026            | 34,089,000            | 3,912,000             |
| South Dakota              | 6,855,975             | 6,924,285             | 5,296,000             | 4,186,000             |
| Tennessee                 | No data               | 44,163                | 1,480,000             | 2,263,000             |
| Texas                     | 8,107,645,550         | 9,895,084,619         | 7,435,659,000         | 7,376,913,000         |
| Utah                      | 149,548,608           | 155,047,940           | 166,945,000           | 148,579,000           |
| Virginia                  | 1,660,599             | 2,156,931             | 3,232,000             | 1,562,000             |
| West Virginia             | 46,654,984            | 26,650,935            | 13,772,000            | 8,337,000             |
| Wyoming                   | 1,559,881,944         | 1,705,309,511         | 2,178,065,000         | 2,355,671,000         |
| <b>State Total</b>        | <b>25,458,257,188</b> | <b>23,816,424,673</b> | <b>20,555,884,000</b> | <b>20,258,560,000</b> |
| <b>Federal Offshore</b>   | 402,597,272           | 575,926,287           | 624,762,000           | 587,353,000           |
| <b>Tribal Lands</b>       | No Data               | No Data               | No Data               | 149,261,000           |
| <b>Federal Total</b>      | <b>402,597,272</b>    | <b>575,926,287</b>    | <b>624,762,000</b>    | <b>736,614,000</b>    |
| <b>U.S. Total Rounded</b> | <b>25,860,854,000</b> | <b>24,392,351,000</b> | <b>21,180,646,000</b> | <b>20,995,174,000</b> |
| Notes:                    |                       |                       |                       |                       |
| 1 - Extrapolated          |                       |                       |                       |                       |

## Produced Water Volumes by State 2021

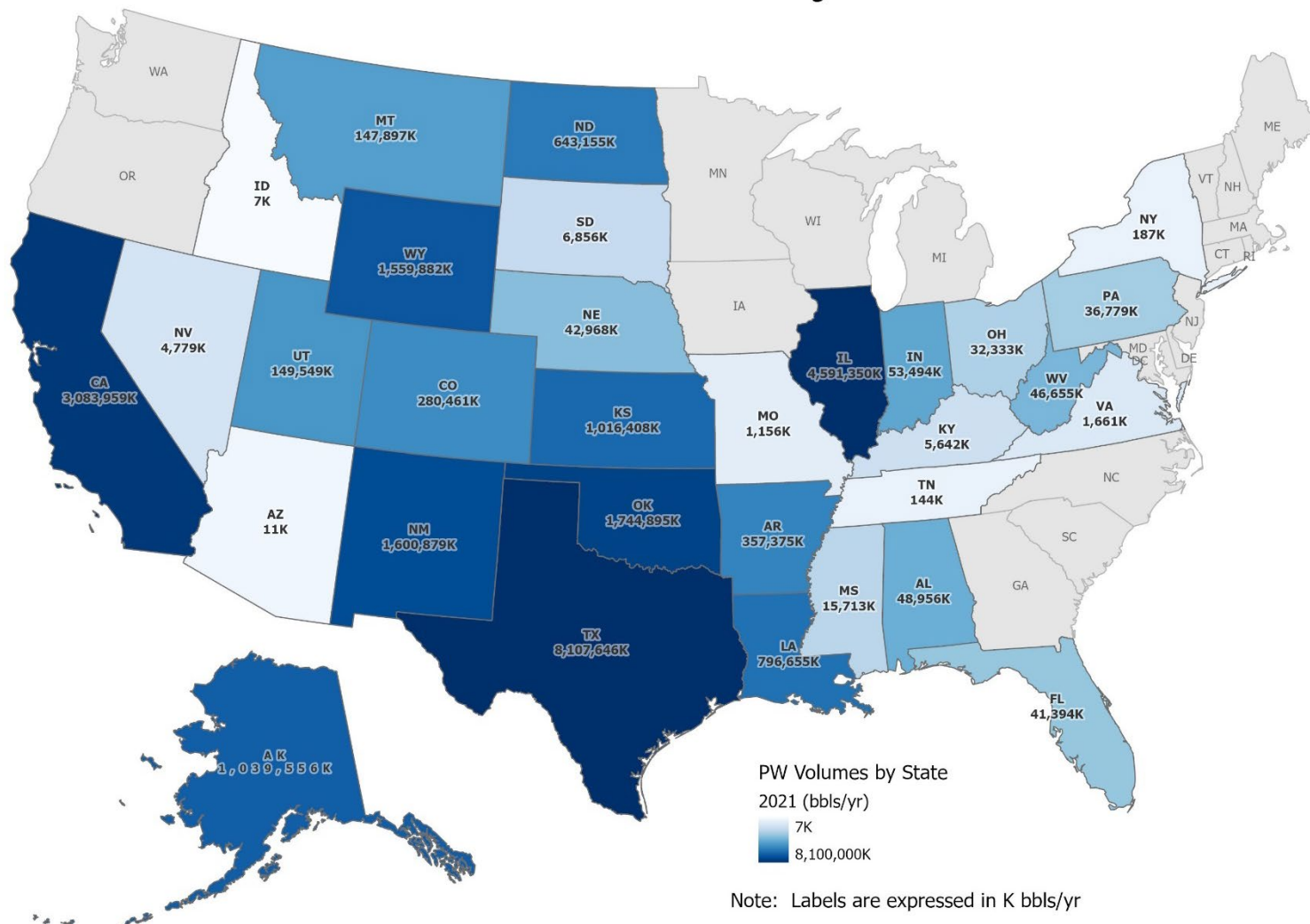


Figure 4-1 – Map of the Oil & Gas Producing States with 2021 Produced Water Volumes



#### 4.3.1 Comparison to 2017 Volumes

The production of crude oil, natural gas, and produced water all increased between 2017 and 2021. The percentage increases from 2017 to 2021 as compared to the percentage increases from 2012 to 2017 are as follows:

- **Crude Oil:** 20.18% (2021 vs. 2017) – 50.41% (2017 vs. 2012)
- **Natural Gas:** 17.21% (2021 vs. 2017) – 17.73% (2017 vs. 2012)
- **Produced Water:** 6.02% (2021 vs. 2017) – 15.16% (2017 vs. 2012)

Natural gas increased at about the same rate for this four-year period versus the early five-year period. Both crude oil and produced water each slowed down their rate of increase; however, the percentage increase in produced water as compared to the increase in crude oil appears to have remained consistent with a near 3.3 fold relationship in their percent increases.

The data from these tables can be used to calculate increases or decreases on a state-by-state or federal offshore basis. Using Texas and New Mexico as examples, since exploration and production activities have sharply increase in the Permian Basin over this period, one can draw conclusions from this comparison. **Table 4-4** depicts the changes in production over this 4-year period for both New Mexico and Texas. It seems as though both New Mexico and Texas have made large strides in production as a percentage over this period. The one striking difference is the reduction in produced water in Texas versus the increase in both crude oil and natural gas. It was reported by the Railroad Commission of Texas (RRC) that they do not keep track of water volumes, nor do they require produced water to be reported, rather their produced water total is an approximation based on the reported injection statewide. Therefore, is it possible the reduction in injection volume or the difference between the 2017 and 2021 produced water total, some -1,787,439,000 bbls that was not injected, could represent the reuse and recycling industry as there has been a big push to recycle in the Permian. If fact, the recent Draft Report titled “*Beneficial Use of Produced Water in Texas: Challenges, Opportunities and the Path Forward*” as prepared by the Texas Produced Water Consortium, mentions a 1,170,000,000 bbl volume that is being reused by the industry for hydraulic fracturing (HF) in the Permian Delaware and Permian Midland basins alone.<sup>11</sup> This amount coupled with other unreported or untracked recycling in other basins across the state could easily amount to or exceed the 1,787,439,000 bbl difference suspected of representing the HF recycling volume. Further research via a Freedom of Information Act (FOIA) request has been made to the RRC to gather data on the number and types of both commercial and non-commercial recycling currently occurring statewide.

**Table 4-4: Production Change 2021 vs. 2017 New Mexico and Texas**

| New Mexico              | 2021          | 2017          | Difference      | Percentage |
|-------------------------|---------------|---------------|-----------------|------------|
| Crude Oil (bbl/yr)      | 451,085,590   | 172,587,378   | 278,498,212     | 161.37%    |
| Natural Gas (Mmcf/yr)   | 2,421,424     | 1,296,990     | 1,124,434       | 86.70%     |
| Produced Water (bbl/yr) | 1,600,878,600 | 879,740,841   | 721,137,759     | 81.97%     |
| <b>Texas</b>            |               |               |                 |            |
| Crude Oil (bbl/yr)      | 1,724,402,106 | 1,271,143,548 | 453,258,558     | 35.66%     |
| Natural Gas (Mmcf/yr)   | 10,741,016    | 8,124,096     | 2,616,920       | 32.21%     |
| Produced Water (bbl/yr) | 8,107,645,550 | 9,895,084,619 | (1,787,439,069) | -18.06%    |

<sup>11</sup> Texas Produced Water Consortium Report to the Texas Legislature 2022 – DRAFT, Beneficial Use of Produced Water in Texas: Challenges, Opportunities and the Path Forward, Pages 14 - 15

### 4.3.2 Top Producing States

Oil, gas, and water are not produced homogeneously between the near 35 oil and gas producing states. **Table 4-5** shows the top ten states with the highest volume of produced water reported for 2021. The table also shows how those states ranked in 2017 and 2012. Note, Illinois has made a rapid move up the rankings based on their reporting of EOR and disposal injection volumes which when combined were used to represent their total production, as was done in 2017. Note, the Illinois Department of Natural Resources – Office of Oil and Gas Resource Management (DNR-OOGRM) reported the volumes of produced water used for EOR and disposal injection for ~30.5 percent of their injection wells and the total for 2021 was then extrapolated. This may account for some of the inflated volume, but the Illinois DNR-OOGRM also provided data for 2019 and revised data for 2017 that reflected the injection volumes from near 100% of all underground injection control (UIC) wells. Therefore, the extrapolated volume for 2021 appears to be in line with this supporting information. **Table 4-5.1** shows the 2019 and revised 2017 data as provided by the Illinois DNR-OOGRM for comparison. Note, accounting for EOR volumes creates the possibility for elevated volumes due to the round-trip nature of EOR injection, EOR is a significant methodology employed to maintain production in Illinois. Also, the inclusion of Illinois in the top ten has pushed the federal offshore production of water to rank 11 for 2021, from their previous rankings of 9th for both 2017 and 2012.

**Table 4-5: Top Ten States in Terms of Water Production in 2021**

| 2021 Rank | State        | Volume (bbl/yr) | Percent of Total | 2017 Rank | 2012 Rank |
|-----------|--------------|-----------------|------------------|-----------|-----------|
| 1         | Texas        | 8,107,645,550   | 31.4%            | 1         | 1         |
| 2         | Illinois     | 4,591,349,632   | 17.8%            | 13        | 18        |
| 3         | California   | 3,083,959,386   | 11.9%            | 2         | 2         |
| 4         | Oklahoma     | 1,744,894,591   | 6.7%             | 3         | 3         |
| 5         | New Mexico   | 1,600,878,600   | 6.2%             | 7         | 7         |
| 6         | Wyoming      | 1,559,881,944   | 6.0%             | 4         | 4         |
| 7         | Alaska       | 1,039,555,842   | 4.0%             | 8         | 8         |
| 8         | Kansas       | 1,016,408,380   | 3.9%             | 5         | 5         |
| 9         | Louisiana    | 796,655,259     | 3.1%             | 6         | 6         |
| 10        | North Dakota | 643,154,596     | 2.5%             | 10        | 11        |

**Table 4-5.1: Illinois Produced Water Supplemental Data**

| Management Practice                  | 2021 Reported (bbl/yr)  | 2021 Extrapolated (bbl/yr) | 2019 (bbl/yr)           | Revised 2017 (bbl/year) |
|--------------------------------------|-------------------------|----------------------------|-------------------------|-------------------------|
| Injection for Enhanced Recovery      | 1,105,614,565           | 3,624,249,956              | 3,315,601,965           | 2,999,759,910           |
| Injection for Disposal (By Operator) | 295,023,660             | 967,099,675                | 1,140,784,505           | 1,291,003,905           |
| <b>Total</b>                         | <b>1,400,638,225.00</b> | <b>4,591,349,631.72</b>    | <b>4,456,386,470.00</b> | <b>4,290,763,815.00</b> |
| Number of EOR Wells Reporting        | 1,594                   | ~5,225                     | 5,530                   | 5,474                   |
| Number of Injection Disposal Wells   | 305                     | ~1,000                     | 704                     | 884                     |
| Percent of UIC Wells Reporting       | 30.50%                  | N/A                        | ~100%                   | ~100%                   |

The top ten states for hydrocarbon production are depicted in **Tables 4-6 and 4-7** Crude Oil and Natural Gas, respectively. Once again, Texas was the largest producer of all three fluids. It generated ~42.1% of the crude oil and condensate, ~26.2% of the natural gas, and ~31.4% of the produced water in the U.S. for 2021.



With regards to the other entities oil production rankings, New Mexico, Colorado, and Utah all moved up two spots each, the Federal Offshore, Oklahoma, and Wyoming retained their ranks, and North Dakota, and Alaska dropped one spot each while California dropped two spots. Noteworthy is that Louisiana was bumped out of the top ten crude oil producing entities, with a reduction in nearly 17,000,000 bbl/yr over this four-year period.

The top ten natural gas producing entities also saw some dramatic shifts with West Virginia and New Mexico leap frogging four and three spots in turn to rank 5<sup>th</sup> and 7<sup>th</sup>, respectively, while Alaska gained one position. Texas, Pennsylvania, and Ohio held steady; however, Louisiana and Oklahoma each slid back one spot, but Colorado and Wyoming lost three positions each.

The sum of the top three entities made up over half of the U.S. total volume in each category (68.4% for oil, 53.4% for gas, and 61.1% for water).

**Table 4-6: Top Ten U.S. Crude Oil Production Entities in 2021**

| 2021 Rank | State            | Volume (bbl/yr) | Percent of Total | 2017 Rank | 2012 Rank |
|-----------|------------------|-----------------|------------------|-----------|-----------|
| 1         | Texas            | 1,724,402,106   | 42.1%            | 1         | 1         |
| 2         | Federal Offshore | 627,291,957     | 15.3%            | 2         | 2         |
| 3         | New Mexico       | 451,085,590     | 11.0%            | 5         | 7         |
| 4         | North Dakota     | 405,127,827     | 9.9%             | 3         | 3         |
| 5         | Alaska           | 159,622,902     | 3.9%             | 4         | 5         |
| 6         | Colorado         | 153,495,589     | 3.8%             | 8         | 9         |
| 7         | Oklahoma         | 148,337,394     | 3.6%             | 7         | 6         |
| 8         | California       | 137,117,236     | 3.4%             | 6         | 4         |
| 9         | Wyoming          | 85,290,133      | 2.1%             | 9         | 10        |
| 10        | Utah             | 35,513,708      | 0.9%             | 12        | 12        |

**Table 4-7: Top Ten U.S. Natural Gas Production Entities in 2021**

| 2021 Rank | State         | Volume (Mmcf/yr) | Percent of Total | 2017 Rank | 2012 Rank |
|-----------|---------------|------------------|------------------|-----------|-----------|
| 1         | Texas         | 10,741,016       | 26.2%            | 1         | 1         |
| 2         | Pennsylvania  | 7,656,814        | 18.7%            | 2         | 4         |
| 3         | Alaska        | 3,505,248        | 8.5%             | 4         | 6         |
| 4         | Louisiana     | 3,379,390        | 8.2%             | 3         | 3         |
| 5         | West Virginia | 2,675,208        | 6.5%             | 9         | 11        |
| 6         | Oklahoma      | 2,544,913        | 6.2%             | 5         | 7         |
| 7         | New Mexico    | 2,421,424        | 5.9%             | 10        | 9         |
| 8         | Ohio          | 2,256,484        | 5.5%             | 8         | 21        |
| 9         | Colorado      | 1,956,843        | 4.8%             | 6         | 2         |
| 10        | Wyoming       | 1,081,393        | 2.6%             | 7         | 5         |

#### 4.3.3 Ratio of Water to Hydrocarbon

The water-to-oil ratios (WORs) and water-to-gas ratios (WGRs) from production activities provide some insight into the relationship of the hydrocarbons to the formation water, but it must be recognized that the same accuracy concerns for volume reported exist here as well. Therefore, the WORs and WGRs calculated in this report represent the average ratio of water and hydrocarbons in the fluids produced to the surface and do not depict the true fluid proportions in the reservoirs.

Only 21 of the states were able to provide water volumes from oil wells separately from water volumes from gas wells, and consequently only 19 states had sufficient data regarding water from gas wells, making calculations of WORs and WGRs a limited set. **Tables 4-8** and **4-9** show the WOR and WGR ratios, respectively, for the states where data was provided. **Tables 4-8.1** and **4-9.1** show the conventional versus unconventional WOR and WGR in turn for states where the data allowed these calculations. A calculated weighted average WOR or WGR is presented at the bottom of each table that takes each state's actual production volumes into account.

**Table 4-8: WORs for States where Data Allowed Calculations**

| State                                | Oil 2021 (bbl/year)  | Condensate (bbl /year) | Water from Oil 2021 (bbl/year) | WOR 2021   |
|--------------------------------------|----------------------|------------------------|--------------------------------|------------|
| Alabama                              | 3,544,505            | 719,838                | 24,657,894                     | 5.8        |
| Alaska                               | 159,622,902          | -                      | 932,498,310                    | 5.8        |
| Arizona                              | 6,379                | -                      | 10,715                         | 1.7        |
| Arkansas                             | 4,211,260            | -                      | 349,429,494                    | 83.0       |
| California                           | 137,117,236          | -                      | 3,051,577,137                  | 22.3       |
| Colorado                             | 153,495,589          | -                      | 190,813,691                    | 1.2        |
| Indiana                              | 1,521,075            | -                      | 49,026,609                     | 32.2       |
| Mississippi                          | 12,931,012           | -                      | 13,673,796                     | 1.1        |
| Missouri                             | 59,579               | -                      | 1,156,481                      | 19.4       |
| Montana                              | 18,920,372           | -                      | 132,908,984                    | 7.0        |
| Nebraska                             | 1,705,559            | -                      | 41,568,415                     | 24.4       |
| Nevada                               | 223,233              | -                      | 4,779,403                      | 21.4       |
| New Mexico                           | 451,085,590          | -                      | 181,651,249                    | 0.4        |
| New York                             | 265,592              | -                      | 140,920                        | 0.5        |
| North Dakota                         | 405,127,827          | -                      | 643,133,441                    | 1.6        |
| Ohio                                 | 18,777,412           | -                      | 4,348,742                      | 0.2        |
| Pennsylvania                         | 863,098              | 5,396,909              | 319,351                        | 0.1        |
| South Dakota                         | 1,028,395            | -                      | 6,855,702                      | 6.7        |
| Texas                                | 1,459,827,134        | 264,574,972            | 8,107,646,550                  | 4.7        |
| West Virginia                        | 17,961,149           | -                      | 470,688                        | 0.0        |
| Wyoming                              | 78,900,632           | 6,389,501              | 1,287,690,676                  | 15.1       |
| <b>Totals / Weighted Average WOR</b> | <b>2,927,195,530</b> | <b>277,081,220</b>     | <b>15,024,358,248</b>          | <b>4.7</b> |

The WORs ranged from 0.1 to 83.0 bbl/bbl for Pennsylvania and Arkansas correspondingly. The weighted average for those states with suitable data sets was 4.7 bbl/bbl. The citation of the weighted average WOR is not appropriate as being representative of the entire United States. The total water volume represented by the states with WOR calculatable data represents just 58% of the total produced water reported from the entities participating in this study.

Of the top ten states in water production, only five are represented on the WOR table (TX, CA, NM, WY, & AK). States with mature fields, such as, KS, LA, and OK, usually have large numbers of older conventional wells and subsequently higher WORs; however, these are also the states where water generated by well type is not recognized. It has been speculated in previous studies that if the wells from the mature field states were averaged in with the wells with WOR data, the national weighted average WOR would be larger.

**Table 4-8.1: Conventional versus Unconventional WORs**

| State                                | Conventional Oil (bbl/year) | Unconventional Oil (bbl /year) | Water From Conventional Oil Wells (bbl/year) | Water from Unconventional Oil Wells (bbl/year) | Conventional WOR | Unconventional WOR |
|--------------------------------------|-----------------------------|--------------------------------|--|--|------------------|--------------------|
| Colorado                             | 7,517,958                   | 145,977,631                    | 124,023,603                                  | 66,790,088                                     | 16.50            | 0.5                |
| Mississippi                          | 12,344,707                  | 586,305                        | 12,847,991                                   | 825,805  | 1.04             | 1.4                |
| Montana                              | 8,713,695                   | 10,206,677                     | 118,386,245                                  | 14,522,739                                     | 13.59            | 1.4                |
| North Dakota                         | 11,571,847                  | 393,555,980                    | 132,996,244                                  | 510,137,197                                    | 11.49            | 1.3                |
| Ohio                                 | 2,385,245                   | 16,392,167                     | 1,528,280                                    | 2,820,462                                      | 0.64             | 0.2                |
| Pennsylvania                         | 781,452                     | 5,478,556                      | 609,939                                      | 6,237  | 0.78             | 0.001              |
| Wyoming                              | 30,217,384                  | 55,072,749                     | 1,159,342,111                                | 128,348,565                                    | 38.37            | 2.3                |
| <b>Totals / Weighted Average WOR</b> | <b>73,532,288</b>           | <b>627,270,065</b>             | <b>1,549,734,413</b>                         | <b>723,451,093</b>                             | <b>21.08</b>     | <b>1.15</b>        |

The seven states that provided sufficient data to calculate the conventional and unconventional WORs show a near 18 to 1 difference between the water to bbl of oil ratio as a weighted average. Ohio and Pennsylvania with their large unconventional fields for the Marcellus and Utica shales show a small value for the conventional WOR, but when compared with the unconventional WOR the difference is still large with a 3.72 and 686 to 1 fold, respectively. This data seems reasonable with respect to the level of EOR for conventional development influencing the WORs or primary unconventional development.

**Table 4-9: WGRs for States in which Data Allows their Calculation**

| State                                | Gas 2021 (Mmcf)      | Water from Gas 2021 (bbl/year) | WGR 2021    |
|--------------------------------------|----------------------|--------------------------------|-------------|
| Alabama                              | 107,818              | 23,970,080                     | 222.3       |
| Alaska                               | 3,505,248            | 71,118,823                     | 20.3        |
| Arkansas                             | 447,881              | 7,945,660                      | 17.7        |
| California                           | 121,534              | 32,382,249                     | 266.4       |
| Colorado                             | 1,956,843            | 89,647,046                     | 45.8        |
| Idaho                                | 1,359                | 7,314                          | 5.4         |
| Indiana                              | 4,136                | 4,467,486                      | 1080.3      |
| Mississippi                          | 27,028               | 2,039,203                      | 75.4        |
| Montana                              | 41,823               | 911,945                        | 21.8        |
| Nebraska                             | 321                  | 1,400,000                      | 4362.1      |
| New Mexico                           | 2,421,424            | 419,227,351                    | 173.1       |
| New York                             | 9,735                | 45,717                         | 4.7         |
| North Dakota                         | 1,075,358            | 21,155                         | 0.02        |
| Ohio                                 | 2,256,484            | 27,983,930                     | 12.4        |
| Pennsylvania                         | 7,656,814            | 36,162,901                     | 4.7         |
| South Dakota                         | 3,353                | 273                            | 0.1         |
| Virginia                             | 96,044               | 1,660,599                      | 17.3        |
| West Virginia                        | 2,675,208            | 42,063,360                     | 15.7        |
| Wyoming                              | 1,081,393            | 272,191,268                    | 251.7       |
| <b>Totals / Weighted Average WOR</b> | <b>23,489,803.93</b> | <b>1,033,246,359.61</b>        | <b>44.0</b> |

The WGRs are extremely wide-ranging from a negligible 0.02 to 4362.1 bbl/Mmcf for North Dakota and Nebraska, respectively. The weighted average for these states is 44.0 bbl/Mmcf. The sum of the

produced water from these states represents just 3.99% of the total produced water reported from the entities participating in this study and, therefore, the weighted average WGR is not representative of a national average, nor should it be cited.

**Table 4-9.1: Conventional versus Unconventional WGRs**

| State                                | Conventional Gas (Mmcf/year) | Unconventional Gas (Mmcf/year) | Water from Conventional Wells (bbl/year) | Water from Unconventional Wells (bbl/year) | WGR Conventional | WGR Unconventional |
|--------------------------------------|------------------------------|--------------------------------|--|--|------------------|--------------------|
| Alabama                              | 65,769                       | 42,049                         | 1,161,783                                | 22,808,297                                 | 17.7             | 542.4              |
| Arkansas                             | 66,939                       | 380,942                        | 727,851                                  | 7,217,809                                  | 10.9             | 18.9               |
| Colorado                             | 837,830                      | 1,119,013                      | 80,844,773                               | 8,802,273                                  | 96.5             | 7.9                |
| Mississippi                          | 26,440,674                   | 587,351                        | 2,024,960                                | 14,243                                     | 0.1              | 0.024              |
| Ohio                                 | 35,106                       | 2,221,378                      | 986,388                                  | 26,997,542                                 | 28.1             | 12.2               |
| Pennsylvania                         | 82,346                       | 7,574,469                      | 228,841                                  | 35,934,060                                 | 2.8              | 4.7                |
| Virginia                             | 15,449                       | 80,595                         | 10,085                                   | 1,650,514                                  | 0.7              | 20.5               |
| Wyoming                              | 1,077,926                    | 3,467                          | 228,909,681                              | 43,281,587                                 | 212.4            | 12483.9            |
| <b>Totals / Weighted Average WOR</b> | <b>28,622,039.79</b>         | <b>12,009,263.99</b>           | <b>314,894,362.00</b>                    | <b>146,706,325.00</b>                      | <b>11.00</b>     | <b>12.22</b>       |

Eight states had sufficient data to allow a comparison of WGRs for conventional versus unconventional development. The weighted average WGRs between conventional and unconventional are very similar with only a barrel difference between the ratios or a 1 to 1.11 relationship. On a state-by-state basis the comparisons range between 1.74 to 1 for Arkansas to 58.8 to 1 for Wyoming. In states with predominate coalbed methane developments such as Alabama and Wyoming, where the groundwater is extracted to reduce the hydrostatic head on the coals seams so that gas can migrate to the surface the unconventional WGRs are elevated.

Another means of identifying the water to hydrocarbon association is to calculate a national water to barrels of oil equivalent (BOE) ratio. The total natural gas volumes were converted to BOE then added to the total crude oil and condensate volumes to generate a national total BOE. Conversion factors for natural gas to BOE are conducted on an energy equivalence basis, where 6 Mcf (6,000 cf) of natural gas equals 1 BOE.

For 2021, the reported national total natural gas volume of 41,026,000 Mmcf equals 7,794,940,000 BOE. When the natural gas BOE is added to the total crude oil and condensate volume of 4,171,934,000, there is an estimated 11,966,874,000 BOE. When divided into the total water volume for 2021, the resulting water-to-BOE ratio is 2.16. When compared with the previous studies' water-to BOE calculations (2007 – 3.40, 2012 – 2.76, 2017 – 2.5) a steady decline is revealed that demonstrates a reduction trend in water per unit of hydrocarbon produced.

#### 4.4 Results of Produced Water Management Analysis

The questionnaire included a request and expanded spreadsheet table for state agencies to provide detailed data regarding the produced water disposition or reuse in 2021. As with previous years, some agencies provided comprehensive data, while others could provide only limited data, only a couple were unable to share any information (Maryland and Michigan).

The total volume of estimated produced water (24,902,774,000 bbl) managed in 2021, pairs tightly with the reported volume of produced water generated (25,860,854,000 bbl). This is expected, since several agencies reported the volumes injected for EOR or disposal as the total volumes produced as they do not require the quantities of produced water to be reported by operators.

**Table 4-10** reveals the state-by-state and federal offshore classification of produced water management methods with volume for each type. The caveats and details supporting these quantities are provided in the specific state discussions in **Chapter 5**.

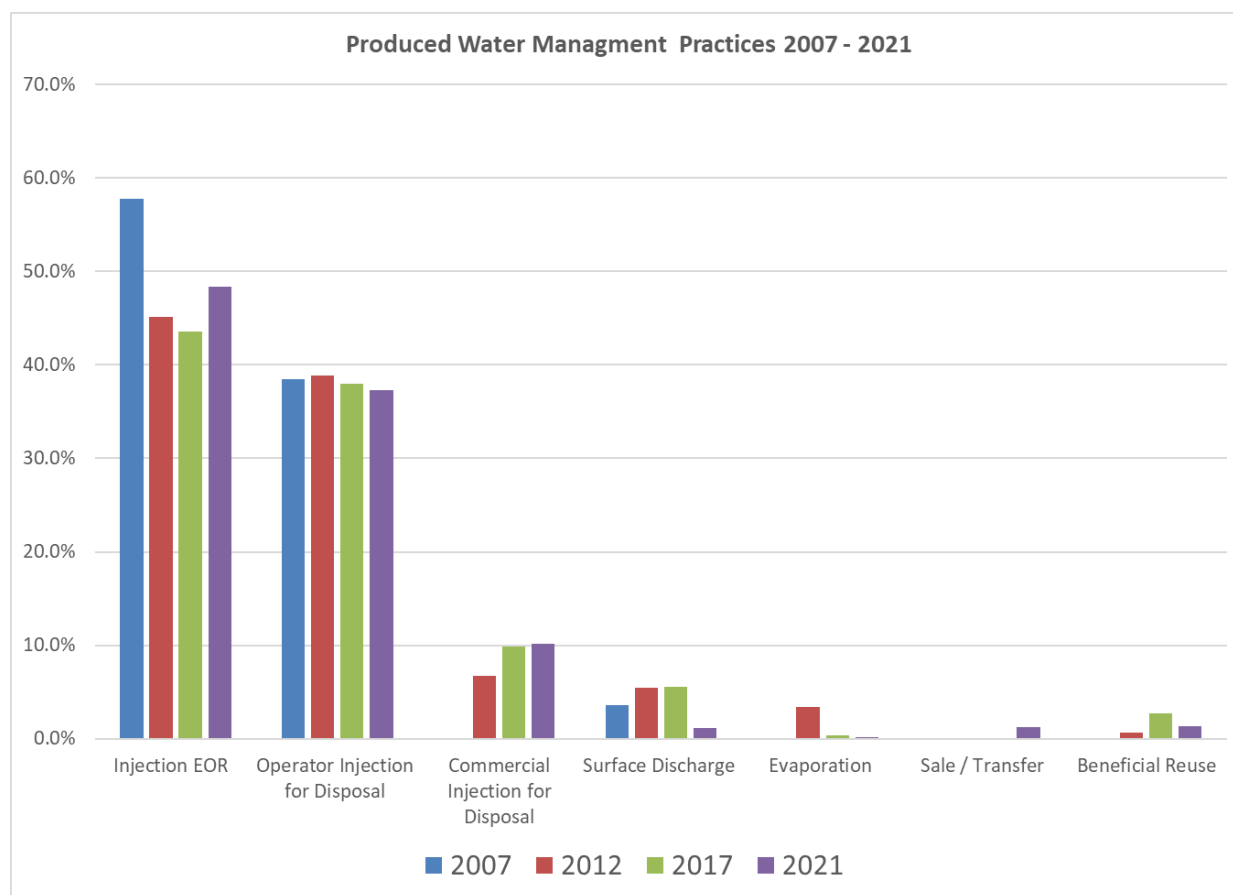
Observation of produced water management categories for 2021 are as follows:

- ~95.74% (23,841,387,000 bbl) of the produced water was injected:
  - ~48.3% (12,038,534,000 bbl) was injected for EOR,
  - ~37.3% (9,284,329,000 bbl) was injected for disposal by operators, and
  - ~10.1% (2,518,524,000 bbl) was injected for disposal by commercial operations.
- ~1.2% (291,036,000 bbl) was discharged as reported by seven states and the federal offshore assets:
  - ~1.15% (287,099,000 bbl) to water bodies, and
  - ~0.02% (3,937,000 bbl) to land surfaces.
- ~0.2% (39,537,000 bbl) was evaporated mainly by several western states (CA, CO, ID, MT, NE, NM) as commercial disposal facilities have moved toward this method to augment injection near seismic sensitive areas:
  - ~0.06% (14,834,000 bbl) in lined Impoundments, and
  - ~0.1% (24,703,000 bbl) in unlined Impoundments.
- ~1.2% (296,506,000 bbl) was sold or transferred for reuse in California as they were the only state to report this management method:
  - ~1.1% (265,760,000 bbl) for domestic reuse, and
  - ~0.1% (30,746,000 bbl) to other oil and gas operators.
- ~1.4% was beneficially reused within and outside of the oil and gas industry as reported by eight states:
  - ~1.3% (331,268,000 bbl) for reuse in the oil field by seven states, and
  - ~0.05% (12,821,000 bbl) for reuse outside the oil field by four states.
- ~0.4% (90,219,000 bbl) was reportedly in the “other” column by four states, including California, Montana, New Mexico, and Pennsylvania. It was mentioned by these states that these amounts represent spilled, unaccounted for, record errors, or differences in produced versus management, but none was identified as being handled in a manner commensurate with reuse or disposal.

Table 4-10: Produced Water Management Practices and Volumes for 2021 (bbl/year)

| State                       | Injection EOR         | Injection for Disposal by Operator | Injection for Disposal Commercial | Surface Discharge into Water Bodies | Surface Discharge onto Land | Evaporation in Lined Impoundments | Evaporation in Unlined Impoundments | Sale / Transfer Domestic | Sale / Transfer to Other O&G Operator | Beneficial Reuse in Oil Field | Beneficial Reuse Outside Oil Field | Other             | Total Produced Water Managed |
|-----------------------------|-----------------------|------------------------------------|-----------------------------------|-------------------------------------|-----------------------------|-----------------------------------|-------------------------------------|--------------------------|---------------------------------------|-------------------------------|------------------------------------|-------------------|------------------------------|
| Alabama                     | 684,985               | 25,463,210                         | -                                 | 22,808,297                          | -                           | -                                 | -                                   | -                        | -                                     | -                             | -                                  | -                 | 48,956,492                   |
| Alaska                      | 1,238,583,110         | 108,393,846                        | -                                 | -                                   | -                           | -                                 | -                                   | -                        | -                                     | -                             | -                                  | -                 | 1,346,976,956                |
| Arizona                     | 10,701                | -                                  | -                                 | -                                   | -                           | -                                 | -                                   | -                        | -                                     | -                             | -                                  | -                 | 10,701                       |
| Arkansas                    | 37,706,664            | 319,668,490                        | 1,082,421                         | -                                   | -                           | -                                 | -                                   | -                        | -                                     | -                             | -                                  | -                 | 358,457,575                  |
| California                  | 1,540,731,145         | 487,399,151                        | -                                 | 2,369,726                           | 3,800,378                   | 2,246,605                         | 23,393,231                          | 265,760,348              | 30,745,992                            | 59,263,489                    | 7,792,195                          | 58,608,634        | 2,482,110,894                |
| Colorado                    | 87,244,195            | 157,335,767                        | 4,509,244                         | 13,476,468                          | -                           | -                                 | 9,672                               | -                        | -                                     | 19,606,106                    | -                                  | -                 | 282,181,452                  |
| Florida                     | 35,033,182            | 6,360,565                          | -                                 | -                                   | -                           | -                                 | -                                   | -                        | -                                     | -                             | -                                  | -                 | 41,393,747                   |
| Idaho                       | -                     | -                                  | -                                 | -                                   | -                           | 7,314                             | -                                   | -                        | -                                     | -                             | -                                  | -                 | 7,314                        |
| Illinois                    | 3,624,249,956         | 967,099,675                        | -                                 | -                                   | -                           | -                                 | -                                   | -                        | -                                     | -                             | -                                  | -                 | 4,591,349,631                |
| Indiana                     | 38,651,684            | 14,842,411                         | -                                 | -                                   | -                           | -                                 | -                                   | -                        | -                                     | -                             | -                                  | -                 | 53,494,095                   |
| Kansas                      | 256,249,232           | 760,157,395                        | 1,753                             | -                                   | -                           | -                                 | -                                   | -                        | -                                     | -                             | -                                  | -                 | 1,016,408,380                |
| Kentucky                    | 5,383,959             | 258,304                            | -                                 | -                                   | -                           | -                                 | -                                   | -                        | -                                     | -                             | -                                  | -                 | 5,642,263                    |
| Louisiana                   | 48,292,239            | 704,851,022                        | 43,511,998                        | -                                   | -                           | -                                 | -                                   | -                        | -                                     | -                             | -                                  | -                 | 796,655,259                  |
| Mississippi                 | 31,834,517            | 114,265,647                        | -                                 | -                                   | -                           | -                                 | -                                   | -                        | -                                     | -                             | -                                  | -                 | 146,100,164                  |
| Missouri                    | 1,065,749             | 90,732                             | -                                 | -                                   | -                           | -                                 | -                                   | -                        | -                                     | -                             | -                                  | -                 | 1,156,481                    |
| Montana                     | 79,072,420            | 51,885,041                         | -                                 | -                                   | -                           | 10,805,134                        | -                                   | -                        | -                                     | -                             | -                                  | 6,134,446         | 147,897,041                  |
| Nebraska                    | 23,312,800            | 23,798,500                         | 112,000                           | 29,615                              | -                           | 12,000                            | 1,300,000                           | -                        | -                                     | -                             | 3,500                              | -                 | 48,568,415                   |
| Nevada                      | 24,897                | 4,813,446                          | -                                 | -                                   | -                           | -                                 | -                                   | -                        | -                                     | -                             | -                                  | -                 | 4,838,343                    |
| New Mexico                  | unknown               | 717,435,541                        | -                                 | -                                   | -                           | 1,762,644                         | -                                   | -                        | -                                     | 181,970,412                   | -                                  | 29,225            | 901,197,822                  |
| New York                    | 17,255                | 6,913                              | 63,668                            | 53                                  | 7,826                       | 210                               | 37                                  | -                        | -                                     | 644                           | 90,031                             | -                 | 186,637                      |
| North Dakota                | 110,377,405           | 264,960,745                        | 262,672,129                       | -                                   | -                           | -                                 | -                                   | -                        | -                                     | -                             | -                                  | -                 | 638,010,279                  |
| Ohio                        | 397,235               | 35,036,096                         | -                                 | -                                   | -                           | -                                 | -                                   | -                        | -                                     | 47,338                        | -                                  | -                 | 35,480,669                   |
| Oklahoma                    | 975,571,994           | 524,776,441                        | 244,546,156                       | -                                   | -                           | -                                 | -                                   | -                        | -                                     | -                             | -                                  | -                 | 1,744,894,591                |
| Pennsylvania                | -                     | 4,551,759                          | -                                 | 125,525                             | 14,733                      | -                                 | -                                   | -                        | -                                     | 34,970,964                    | 4,935,594                          | 25,446,886        | 70,045,460                   |
| South Dakota                | 6,340,452             | 1,636,555                          | -                                 | -                                   | -                           | -                                 | -                                   | -                        | -                                     | -                             | -                                  | -                 | 7,977,007                    |
| Tennessee                   | 138,675               | 5,092                              | -                                 | -                                   | -                           | -                                 | -                                   | -                        | -                                     | -                             | -                                  | -                 | 143,767                      |
| Texas                       | 2,605,715,654         | 3,541,581,140                      | 1,960,348,756                     | unknown                             | unknown                     | unknown                           | unknown                             | unknown                  | unknown                               | unknown                       | unknown                            | unknown           | 8,107,645,550                |
| Utah                        | 67,626,647            | 77,421,870                         | -                                 | -                                   | -                           | -                                 | -                                   | -                        | -                                     | -                             | -                                  | -                 | 145,048,517                  |
| Virginia                    | -                     | 1,572,794                          | 54,445                            | -                                   | -                           | -                                 | -                                   | -                        | -                                     | -                             | -                                  | -                 | 1,627,239                    |
| West Virginia               | 3,660,000             | 5,850,365                          | 1,621,584                         | -                                   | 114,380                     | -                                 | -                                   | -                        | -                                     | 35,408,655                    | -                                  | -                 | 46,654,984                   |
| Wyoming                     | 1,220,556,814         | 208,502,298                        | -                                 | -                                   | -                           | -                                 | -                                   | -                        | -                                     | -                             | -                                  | -                 | 1,429,059,112                |
| <b>State Total</b>          | <b>12,038,533,566</b> | <b>9,130,020,810</b>               | <b>2,518,524,154</b>              | <b>38,809,684</b>                   | <b>3,937,317</b>            | <b>14,833,907</b>                 | <b>24,702,940</b>                   | <b>265,760,348</b>       | <b>30,745,992</b>                     | <b>331,267,608</b>            | <b>12,821,320</b>                  | <b>90,219,191</b> | <b>24,500,176,837</b>        |
| <b>Federal Offshore</b>     |                       |                                    |                                   |                                     |                             |                                   |                                     |                          |                                       |                               |                                    |                   |                              |
| Gulf of Mexico              |                       | 119,224,348                        |                                   | 236,599,954                         |                             |                                   |                                     |                          |                                       |                               |                                    |                   | 355,824,302                  |
| Pacific                     |                       | 35,083,883                         |                                   | 11,689,087                          |                             |                                   |                                     |                          |                                       |                               |                                    |                   | 46,772,970                   |
| <b>Federal Total</b>        | <b>-</b>              | <b>154,308,231</b>                 | <b>-</b>                          | <b>248,289,041</b>                  | <b>-</b>                    | <b>-</b>                          | <b>-</b>                            | <b>-</b>                 | <b>-</b>                              | <b>-</b>                      | <b>-</b>                           | <b>-</b>          | <b>402,597,272</b>           |
| <b>U.S. Total (rounded)</b> | <b>12,038,534,000</b> | <b>9,284,329,000</b>               | <b>2,518,524,000</b>              | <b>287,099,000</b>                  | <b>3,937,000</b>            | <b>14,834,000</b>                 | <b>24,703,000</b>                   | <b>265,760,000</b>       | <b>30,746,000</b>                     | <b>331,268,000</b>            | <b>12,821,000</b>                  | <b>90,219,000</b> | <b>24,902,774,000</b>        |
| Percent of Total            | 48.34%                | 37.28%                             | 10.11%                            | 1.15%                               | 0.02%                       | 0.06%                             | 0.10%                               | 1.07%                    | 0.12%                                 | 1.33%                         | 0.05%                              | 0.36%             | 100.00%                      |

The water management categories for 2021 with some consolidated (Surface Discharge, Evaporation, Beneficial Reuse) for comparison are shown graphically in **Figures 4-2** versus the previous year's study data as a percentage for similar categories. Note, as best practices and management strategies have evolved to accommodate changing priorities more categories have been included on the questionnaires over time, hence fewer management options were surveyed in 2007 and 2012.



**Figure 4-2 — Water Management Practices by Percentage 2007 - 2021**

An examination of the percentages across the years reveals that injection, be it for EOR or disposal, remains the primary management method employed. Note that in 2007 commercial injection for disposal was not segregated and may have been represented in the operator injection for disposal category. A graph of just produced water injected over time is presented in **Figure 4-3**. One can see that the percentage of water injected has remained above 90% over this 15-year period. This minor variation across the datasets could be explained as state or agency reporting discrepancies or unique assumptions made while assembling the data, in any case injection remains the leading practice.

Surface discharge appears to have taken a considerable reduction as a percentage in 2021. **Figure 4-4** depicts the percentage of surface discharge as reported for 2021. Practically all produced water from offshore wells is treated then discharged to the ocean under the terms of EPA-issued discharge permits. The Gulf of Mexico discharges dwarf the state total and Pacific amounts, however, with regards to the states' total, as one can see in **Table 4-10**, Alabama far exceeds the other states discharge to water bodies, most likely due to the coalbed methane produced water discharges from the Black Warrior Basin.

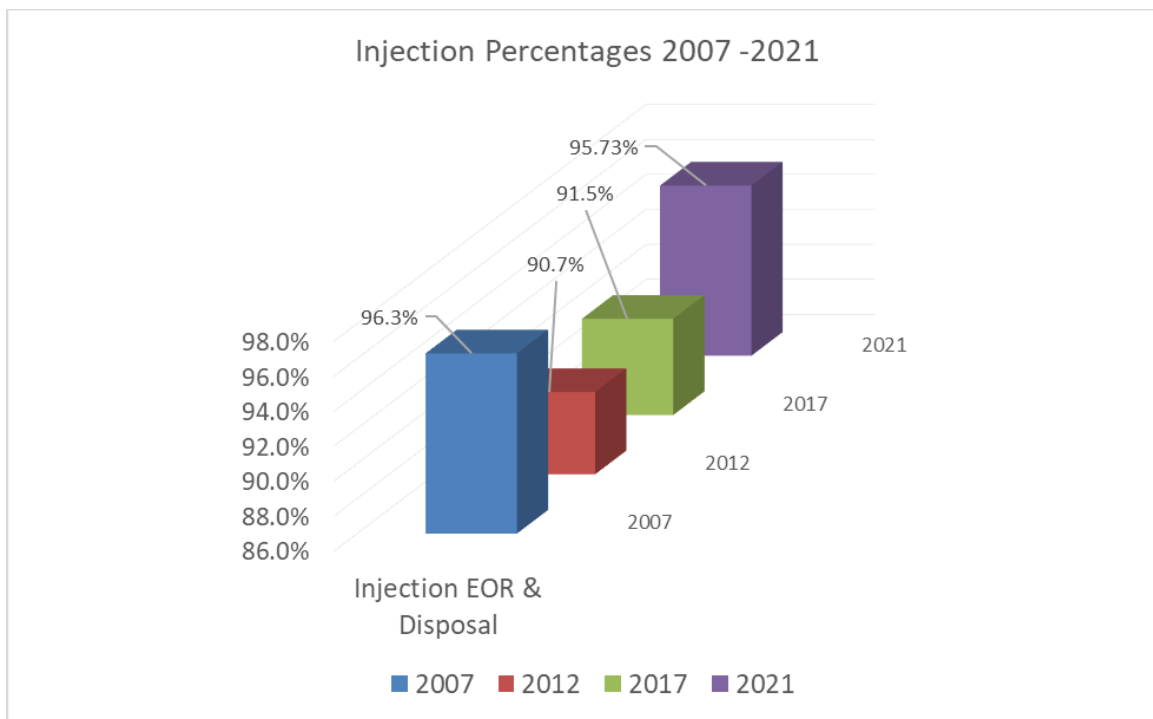


Figure 4-3 — Injection Percentage 2007 – 2021

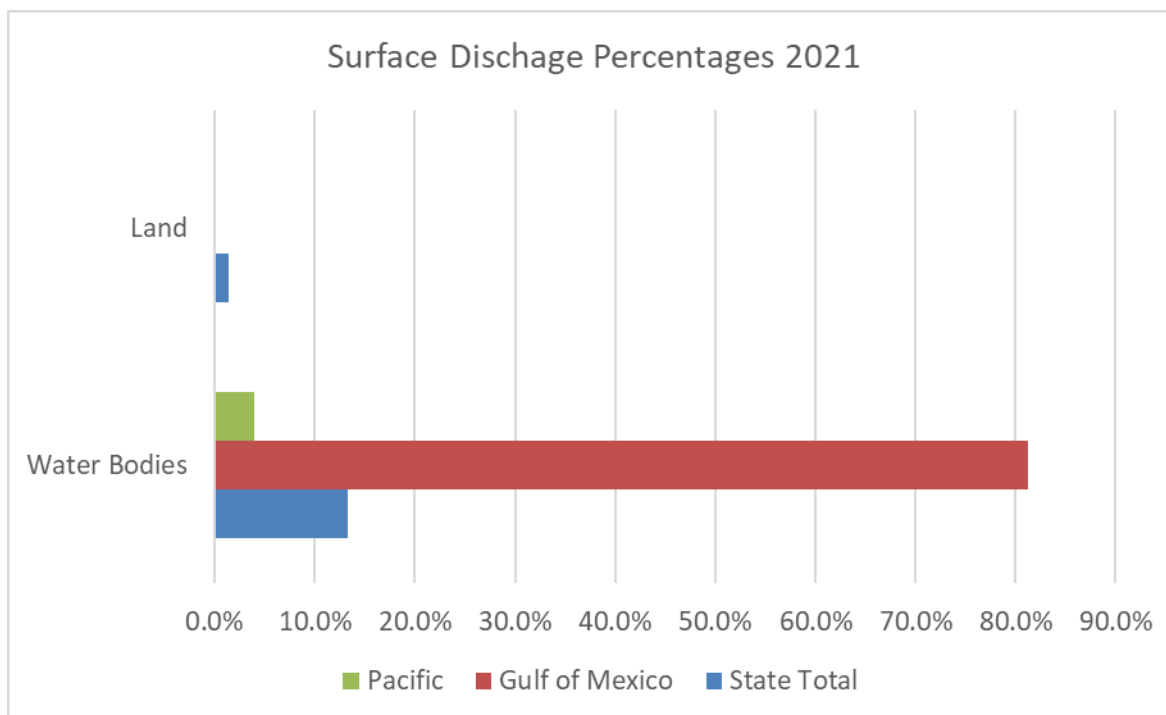


Figure 4-4 — Surface Discharge Percentages 2021



#### 4.4.1 Comments and Caveats on Water Management

Most state oil and gas agencies managed the Class II UIC programs and therefore the data concerning injection, be it EOR or disposal, was available from 30 of the 32 hydrocarbon producing states. Of the 30 state agencies that provided data, 26 were able to distinguish volumes for EOR versus disposal injection. However, from those 26, only 11 states were able to separate the disposal volumes by operator (non-commercial) versus commercial or third-party disposal. All in all, the data set as received was rather complete, so it was not necessary to use many assumptions or extrapolation to augment the injected water volumes.

It is understood in some cases, water produced in one state may have been successively handled in another state. It is known that Pennsylvania and West Virginia do not have the geology to support a large injection disposal industry and therefore send the majority of their produced water to Ohio for disposal. Ohio's produced water disposal volume exceeded their production by over 3,000,000 bbls. Also, due to the scarcity of fresh water in the Permian, a large recycling effort has been initiated that moves produced water back and forth between Texas and New Mexico and goes untracked as reported by the NMOCD. **Chapter 5** contains discussions for each of the states.

Some states that reported large EOR volumes also recognized that the operators augment their inject with makeup water from other sources, thus boosting their total. Furthermore, some of these states also acknowledged, via follow-up emails, that their EOR volumes may contain round-trip water that has been injected, recovered and injected again as part of their EOR operations. It was not possible to estimate the make-up or round-trip volumes and therefore the data was not adjusted but rather analyzed at nominal value.

## 5 State-by-State Summary

This chapter provides a state-by-state summary of the data received. As previously mentioned in **Chapter 3**, most states (all but six) replied to our inquiry with populated copies of Tables 1 and 2 from the questionnaire and that data is presented as received with some basic rounding. In a hand full on cases, extrapolations or reaching out to other state agencies were necessary to consolidate their data for a specific year, most often 2021, or to revise units so numbers were consistent between states and allowed comparisons. For the six states (AZ, AR, FL, LA, OK, UT) that required additional data be obtained via online sources or from different agencies, Tables 1 and 2 are populated with the gathered data and shown with notes describing the origin or caveats used to populate the data.

Since the inception of this GWPC lead produced water volume study in 2007, the U.S. oil and gas production has evolved from nearly all wells producing from conventional formations to an increasing number of wells producing from unconventional formations. Water production profiles often are quite different in conventional and unconventional formations.

The U.S. Department of Energy's Energy Information Administration (DOE EIA) defines unconventional oil and natural gas production as: *"an umbrella term for oil and natural gas that is produced by means that do not meet the criteria for conventional production."* EIA defines conventional oil and natural gas production as: *"crude oil and natural gas that is produced by a well drilled into a geologic formation in which the reservoir and fluid characteristics permit the oil and natural gas to readily flow to the wellbore."* The boundaries between conventional and unconventional production have changed over time and may differ among users of the terms. However, production of the following types of hydrocarbon resources are generally considered to be unconventional (coalbed methane, shale gas, shale oil, tight oil, tight gas sands). Other hydrocarbon types less common in the United States but considered as unconventional production include oil shale, oil/tar sands, extra heavy oil, natural bitumen, and gas hydrates. Some states as noted did not differentiate between conventional and unconventional production as their reporting requirements do not require this designation while others provide the data separately. Furthermore, a few states reported production of condensate separately from crude oil. In these instances, we rolled the condensate into the crude oil production for the state and national oil production totals, as well as for the WOR calculations.

With regards to enhanced recovery, it was noted some states reported the total volume of water injected higher than the total volume of produced water generated. This is most likely the consequence of either accounting for the round-trip nature of water in enhanced recovery operations or the use of make-up water from other sources to augment the enhanced recovery injection volumes. The enhanced recovery volumes reported were included in the tables without alteration, as estimates of make-up water were not provided; however, these instances are noted where applicable.

Data was collected from all participating states by mid-September 2022; however, clarifications continued through early October 2022.

## 5.1 Alabama

### 5.1.1 Introduction

The State Oil and Gas Board of Alabama (OGBA) regulates waste prevention in the state and promotes the conservation of oil and gas while protecting the environment and rights of owners. Below are key data considerations developed after data compilation and assessment. **Tables 5-1** and **5-2** present 2021 production data.

- **Production:** The state reported 5,800 hydrocarbon wells that produced 3,544,505 bbls of oil, 107,818 Mmcf of natural gas; and 719,838 bbls of condensate.
- **Combined BOE:** 22,234,051
- **Produced Water:** Total produced water volume for the state was 48,956,492 bbls: 24,657,894 bbls from oil development and 23,970,080 bbls from natural gas development.
- **Water Management Practice:** 22,808,297 bbls (46.59%) of produced water was disposed of via surface discharge.
- **Ratios:**
  - Combined WOR = 5.8; WGR = 222.3,
  - Conventional WOR = Insufficient data, WGR = 18.0
  - Unconventional WOR = Insufficient data, WGR 542.2
- **State Ranking:** Total Crude Oil and Condensate Production = 20<sup>th</sup>  
                                     Total Natural Gas Production = 17<sup>th</sup>  
                                     Total Produced Water Volume = 17<sup>th</sup>

### 5.1.2 Production and Produced Water Data

When compared to the previous GWPC studies (2012, 2017), produced water volumes in Alabama decreased 40% between 2012 (106,619,000 bbls) and 2017 (63,870,227 bbls); and 23% between 2017 and 2021 (48,956,492 bbls). The number of producing wells from 2017 (6,462) to 2021 (5,800) also declined by 10.24%, or 662 wells.

The percentage of water produced from conventional versus unconventional development was nearly even—approximately 53% and 47%, respectively,— which also held true for the percentage of produced water from crude oil versus natural gas —51% and 49%, respectively (refer to **Table 5-1**).

### 5.1.3 Produced Water Management Practices

Similar to data reported for 2017, Alabama continues to manage a large percentage (46.59%) of produced water volumes by surface discharge, due to the presence of the Black Warrior Coal Bed Methane Basin.<sup>12</sup> This is uncommon when compared to other oil and gas producing states primarily due to water quality limitations as recognized under the EPA’s NPDES program (**Table 5-2**). The remaining volumes of produced water in Alabama are disposed of via injection (52.01%) or used for EOR projects (1.40%). The state did not report any beneficial reuse of produced water in 2021.

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<sup>12</sup> Veil, J., 2002, “Regulatory Issues Affecting Management of Produced Water from Coal Bed Methane Wells,” prepared for U.S. Department of Energy, Office of Fossil Energy. Available at <http://www.veilenvironmental.com/publications/pw/cbm-prod-water-rev902.pdf>.

Table 5-1: Oil and Gas Production for Alabama by Development Method - 2021

| Type of Hydrocarbon              | Number of Wells Producing | Total Volume of Produced Water Brought to Surface (bbl/year) | Volume of Hydrocarbon Produced           |
|----------------------------------|---------------------------|--|--|
| <b>Conventional Formations</b>   |                           |  |  |
| Crude oil                        | 407                       | 24,657,894   | 3,544,505 bbl                            |
| Natural gas                      | 214                       | 1,161,783  | 65,769.01 Mmcf                           |
| Other (Condensate, etc.)         | 32                        | 328,518  | 719,838 bbl                              |
| <b>Unconventional Formations</b> |                           |  |  |
| Crude oil                        | 0                         | 0  | 0  |
| Natural gas                      | 5,147                     | 22,808,297   | 42,049.24 Mmcf                           |
| Other (Condensate, etc.)         | 0                         | 0  | 0  |
| <b>Total</b>                     | <b>5,800</b>              | <b>48,956,492</b>  | <b>4,264,343 bbl<br/>107,818.25 Mmcf</b> |

Table 5-2: Produced Water Management Practices for Alabama - 2021

| Management Practice   | Total Volume of Produced Water Managed by that Practice (bbl/year) | Percentage of Produced Water Managed by that Practice |
|---|--|---|
| Injection for Enhanced Recovery   | 684,985  | 1.40%   |
| Injection for Disposal (By Operator)  | 25,463,210   | 52.01%  |
| Injection for Disposal (Commercial / Offsite)<br>(3rd Party Managed Produced Water) | 0  | 0 %   |
| Surface Water Discharge<br>(Ocean, Lake, Pond, Stream)                              | 22,808,297   | 46.59%  |
| Surface Water Discharge (Land Application)  | 0  | 0 %   |
| Evaporation (Lined Sump)  | 0  | 0 %   |
| Evaporation / Infiltration (Unlined Sump)   | 0  | 0 %   |
| Sale / Transfer – Domestic Use  | 0  | 0 %   |
| Sale / Transfer – Other Oil & Gas Operator  | 0  | 0 %   |
| Reuse Within the Oil & Gas Industry   | 0  | 0 %   |
| Reuse Outside the Oil & Gas Industry  | 0  | 0 %   |
| Other   | 0  | 0 %   |
| <b>Total</b>  | <b>48,956,492</b>  | <b>100 %</b>  |

## 5.2 Alaska

### 5.2.1 Introduction

The Alaska Oil and Gas Conservation Commission (AOGCC) is a quasi-judicial agency of the State of Alaska that oversees oil and gas drilling, development and production, reservoir depletion, and metering operations on all lands subject to the state's authority. The AOGCC did not differentiate hydrocarbon production and produced water data between unconventional and conventional development. Below is a list of key considerations developed after questionnaire data compilation and assessment. **Tables 5-3** and **5-4** present 2021 production data.

- **Production:** The state reported 2,947 hydrocarbon wells that produced 159,622,902 bbls of crude oil; 3,505,247.56 Mmcf of natural gas; and an additional 154.71 Mmcf of natural gas from water supply wells.
- **Combined BOE:** 743,830,829.83 (*modified to account for gas from water wells*)
- **Produced Water:** Total produced water volume for the state was 1,039,555,842 bbls: 932,498,310 bbls from oil development and 71,118,823 bbls from natural gas development.
- **Water Management Practice:** The largest volume of produced water under management practices was injection for enhanced recovery projects with 1,039,555,842 bbls, or 91.95% of the state's total produced water.
- **Ratios:** WOR = 5.8; WGR = 20.3
- **State Ranking:** Total Crude Oil and Condensate Production = 5<sup>th</sup>  
Total Natural Gas Production = 3<sup>rd</sup>  
Total Produced Water Volume = 7<sup>th</sup>

### 5.2.2 Production and Produced Water Data

When compared to previous GWPC studies (2012, 2017), produced water volumes in Alaska increased 7.7% between 2012 (769,153,000 bbls) and 2017 (828,067,983 bbls); and 26% between 2017 and 2021 (1,039,555,842 bbls). The number of producing wells from 2017 to 2021 also increased by 497.

The percentage of produced water from oil production accounted for approximately 90% while the remaining 10% was from natural gas wells (~7%) and water supply wells (~3%), some of which were reported as producing small amounts of natural gas (154.71 Mmcf/year) (refer to **Table 5-3**).

### 5.2.3 Produced Water Management Practices

Based on data received from the AOGCC for 2021, 1,238,583,110 bbls (91.95%) of produced water was injected for EOR, while 108,393,846 bbls (8.05%) was disposed of via injection (refer to **Table 5-4**). Contrary to the 2017 report (37,222 bbls), the state reported no surface discharge of produced water nor beneficial reuse.

The AOGC reported several oil and gas fields in the state also inject seawater for EOR, which accounts for the greater ratio of EOR water to total produced water reported. AOGCC further noted other types of fluids (*i.e.*, camp waste, rainwater, snow melt, drilling fluids, etc.) are disposed of via injection. Additionally, state commercial waste facilities accept produced water from oil and gas operators; however, reported disposal volumes from operators and third-party commercial facilities are not distinct. Therefore, the *Injection for Disposal via Commercial Offsite* category is blank, as all Injection for Disposal has been accounted for in the "By Operator" category (refer to **Table 5-4**).

Table 5-3: Oil and Gas Production for Alaska by Development Method - 2021

| Type of Hydrocarbon   | Number of Wells Producing | Total Volume of Produced Water Brought to Surface (bbl/year) | Volume of Hydrocarbon Produced                |
|---|---------------------------|--|---|
| <b>Conventional Formations</b>  |                           |  |   |
| Crude oil   | 2,612                     | 932,498,310  | 159,622,902 bbl                               |
| Natural gas   | 312                       | 71,118,823   | 3,505,092.85 Mmcf                             |
| Other (Water Supply Wells)  | 23                        | 35,938,709   | 154.71 Mmcf                                   |
| <b>Unconventional Formations</b>  |                           |  |   |
| Crude oil   | 0                         | 0  | 0   |
| Natural gas   | 0                         | 0  | 0   |
| Other (Condensate, etc.)  | 0                         | 0  | 0   |
| <b>Total</b>  | <b>2,947</b>              | <b>1,039,555,842</b>   | <b>159,622,902 bbls<br/>3,505,247.56 Mmcf</b> |
| <b>Note:</b> Production and water volumes also includes offshore hydrocarbon and water production from wells located within State waters. |                           |  |   |

Table 5-4: Produced Water Management Practices for Alaska - 2021

| Management Practice   | Total Volume of Produced Water Managed by that Practice (bbl/year) | Percentage of Produced Water Managed by that Practice |
|---|--|---|
| Injection for Enhanced Recovery   | 1,238,583,110  | 91.95%  |
| Injection for Disposal (By Operator)  | 108,393,846  | 8.05%   |
| Injection for Disposal (Commercial / Offsite)<br>(3rd Party Managed Produced Water) | 0  | 0 %   |
| Surface Water Discharge<br>(Ocean, Lake, Pond, Stream)                              | 0  | 0 %   |
| Surface Discharge (Land Application)  | 0  | 0 %   |
| Evaporation (Lined Sump)  | 0  | 0 %   |
| Evaporation / Infiltration (Unlined Sump)   | 0  | 0 %   |
| Sale / Transfer – Domestic Use  | 0  | 0 %   |
| Sale / Transfer – Other Oil & Gas Operator  | 0  | 0 %   |
| Reuse Within the Oil & Gas Industry   | 0  | 0 %   |
| Reuse Outside the Oil & Gas Industry  | 0  | 0 %   |
| Other   | 0  | 0 %   |
| <b>Total</b>  | <b>1,346,976,956</b>   | <b>100 %</b>  |

## 5.3 Arizona

### 5.3.1 Introduction

The administrative duties of the Arizona Oil and Gas Commission (AOGC) were transferred to the Arizona Department of Environmental Quality (ADEQ) in 2016 including requirements for drilling, completing, and producing oil and gas wells. ADEQ did not respond to the questionnaire; however, ADEQ sent data via Form 14 (Report to Injection Project) and Form 16 (Monthly Producers Report). Below is a list of key considerations developed after questionnaire data compilation and assessment. **Tables 5-5 and 5-6** present 2021 production data.

- **Production:** The state reported 28 hydrocarbon wells that produced 6,379 bbls of crude oil; 77.67 Mmcf of natural gas, and 0 bbls condensate.
- **Combined BOE:** 19,325
- **Produced Water:** Total produced water volume for the state was 10,715 bbls.
- **Water Management Practice:** Injection for disposal by operators represented 100% of the produced water management practice in the state with 10,701 bbls.
- **Ratios:** WOR = 1.7; WGR = Insufficient data.
- **State Ranking:** Total Crude Oil and Condensate = 32<sup>nd</sup>  
Total Natural Gas Production = 32<sup>nd</sup>  
Total Produced Water Volume = 31<sup>st</sup>

### 5.3.2 Production and Produced Water Data

When compared to previous GWPC studies (2012, 2017), produced water volumes decreased a substantial 52% between 2012 (81,000 bbls) and 2017 (38,786 bbls), and 72% between 2017 and 2021 (10,715 bbls). Consistent with the decrease, the number of producing wells also declined from 2017 to 2021, with a loss of 14 wells.

The percentage of water produced from the conventional development of crude oil accounted for 100% of the states reported produced water production in 2021 (refer to **Table 5-6**).

### 5.3.3 Produced Water Management Practices

Based on data received from the AOGCM for 2021, 100% of the state's produced water (10,701 bbls) was injected for disposal (refer to **Table 5-6**). The state reported no beneficial reuse of produced water in 2021.



Table 5-5: Oil and Gas Production for Arizona by Development Method - 2021

| Type of Hydrocarbon  | Number of Wells Producing | Total Volume of Produced Water Brought to Surface (bbl/year) | Volume of Hydrocarbon Produced   |
|--|---------------------------|--|----------------------------------|
| <b>Conventional Formations</b>   |                           |  |                                  |
| Crude oil  | 20                        | 10,715   | 6,379 bbl                        |
| Natural gas  | 8                         | 0  | 77.68 Mmcf                       |
| Other  | 0                         | 0  | 0                                |
| <b>Unconventional Formations</b>   |                           |  |                                  |
| Crude oil  | 0                         | 0  | 0                                |
| Natural gas  | 0                         | 0  | 0                                |
| Other (Condensate, etc.)   | 0                         | 0  | 0                                |
| <b>Total</b>   | <b>28</b>                 | <b>10,715</b>  | <b>6,379 bbls<br/>77.68 Mmcf</b> |
| <b>Note:</b> Data provided in Table 5-5 represents tallied results from ADEQ Form 14 (Report of Injection Project) and Form 16 (Monthly Producers Report). The number of reported wells was tabulated from the Producers Report. |                           |  |                                  |

Table 5-6: Produced Water Management Practices for Arizona - 2021

| Management Practice   | Total Volume of Produced Water Managed by that Practice (bbl/year) | Percentage of Produced Water Managed by that Practice |
|---|--|---|
| Injection for Enhanced Recovery   | 0  | 0%  |
| Injection for Disposal (By Operator)  | 10,701   | 100%  |
| Injection for Disposal (Commercial / Offsite)<br>(3rd Party Managed Produced Water) | 0  | 0%  |
| Surface Water Discharge<br>(Ocean, Lake, Pond, Stream)                              | 0  | 0%  |
| Surface Discharge (Land Application)  | 0  | 0%  |
| Evaporation (Lined Sump)  | 0  | 0%  |
| Evaporation / Infiltration (Unlined Sump)   | 0  | 0%  |
| Sale / Transfer – Domestic Use  | 0  | 0%  |
| Sale / Transfer – Other Oil & Gas Operator  | 0  | 0%  |
| Reuse Within the Oil & Gas Industry   | 0  | 0%  |
| Reuse Outside the Oil & Gas Industry  | 0  | 0%  |
| Other   | 0  | 0%  |
| <b>Total</b>  | <b>10,701</b>  | <b>100%</b>   |

## 5.4 Arkansas

### 5.4.1 Introduction

The Arkansas Oil and Gas Commission (AOGC) is responsible for regulating oil and gas in the state, with an objective of conserving these resources while protecting the environment during the production, extraction, and transportation of those resources. Below is a list of key considerations developed after questionnaire data compilation and assessment. **Tables 5-7** and **5-8** present 2021 production data.

- **Production:** The state reported 17,593 hydrocarbon wells that produced 4,211,260 bbls of oil, 447,881.07 Mmcf of natural gas, and no condensate.
- **Combined BOE:** 4,285,906.85
- **Produced Water:** Total produced water volume for the state was 357,375,154 bbls: 349,429,494 bbls from oil development and 7,945,660 bbls from natural gas development.
- **Water Management Practice:** 319,668,490 bbls (89.8%) of produced water is disposed of via injection.
- **Ratios:**
  - Combined WOR = 83.0; WGR = 17.7
  - Conventional WOR = Insufficient data, WGR = 10.9
  - Unconventional WOR = Insufficient data, WGR = 18.9
- **State Ranking:** Total Crude Oil and Condensate = 21<sup>st</sup>  
Total Natural Gas Production = 13<sup>th</sup>  
Total Produced Water Volume = 12<sup>th</sup>

### 5.4.2 Production and Produced Water Data

When compared to the previous GWPC studies (2012, 2017), produced water volumes increased 71% between 2012 (184,867,000 bbls) and 2017 (315,958,569 bbls); and an additional 13% increase between 2017 and 2021 (357,375,154 bbls). The number of producing wells from 2017 to 2021 decreased by 308.

Produced water from unconventional crude oil production was approximately 98% of the total while the remaining 2% was from conventional and unconventional natural gas wells. The ratio for conventional oil and gas production was identical (refer to **Table 5-7**).

The state noted wells in existence prior to 1939 are not covered by AOGC's production reporting regulations and not required to report hydrocarbon or water production. According to the AOGC, these "uncontrolled" production wells account for approximately a third of the state's total wells. In addition, the AOGC reported that some water production is inferred by assuming SWD injection wells associated with these uncontrolled production wells represents the produced water volumes for those wells.

### 5.4.3 Produced Water Management Practices

Based on data received from the AOGC for 2021, 319,668,490 bbls (89.8%) of produced water was injected for disposal by operator, while 37,706,664 bbls (10%) was used for EOR projects (refer to **Table 5-8**). The state does not collect beneficial reuse data; however, the AOGC noted the practice is minimal as drilling activity has declined since 2017.

Table 5-7: Oil and Gas Production for Arkansas by Development Method - 2021

| Type of Hydrocarbon   | Number of Wells Producing | Total Volume of Produced Water Brought to Surface (bbl/year) | Volume of Hydrocarbon Produced   |
|---|---------------------------|--|----------------------------------|
| <b>Conventional Formations</b>  |                           |  |                                  |
| Crude oil   | 7,677                     | 349,429,494  | 4,211,260 bbl                    |
| Natural gas   | 4,090                     | 727,851  | 66,939.49 Mmcf                   |
| Other (Condensate, etc.)  | 0                         | 0  | 0                                |
| <b>Unconventional Formations</b>  |                           |  |                                  |
| Crude oil   | 0                         | 0  | 0                                |
| Natural gas   | 5,826                     | 7,217,809  | 380,941.58 Mmcf                  |
| Other (Condensate, etc.)  | 0                         | 0  |                                  |
| <b>Total</b>  | 17,593                    | 357,375,154  | 4,211,260 bbl<br>447,881.07 Mmcf |
| <b>Note:</b> Lastly, AOGC reported that the brine industry, which is unrelated to the crude oil industry water reports, in many cases get included in queries of produced water production related to oil and gas produced water. |                           |  |                                  |

Table 5-8: Produced Water Management Practices for Arkansas - 2021

| Management Practice   | Total Volume of Produced Water Managed by that Practice (bbl/year) | Percentage of Produced Water Managed by that Practice |
|---|--|---|
| Injection for Enhanced Recovery   | 37,706,664   | 10%   |
| Injection for Disposal (By Operator)  | 319,668,490  | 89.8%   |
| Injection for Disposal (Commercial / Offsite)<br>(3rd Party Managed Produced Water) | 0  | 0   |
| Surface Water Discharge<br>(Ocean, Lake, Pond, Stream)                              | 0  | 0   |
| Surface Discharge (Land Application)  | 0  | 0   |
| Evaporation (Lined Sump)  | 0  | 0   |
| Evaporation / Infiltration (Unlined Sump)   | 0  | 0   |
| Offsite Commercial Disposal   | 1,082,421  | 0.2%  |
| Reuse Within the Oil & Gas Industry   | 0  | 0   |
| Reuse Outside the Oil & Gas Industry  | 0  | 0   |
| Other   |  |   |
| <b>Total</b>  | 358,457,575  | 100%  |
| <b>Note:</b> AOGC used the 2017 Table 2 to response to the 2021 Questionnaire       |  |   |

## 5.5 California

### 5.5.1 Introduction

The California Department of Conservation (CDOC), Geologic Energy Management Division (CalGEM), has been regulating oil and gas activities in the state since January 1, 2020. CalGEM's authority extends from onshore to three miles offshore and is responsible for protecting human health and safety, and the environment from oil and gas related drilling and operations. While California is a top-10 oil-producing state, production has been declining since the mid-1980s, and CalGEM is tasked with advancing California's goal to become carbon-neutral by 2045.

CalGEM does not differentiate between unconventional and conventional production; therefore, the volumes of produced water and hydrocarbons reported represent the total. Below is a list of key considerations developed after questionnaire data compilation and assessment. **Tables 5-9** and **5-10** present 2021 production data.

- **Production:** The state reported 82,293 hydrocarbon wells that produced 137,117,236 bbls of oil, 121,534 Mmcf of natural gas, and 0 bbls of condensate (*included with crude oil volumes*).
- **Combined BOE:** 157,372,960
- **Produced Water:** Total produced water volume for the state was 3,094,296,830 bbls, to include 10,337,444 bbls from water source wells.
- **Water Management Practice:** The largest volume of produced water management by practice was injection for enhanced recovery with 1,540,731,145 bbls, or 49.79%.
- **Ratios:** WOR = 22.3; WGR = 266.4
- **State Ranking:** Total Crude Oil and Condensate = 8<sup>th</sup>  
Total Natural Gas Production = 16<sup>th</sup>  
Total Produced Water Volume = 3<sup>rd</sup>

### 5.5.2 Production and Produced Water Data

When compared to the previous GWPC studies (2012, 2017), produced water volumes have only slightly increased ~2% from 2012 (3,074,585,000 bbls) to 2017 (3,134,503,023 bbls). Volumes decreased 1.28% from between 2017 and 2021 (3,094,296,830 bbls). Aggregate volumes of produced water include reported and estimated volumes from WellStar, and when comparing well counts to 2017, the number of hydrocarbon producing wells in the state increased by 31,997 wells. The state did report that well types (i.e., active, shut-in, idle) can change annually for a given well and well counts are thus approximations, which may account for the large discrepancy in wells observed when comparing 2017 and 2021 data.

Produced water from crude oil production accounted for nearly 99% of the state's total produced water, while the remaining ~1 percent was associated with natural gas development and water source wells.

### 5.5.3 Produced Water Management Practices

Based on data received from the CalGEM for 2021, 49.79% of the produced water in the state was injected for EOR, and 15.75% was injected for disposal by operator. An additional 265,760,348 bbls (8.59%) and 59,263,489 bbls (1.92%) was disposed of offsite at commercial disposal facilities or reused outside of the industry, respectively (refer to **Table 5-10**). CalGEM also reported that 612,185,936 bbls, or 19.78% of the produced water, is unaccounted for; however, the state did report monthly production and quarterly reporting errors may occur when the same wells are reported to the state multiple times per month or when operators miss quarterly reporting. Lastly, CalGEM indicated they do not separate volumes of produced water disposed of at private versus commercial facilities.

Table 5-9: Oil and Gas Production for California by Development Method - 2021

| Type of Hydrocarbon   | Number of Wells Producing | Total Volume of Produced Water Brought to Surface (bbl/year) | Volume of Hydrocarbon Produced           |
|---|---------------------------|--|--|
| <b>Conventional Formations</b>  |                           |  |  |
| Crude oil   | 79,931                    | 3,051,577,137  | 137,117,236 bbls                         |
| Natural gas   | 2,246                     | 32,382,249   | 121,534 Mmcf                             |
| Other (water source wells)  | 116                       | 10,337,444   | 0  |
| <b>Unconventional Formations</b>  |                           |  |  |
| Crude oil   | 0                         | 0  | 0  |
| Natural gas   | 0                         | 0  | 0  |
| Other (Condensate, etc.)  | 0                         | 0  | 0  |
| <b>Total</b>  | <b>82,293</b>             | <b>3,094,296,830</b>   | <b>137,117,236 bbls<br/>121,534 Mmcf</b> |
| <b>Note:</b> CalGEM reported condensate volumes are included with crude oil volumes and water source wells are used to support oil and gas operations and can be in either oil, or gas fields. The state also reported hydrocarbon volumes are based on reported and estimated volumes. |                           |  |  |

Table 5-10: Produced Water Management Practices for California - 2021

| Management Practice   | Total Volume of Produced Water Managed by that Practice (bbl/year) | Percentage of Produced Water Managed by that Practice |
|---|--|---|
| Injection for Enhanced Recovery   | 1,540,731,145  | 49.79%  |
| Injection for Disposal (By Operator)  | 487,399,151  | 15.75%  |
| Injection for Disposal (Commercial / Offsite)<br>(3rd Party Managed Produced Water) | 0  | 0%  |
| Surface Water Discharge<br>(Ocean, Lake, Pond, Stream)                              | 2,369,726  | 0.08%   |
| Surface Discharge (Land Application)  | 3,800,378  | 0.12%   |
| Evaporation (Lined Sump)  | 2,246,605  | 0.07%   |
| Evaporation / Infiltration (Unlined Sump)   | 23,393,231   | 0.76%   |
| Sale / Transfer – Domestic Use  | 265,760,348  | 8.59%   |
| Sale / Transfer – Other Oil & Gas Operator  | 30,745,992   | 0.99%   |
| Reuse Within the Oil & Gas Industry   | 59,263,489   | 1.92%   |
| Reuse Outside the Oil & Gas Industry  | 7,792,195  | 0.25%   |
| Other   | 58,608,634   | 1.89%   |
| Other Unaccounted for per CalGEM  | 612,185,936  | 19.78%  |
| <b>Total</b>  | <b>3,094,296,830</b>   | <b>100%</b>   |

## 5.6 Colorado

### 5.6.1 Introduction

The Colorado Oil and Gas Conservation Commission (COGCC) regulates the development and production oil and gas in the state and does so in a manner that protects public health, safety, welfare, the environment, and wildlife resources. Below is a list of key considerations developed after questionnaire data compilation and assessment. **Tables 5-11** and **5-12** present 2021 production data

- **Production:** The state reported 60,450 hydrocarbon wells that produced 153,495,589.11 bbls of oil, 1,956,843.46 Mmcf of natural gas, and 0 bbls of condensate.
- **Combined BOE:** 479,636,165.83
- **Produced Water:** Total produced water volume for the state was 280,460,737 bbls.
- **Water Management Practice:** Disposal of produced water via injection is the largest management practice (55.76%) in the state with 319,668,490 bbls.
- **Ratios:**
  - Combined WOR = 1.24; WGR = 45.81
  - Conventional WOR = 16.5, WGR = 96.5
  - Unconventional WOR = 0.5, WGR = 7.9
- **State Ranking:** Total Crude Oil and Condensate = 32<sup>nd</sup>  
Total Natural Gas Production = 32<sup>nd</sup>  
Total Produced Water Volume = 30<sup>th</sup>

When compared to the previous GWPC studies (2012, 2017), produced water volume trends in Colorado decreased ~13% in volume between 2012 (358,389,000 bbls) and 2017 (310,650,278 bbls), and 15% in volume between 2017 and 2021 (280,460,737 bbls). The number of producing wells decreased by 12,053 from 2017 to 2021 hydrocarbon.

Produced water from crude oil production was approximately 68% of the total, while the remaining 32% was from conventional and unconventional natural gas wells. Produced water from conventional development (73%) was a sizable portion of the total water volume, while water from unconventional development was ~24% of the total (refer to **Table 5-11**).

### 5.6.2 Produced Water Management Practices

Based on data received from the COGCC for 2021, 157,335,767 bbls (55.76%) of produced water was injected for disposal, while 87,244,195 bbls (30.92%) was used for EOR projects (refer to **Table 5-12**). In addition, the state tracks beneficial reuse of produced water, which was 6.95% of the total produced water volume. Specific beneficial reuses were not provided.

Per the 2017 report, the produced water management data COGCC provided did not match the categories provided in the questionnaire and in some cases required extrapolation, assumptions, or relocation in order to make the data consistent and relative.<sup>13</sup> Consequently, conclusions associated with the 2017 data indicated the reported volumes were estimates per category. For comparative purposes, the data received by the COGCC in 2021 included a completed questionnaire spreadsheet table and did not require any modification to calculate water volumes by management practice category.

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<sup>13</sup> Veil, John. U.S. Produced Water Volumes and Management Practices in 2017. Prepared for the Ground Water Research and Education Foundation. February 2020.

Table 5-11: Oil and Gas Production for Colorado by Development Method - 2021

| Type of Hydrocarbon   | Number of Wells Producing | Total Volume of Produced Water Brought to Surface (bbl/year) | Volume of Hydrocarbon Produced             |
|---|---------------------------|--|--|
| <b>Conventional Formations</b>  |                           |  |  |
| Crude oil   | 3,587                     | 124,023,603  | 7,517,958 bbl                              |
| Natural gas   | 27,032                    | 80,844,773   | 837,830 Mmcf                               |
| Other (Condensate, etc.)  | 0                         | 0  | 0  |
| <b>Unconventional Formations</b>  |                           |  |  |
| Crude oil   | 6,766                     | 66,790,088   | 145,977,631 bbl                            |
| Natural gas   | 2,799                     | 8,802,273  | 1,119,013 Mmcf                             |
| Other (Condensate, etc.)  |                           |  |  |
| <b>Total</b>  | <b>40,184</b>             | <b>280,460,737</b>   | <b>153,495,589 bbls<br/>1,956,843 Mmcf</b> |
| <b>Note:</b> As COGCC reported, wells in Colorado often produce both liquids and gases, so while the volume of hydrocarbons produced are distinct for conventional and unconventional categories, they are not separated by the type of hydrocarbons. For example, the volume of hydrocarbon produced for conventional crude oil will include only oil produced from conventional crude oil wells and conventional natural gas wells; and the volume of hydrocarbon produced for conventional natural gas will include natural gas produced from conventional crude oil wells and conventional natural gas wells. |                           |  |  |

Table 5-12: Produced Water Management Practices for Colorado – 2021

| Management Practice   | Total Volume of Produced Water Managed by that Practice (bbl/year) | Percentage of Produced Water Managed by that Practice |
|---|--|---|
| Injection for Enhanced Recovery   | 87,244,195   | 30.92%  |
| Injection for Disposal (By Operator)  | 157,335,767  | 55.76%  |
| Injection for Disposal (Commercial / Offsite)<br>(3rd Party Managed Produced Water) | 4,509,244  | 1.60%   |
| Surface Water Discharge<br>(Ocean, Lake, Pond, Stream)                              | 13,476,468   | 4.78%   |
| Surface Discharge (Land Application)  | 0  | 0%  |
| Evaporation (Lined Sump)  | 0  | 0%  |
| Evaporation / Infiltration (Unlined Sump)   | 9,672  | <0.01%  |
| Sale / Transfer – Domestic Use  | 0  | 0%  |
| Sale / Transfer – Other Oil & Gas Operator  | 0  | 0%  |
| Reuse Within the Oil & Gas Industry   | 19,606,1060  | 6.95%   |
| Reuse Outside the Oil & Gas Industry  | 0  | 0%  |
| Other   | 0  | 0%  |
| <b>Total</b>  | <b>0</b>   | <b>0%</b>   |

## 5.7 Florida

### 5.7.1 Introduction

The Florida Department of Environmental Protection (FDEP) Oil and Gas Program is responsible for the conservation of oil and gas resources, correlative rights protection, health and human safety, and protection of the environment. Pertinent regulations of the FDEP are enforced through a system of permits and field inspections to ensure compliance. FDEP did not complete the questionnaire instead, total crude oil, natural gas, and produced water volumes for the state were obtained from the FDEP's Electronic Document Management System (EDMS), referred to as OCULUS.

Based on a review of this data, the FDEP does not differentiate between unconventional and conventional production; therefore, the volume of produced water and hydrocarbons developed from unconventional formations is not discrete. Below is a list of key considerations developed after questionnaire data compilation and assessment. **Tables 5-13** and **5-14** present 2021 production data.

- **Production:** The state reported 84 hydrocarbon wells that produced 1,490,492 bbls of crude oil; 14,957.22 Mmcf of natural gas; and 0 bbls condensate.
- **Combined BOE:** 3,983,362
- **Produced Water:** Total produced water volume reported for the state was 41,393,747 bbls.
- **Water Management Practice:** The largest volume of produced water management by practice was injection for enhance recovery with 35,033,182 bbls or 84.6%.
- **Ratios:** WOR = Insufficient data; WGR = Insufficient data.
- **State Ranking:** Total Crude Oil and Condensate = 24<sup>th</sup>  
Total Natural Gas Production = 23<sup>rd</sup>  
Total Produced Water Volume = 20<sup>th</sup>

### 5.7.2 Production and Produced Water Data

When compared to the previous GWPC studies (2012, 2017), produced water volumes decreased ~41% between 2012 (62,641,000 bbls) and 2017 (58,673,032 bbls); and an additional 29% from 2017 to 2021 (41,393,747 bbls). The number of hydrocarbon producing wells decreased by 19 wells (25%) from 2017 to 2021.

### 5.7.3 Produced Water Management Practices

Based on FDEP data for 2021, 84.63% of the produced water in the state was injected for EOR, while the remaining 15.37% was injected for disposal by operator (refer to **Table 5-14**). As FDEP reported, the northwest oil and gas fields utilized EOR, while the south fields used injection for disposal by operator. The state reported no beneficial re-use of produced water in 2021.



**Table 5-13: Oil and Gas Production for Florida by Development Method - 2021**

| Type of Hydrocarbon   | Number of Wells Producing | Total Volume of Produced Water Brought to Surface (bbl/year) | Volume of Hydrocarbon Produced   |
|---|---------------------------|--|----------------------------------|
| <b>Conventional Formations</b>  |                           |  |                                  |
| Crude oil   | 84                        | 0  | 1,490,492 bbl                    |
| Natural gas   |                           | 0  | 14,957.22 Mmcf                   |
| Other (Condensate, etc.)  | 0                         | 0  | 0                                |
| <b>Unconventional Formations</b>  |                           |  |                                  |
| Crude oil   | 0                         | 0  | 0                                |
| Natural gas   | 0                         | 0  | 0                                |
| Other (Condensate, etc.)  | 0                         | 0  | 0                                |
| <b>Total</b>  | 84                        | 41,393,747   | 1,490,492 bbls<br>14,957.22 Mmcf |
| <b>Note:</b> Well status data does not distinguish between crude oil and natural gas wells. |                           |  |                                  |

**Table 5-14: Produced Water Management Practices for Florida - 2021**

| Management Practice  | Total Volume of Produced Water Managed by that Practice (bbl/year) | Percentage of Produced Water Managed by that Practice |
|--|--|---|
| Injection for Enhanced Recovery  | 35,033,182   | 84.63   |
| Injection for Disposal (By Operator)   | 6,360,565  | 15.37   |
| Injection for Disposal (Commercial / Offsite)<br>(3rd Party Managed Produced Water)  | 0  | 0   |
| Surface Water Discharge<br>(Ocean, Lake, Pond, Stream)   | 0  | 0   |
| Surface Discharge (Land Application)   | 0  | 0   |
| Evaporation (Lined Sump)   | 0  | 0   |
| Evaporation / Infiltration (Unlined Sump)  | 0  | 0   |
| Sale / Transfer – Domestic Use   | 0  | 0   |
| Sale / Transfer – Other Oil & Gas Operator   | 0  | 0   |
| Reuse Within the Oil & Gas Industry  | 0  | 0   |
| Reuse Outside the Oil & Gas Industry   | 0  | 0   |
| Other  | 0  | 0   |
| <b>Total</b>   | 41,393,747   |   |
| <b>Note:</b> As reported by the FDEP, the northwest oil and gas fields in Florida dispose of their water by enhanced recovery, while the south fields disposed of produced water by injection for disposal by operator. Data was obtained for the state's Oculus database. |  |   |

## 5.8 Idaho

### 5.8.1 Introduction

The Idaho Oil and Gas Conservation Commission (IOGCC) regulates the exploration, drilling and production of oil and gas resources to ensure the conservation of oil and gas and the protection of surface and groundwater. The Oil and Gas Program in Idaho resides under the Minerals, Navigable Waters, and Oil and Gas Division within the Idaho Department of Lands. Production data from the questionnaire included natural gas and condensate production from conventional formations. Below is a list of key considerations developed after questionnaire data compilation and assessment. **Tables 5-15** and **5-16** present pertinent 2021 production data.

- **Production:** The state reported seven (7) natural gas wells that produced 1,359.36 Mmcf of natural gas and 25,500 bbls of condensate.
- **Combined BOE:** 226,559.50
- **Produced Water:** Total produced water volume from natural gas development was 7,314 bbls. No other produced water volume production was reported.
- **Water Management Practice:** All produced water in the state (7,314 bbls) is disposed of via evaporation.
- **Ratios:** WOR = Insufficient data; WGR = 5.4
- **State Ranking:** Total Crude Oil and Condensate = 31<sup>st</sup>  
Total Natural Gas Production = 29<sup>th</sup>  
Total Produced Water Volume = 32<sup>nd</sup>

### 5.8.2 Production and Produced Water Data

When compared to the previous GWPC study (2017), produced water volumes in Idaho declined 92% between 2017 (91,556 bbls) and 2021 (7,314 bbls). The IOGCC reported the number of producing wells from 2017 to 2021 decreased by one well.

The percentage of water produced from conventional development accounted for 100% of the total water volume (refer to **Table 5-15**).

### 5.8.3 Produced Water Management Practices

Based on data received from the IOGCC for 2021, 7,314 bbls (100%) of produced water was disposed of by evaporation (refer to **Table 5-16**). The state reported no beneficial re-use of produced water in 2021.

Table 5-15: Oil and Gas Production for Idaho by Development Method - 2021

| Type of Hydrocarbon       | Number of Wells Producing | Total Volume of Produced Water Brought to Surface (bbl/year) | Volume of Hydrocarbon Produced |
|---------------------------|---------------------------|--|--------------------------------|
| Conventional Formations   |                           |  |                                |
| Crude oil                 | 0                         | 0  | 0                              |
| Natural gas               | 7                         | 7,314  | 1,359.36 Mmcf                  |
| Other (Condensate, etc.)  |                           | 0  | 25,500 bbls                    |
| Unconventional Formations |                           |  |                                |
| Crude oi                  | 0                         | 0  | 0                              |
| Natural gas               | 0                         | 0  | 0                              |
| Other (Condensate, etc.)  | 0                         | 0  | 0                              |
| Total                     | 7                         | 7,314  | 1,359.36 Mmcf<br>25,500 bbls   |

Table 5-16: Produced Water Management Practices for Idaho - 2021

| Management Practice   | Total Volume of Produced Water Managed by that Practice (bbl/year) | Percentage of Produced Water Managed by that Practice |
|---|--|---|
| Injection for Enhanced Recovery   | 0  | 0%  |
| Injection for Disposal (By Operator)  | 0  | 0%  |
| Injection for Disposal (Commercial / Offsite)<br>(3rd Party Managed Produced Water) | 0  | 0%  |
| Surface Water Discharge<br>(Ocean, Lake, Pond, Stream)                              | 0  | 0%  |
| Surface Discharge (Land Application)  | 0  | 0%  |
| Evaporation (Lined Sump)  | 7,314  | 100%  |
| Evaporation / Infiltration (Unlined Sump)   | 0  | 0%  |
| Sale / Transfer – Domestic Use  | 0  | 0%  |
| Sale / Transfer – Other Oil & Gas Operator  | 0  | 0%  |
| Reuse Within the Oil & Gas Industry   | 0  | 0%  |
| Reuse Outside the Oil & Gas Industry  | 0  | 0%  |
| Other   | 0  | 0%  |
| <b>Total</b>  | <b>7,314</b>   | <b>100%</b>   |

## 5.9 Illinois

### 5.9.1 Introduction

The Illinois Department of Natural Resources, Office of Oil and Gas Resource Management (OOGRM) is the regulatory authority in Illinois for permitting, drilling, operating, and plugging oil and gas production wells. The Office implements the Illinois Oil and Gas Act and enforces standards for the construction and operation of related production equipment and facilities. Illinois completed the questionnaire, although the produced water volume only represented 30.5% of the state's total reporting wells. In addition, natural gas volumes were from reporting year 2020, and hydrocarbon production data and produced water volumes were not reported for unconventional development. Below is a list of key considerations developed after questionnaire data compilation and assessment. **Tables 5-17** and **5-18** present reported production data.

- **Production:** The state reported 21,067 hydrocarbon wells that produced 7,390,000 bbls of crude oil; 1,843 Mmcf of natural gas; and 0 bbls condensate.
- **Combined BOE:** 7,697,166.67
- **Produced Water:** Total produced water volume for the state was ~4,591,349,632 bbls (*value was extrapolated from 30.5% of the state's reporting wells*).
- **Water Management Practice:** The largest volume of produce water managed by practice was injection for enhanced recovery, or 78.9% of the state's total water volume (*value was extrapolated from 30.5% of the state's reporting wells*).
- **Ratios:** WOR = Insufficient data; WGR = Insufficient data
- **State Ranking:** Total Crude Oil and Condensate = 17<sup>th</sup>  
Total Natural Gas Production = 28<sup>th</sup>  
Total Produced Water Volume = 2<sup>nd</sup>

### 5.9.2 Production and Produced Water Data

When compared to the previous GWPC studies (2012, 2017), produced water volumes increased 185% from 2012 (99,142,000) to 2017 (282,599,989). Water volumes also increased greater than 1,000% from 2017 to 2021 (4,591,349,632 bbls); however, as previously noted, water volume data was extrapolated from 30.5% of the reporting wells and may not provide a correct value of the total produced water volume in the state for reporting year 2021 (refer to **Table 5-17**). However, Illinois DNR-OOGRM also provided data for 2019 and revised data for 2017 that reflected the injection volumes from near 100% of all UIC wells. Therefore, the extrapolated volume for 2021 appears to be in line with this supporting information. Note, accounting for EOR volumes creates the possibility for elevated volumes due to the round-trip nature of EOR injection, EOR is a significant methodology employed to maintain production in Illinois.

### 5.9.3 Produced Water Management Practices

Based on 2021 OOGRM data, 78.94% of the produced water in the state was injected for EOR, while 21.06% was injected for disposal by operator (refer to **Table 5-18**). The state did not report any beneficial reuse of produced water in 2021.

Table 5-17: Oil and Gas Production for Illinois by Development Method - 2021

| Type of Hydrocarbon                                       | Number of Wells Producing | Total Volume of Produced Water Brought to Surface (bbl/year) | Volume of Hydrocarbon Produced       |
|---|---------------------------|--|--------------------------------------|
| <b>Conventional Formations</b>                            |                           |  |                                      |
| Crude oil   | 20,766                    | 0  | 7,390,000 bbl                        |
| Natural gas   | 301                       | 0  | 1,843 Mmcf                           |
| Other (Condensate, etc.)                                  | 0                         | 0  | 0                                    |
| <b>Unconventional Formations</b>                          |                           |  |                                      |
| Crude oil   | 0                         | 0  | 0                                    |
| Natural gas   | 0                         | 0  | 0                                    |
| Other (Condensate, etc.)                                  | 0                         | 0  | 0                                    |
| <b>Total</b>  | <b>21,067</b>             | <b>4,591,349,632</b>   | <b>7,390,000 bbls<br/>1,843 Mmcf</b> |
| <b>Note:</b> OOGRM reported natural gas volumes for 2020. |                           |  |                                      |

Table 5-18: Produced Water Management Practices for Illinois - 2021

| Management Practice  | Total Volume of Produced Water Managed by that Practice (bbl/year) | Percentage of Produced Water Managed by that Practice |
|--|--|---|
| Injection for Enhanced Recovery  | 3,624,249,956  | 78.94%  |
| Injection for Disposal (By Operator)   | 967,099,675  | 21.06%  |
| Injection for Disposal (Commercial / Offsite)<br>(3rd Party Managed Produced Water)  | 0  | 0%  |
| Surface Water Discharge<br>(Ocean, Lake, Pond, Stream)   | 0  | 0%  |
| Surface Discharge (Land Application)   | 0  | 0%  |
| Evaporation (Lined Sump)   | 0  | 0%  |
| Evaporation / Infiltration (Unlined Sump)  | 0  | 0%  |
| Sale / Transfer – Domestic Use   | 0  | 0%  |
| Sale / Transfer – Other Oil & Gas Operator   | 0  | 0%  |
| Reuse Within the Oil & Gas Industry  | 0  | 0%  |
| Reuse Outside the Oil & Gas Industry   | 0  | 0%  |
| Other  | 0  | 0%  |
| <b>Total</b>   | <b>4,591,349,631</b>   | <b>100%</b>   |
| <b>Note:</b> The OOGRM provided produced water volumes for 30.5% of the state's reporting wells. Water volumes presented in this table were extrapolated per the number of wells versus reported volumes to estimate the total (100%) produced water volume for the state. |  |   |

## 5.10 Indiana

### 5.10.1 Introduction

The Indiana Department of Natural Resources (IDNR), Division of Oil and Gas oversees oil and gas operations in the state and provides the regulatory framework to conserve energy resources and protect the environment. Except for the number of wells, the IDNR does not differentiate between unconventional and conventional production of hydrocarbons or produced water. Additionally produced water volumes are estimated based on the volume of water injected and are not differentiated by well source type. Below is a list of key considerations developed after questionnaire data compilation and assessment. **Tables 5-19** and **5-20** present 2021 production data.

- **Production:** The state reported 4,899 hydrocarbon wells that produced 1,521,075 bbls of crude oil; 4,135 Mmcf of natural gas; and 0 bbls of condensate.
- **Combined BOE:** 1,521,764.26
- **Produced Water:** Total produced water volume for the state was ~53,494,095 bbls (*estimated based on the amount of water injected*).
- **Water Management Practice:** 38,651,684 bbls (72.25%) of produced water is disposed of via enhanced recovery projects.
- **Ratios:** WOR = 32.2; WGR = Insufficient data
- **State Ranking:** Total Crude Oil and Condensate = 23<sup>rd</sup>  
Total Natural Gas Production = 25<sup>th</sup>  
Total Produced Water Volume = 16<sup>th</sup>

### 5.10.2 Production and Produced Water Data

When compared to previous GWPC studies (2012, 2017), produced water volumes remained relatively constant, with an approximate reduction of 12% between 2012 (57,566,000 bbls) and 2017 (50,797,713 bbls), and a 5% increase between 2017 and 2021 (~53,494,095 bbls). The number of producing wells from 2017 (5,317) to 2021 (4,889) declined by 8%, or 428 wells.

### 5.10.3 Produced Water Management Practices

Based on 2021 IDNR data, 38,651,684 bbls (72.25%) of produced water was injected for EOR projects while 14,842,411 bbls (27.75%) was injected for disposal (refer to **Table 5-20**). The state did not report any beneficial reuse of produced water in 2021.

Table 5-19: Oil and Gas Production for Indiana by Development Method - 2021

| Type of Hydrocarbon  | Number of Wells Producing | Total Volume of Produced Water Brought to Surface (bbl/year) | Volume of Hydrocarbon Produced  |
|--|---------------------------|--|---------------------------------|
| <b>Conventional Formations</b>   |                           |  |                                 |
| Crude oil  | 4,236                     | ~53,494,095  | 1,521,075 bbl                   |
| Natural gas  | 386                       | 0  | 4135.58 Mmcf                    |
| Other (Condensate, etc.)   | 0                         | 0  |                                 |
| <b>Unconventional Formations</b>   |                           |  |                                 |
| Crude oil  | 10                        | 0  | 0                               |
| Natural gas  | 267                       | 0  | 0                               |
| Other (Condensate, etc.)   | 0                         | 0  | 0                               |
| <b>Total</b>   | 4,899                     | ~53,494,095  | 1,521,075 bbls<br>4,135.58 Mmcf |
| <b>Note:</b> Production numbers are provided by the Department of Revenue as total production that they receive from crude oil or gas purchasers. The volume of produced water is estimated based on the amount of water injected and is not differentiated between oil and gas wells. |                           |  |                                 |

Table 5-20: Produced Water Management Practices for Indiana - 2021

| Management Practice   | Total Volume of Produced Water Managed by that Practice (bbl/year) | Percentage of Produced Water Managed by that Practice |
|---|--|---|
| Injection for Enhanced Recovery   | 38,651,684   | 72.25%  |
| Injection for Disposal (By Operator)  | 14,842,411   | 27.75%  |
| Injection for Disposal (Commercial / Offsite)<br>(3rd Party Managed Produced Water) | 0  | 0%  |
| Surface Water Discharge<br>(Ocean, Lake, Pond, Stream)                              | 0  | 0%  |
| Surface Discharge (Land Application)  | 0  | 0%  |
| Evaporation (Lined Sump)  | 0  | 0%  |
| Evaporation / Infiltration (Unlined Sump)   | 0  | 0%  |
| Sale / Transfer – Domestic Use  | 0  | 0%  |
| Sale / Transfer – Other Oil & Gas Operator  | 0  | 0%  |
| Reuse Within the Oil & Gas Industry   | 0  | 0%  |
| Reuse Outside the Oil & Gas Industry  | 0  | 0%  |
| Other   | 0  | 0%  |
| <b>Total</b>  | 53,494,095   | 100%  |

## 5.11 Kansas

### 5.11.1 Introduction

The Kansas Corporation Commission (KCC) regulates oil and gas in the state with a mission to protect correlative rights and environmental resources with effective oversight of oil and gas exploration and production activities. The KCC does distinguish between conventional and unconventional development and does not track produced water volumes. However, the state did report total produced water volume by management practice, which was used to approximate a total volume of produced water for the state. Below is a list of key considerations developed after questionnaire data compilation and assessment. **Tables 5-21** and **5-22** present 2021 production data.

- **Production:** The state reported 72,161 hydrocarbon wells that produced 27,908,720 bbls of crude oil; 167,849.25 Mmcf of natural gas; and 0 bbls of condensate.
- **Combined BOE:** 55,883,595.50
- **Produced Water:** Total produced water volume for the state was 1,016,408,380 bbls (*total water volume approximated from volumes reported for produced water management practices*).
- **Water Management Practice:** 760,157,395 bbls (74.79%) of produced water is disposed of via enhanced recovery projects.
- **Ratios:** WOR = Insufficient data; WGR = Insufficient data
- **State Ranking:** Total Crude Oil and Condensate = 12<sup>th</sup>  
Total Natural Gas Production = 15<sup>th</sup>  
Total Produced Water Volume = 8<sup>th</sup>

### 5.11.2 Production and Produced Water Data

When compared to previous GWPC studies (2012, 2017), produced water volumes increased 14% between 2012 (1,061,019,000 bbls) and 2017 (1,205,091,949 bbls), and ~19% from 2017 to 2021 (1,016,408,380 bbls). The number of producing wells decreased by 3,318 from 2017 to 2021 or 4.40%.

### 5.11.3 Produced Water Management Practices

Based 2021 KCC data, 760,157,395 bbls (74.79%) of produced water was disposed of via injection by operator, 256,249,232 bbls for EOR projects, and 256,249,232 bbls (25.21%) via injection for disposal (refer to **Table 5-22**). The state did not report any beneficial reuse of produced water in 2021.



Table 5-21: Oil and Gas Production for Kansas by Development Method - 2021

| Type of Hydrocarbon  | Number of Wells Producing | Total Volume of Produced Water Brought to Surface (bbl/year) | Volume of Hydrocarbon Produced            |
|--|---------------------------|--|---|
| <b>Conventional Formations</b>   |                           |  |   |
| Crude oil  | 48,695                    | 0  | 27,908,720 bbl                            |
| Natural gas  | 19,815                    | 0  | 153,832.25 Mmcf                           |
| Other (Condensate, etc.)   | 0                         | 0  | 0   |
| <b>Unconventional Formations</b>   |                           |  |   |
| Crude oil  | 0                         | 0  | 0   |
| Natural gas  | 3,651                     | 0  | 14,017 Mmcf                               |
| Other (Condensate, etc.)   | 0                         | 0  | 0   |
| <b>Total</b>   | <b>72,161</b>             | <b>1,016,408,380</b>   | <b>27,908,720 bbl<br/>167,849.25 Mmcf</b> |
| <b>Note:</b> Total volume of produced water represents reported total volume of produced water by management practice. |                           |  |   |

Table 5-22: Produced Water Management Practices for Kansas - 2021

| Management Practice   | Total Volume of Produced Water Managed by that Practice (bbl/year) | Percentage of Produced Water Managed by that Practice |
|---|--|---|
| Injection for Enhanced Recovery   | 256,249,232  | 25.21%  |
| Injection for Disposal (By Operator)  | 760,157,395  | 74.79%  |
| Injection for Disposal (Commercial / Offsite)<br>(3rd Party Managed Produced Water) | 1,753  | 0%  |
| Surface Water Discharge<br>(Ocean, Lake, Pond, Stream)                              | 0  | 0%  |
| Surface Discharge (Land Application)  | 0  | 0%  |
| Evaporation (Lined Sump)  | 0  | 0%  |
| Evaporation / Infiltration (Unlined Sump)   | 0  | 0%  |
| Sale / Transfer – Domestic Use  | 0  | 0%  |
| Sale / Transfer – Other Oil & Gas Operator  | 0  | 0%  |
| Reuse Within the Oil & Gas Industry   | 0  | 0%  |
| Reuse Outside the Oil & Gas Industry  | 0  | 0%  |
| Other   | 0  | 0%  |
| <b>Total</b>  | <b>1,016,408,380</b>   | <b>100%</b>   |

## 5.12 Kentucky

### 5.12.1 Introduction

The Kentucky Department of Natural Resources (KDNR), Division of Oil and Gas, regulates the crude oil and natural gas industry in the state and protects the rights of mineral owners, freshwater zones and minable coal seams in a manner that conserves oil and gas reserves. Oil and gas production data and produced water management data for 2020 was received via completion of the questionnaire spreadsheet tables. The KDNR does not differentiate between unconventional and conventional production; so produced water volumes and hydrocarbon production from unconventional formations is not discrete. Although the state does not track produced water volumes, the KDNR did provide the total volume of produced water by management practice, which was used to approximate the state's total volume of produced water. Below is a list of key considerations developed after questionnaire data compilation and assessment. **Tables 5-23** and **5-24** present 2020 production data.

- **Production:** The state reported 39,622 hydrocarbon wells that produced 1,429,277 bbls of crude oil; 63,578 Mmcf of natural gas; and 0 bbls of condensate.
- **Combined BOE:** 12,025,610.33
- **Produced Water:** Total produced water volume for the state was 5,642,263 bbls (*total water volume was approximated from injection for enhanced recovery projects and disposal by operator*).
- **Water Management Practice:** 5,383,959 bbls (95.42%) of produced water is disposed of from enhanced recovery projects.
- **Ratios:** WOR = Insufficient data; WGR = Insufficient data
- **State Ranking:** Total Crude Oil and Condensate = 25<sup>th</sup>  
Total Natural Gas Production = 20<sup>th</sup>  
Total Produced Water Volume = 25<sup>th</sup>

### 5.12.2 Production and Produced Water Data

When compared to previous GWPC studies (2012, 2017), produced water volumes decreased 29% between 2012 (19,689,000 bbls) and 2017 (13,913,894 bbls), and nearly 60% between 2017 and 2020 (5,642,263 bbls). The number of producing wells decreased by 7,234 (~15%) from 2017 to 2020.

### 5.12.3 Produced Water Management Practices

Based on 2020 KDNR data, 5,383,959 bbls (95.42%) of produced water were used for EOR projects and 258,304 bbls (4.58%) via injection for disposal by operator (refer to **Table 5-24**). The state did not report any beneficial reuse of produced water in 2021.

Table 5-23: Oil and Gas Production for Kentucky by Development Method - 2020

| Type of Hydrocarbon  | Number of Wells Producing | Total Volume of Produced Water Brought to Surface (bbl/year) | Volume of Hydrocarbon Produced |
|--|---------------------------|--|--------------------------------|
| <b>Conventional Formations</b>   |                           |  |                                |
| Crude oil  | 19,268                    | 0  | 1,429,277 bbl                  |
| Natural gas  | 20,354                    | 0  | 63,578 Mmcf                    |
| Other (Condensate, etc.)   | 0                         | 0  | 0                              |
| <b>Unconventional Formations</b>   |                           |  |                                |
| Crude oil  | 0                         | 0  | 0                              |
| Natural gas  | 0                         | 0  | 0                              |
| Other (Condensate, etc.)   | 0                         | 0  |                                |
| <b>Total</b>   | 39,622                    | 5,642,263  | 1,429,277 bbl<br>63,578 Mmcf   |
| <b>Note:</b> Total volume of produced water represents reported total volume of produced water by management practice. |                           |  |                                |

Table 5-24: Produced Water Management Practices for Kentucky - 2020

| Management Practice   | Total Volume of Produced Water Managed by that Practice (bbl/year) | Percentage of Produced Water Managed by that Practice |
|---|--|---|
| Injection for Enhanced Recovery   | 5,383,959  | 95.42%  |
| Injection for Disposal (By Operator)  | 258,304  | 4.58%   |
| Injection for Disposal (Commercial / Offsite)<br>(3rd Party Managed Produced Water) | 0  | 0%  |
| Surface Water Discharge<br>(Ocean, Lake, Pond, Stream)                              | 0  | 0%  |
| Surface Discharge (Land Application)  | 0  | 0%  |
| Evaporation (Lined Sump)  | 0  | 0%  |
| Evaporation / Infiltration (Unlined Sump)   | 0  | 0%  |
| Sale / Transfer – Domestic Use  | 0  | 0%  |
| Sale / Transfer – Other Oil & Gas Operator  | 0  | 0%  |
| Reuse Within the Oil & Gas Industry   | 0  | 0%  |
| Reuse Outside the Oil & Gas Industry  | 0  | 0%  |
| Other   | 0  | 0%  |
| <b>Total</b>  | 5,642,263  | 100%  |

## 5.13 Louisiana

### 5.13.1 Introduction

The Louisiana Office of Conservation (LOC) is responsible for conserving and regulating oil, gas, and lignite resources in the state and regulating the exploration and production of oil, gas and other hydrocarbons while protecting public safety and the environment from oilfield waste, including regulation of underground injection and disposal practices. Louisiana did not provide production or produced water management data via questionnaire, but such data is available on the LOC's SONRIS Data Portal.<sup>14</sup> The data did not distinguish between conventional and unconventional development or provide total produced water volumes for the state. However, volumes of produced water were available via the LOC's SONRIS portal and were used to approximate the state's total volume of produced water.

Provided below is a list of key data considerations that were developed after data compilation and assessment. In addition, **Tables 5-25** and **5-26** presents pertinent oil and gas data for 2021, as provided by the state of Louisiana.

- **Production:** The state reported 41,729 hydrocarbon wells that produced 27,866,065 bbls of crude oil; 33,793,904.66 Mmcf of natural gas; and 6,858,420 bbls of condensate.
- **Combined BOE:** 5,667,041,928.33
- **Produced Water:** Total produced water volume for the state was 796,655,259 bbls (*total water volume approximated from volumes reported for produced water management practices*).
- **Water Management Practice:** 704,851,022 bbls (88.48%) of produced water is disposed of by injection (by operator).
- **Ratios:** WOR = Insufficient data; WGR = Insufficient data
- **State Ranking:** Total Crude Oil and Condensate = 11<sup>th</sup>  
Total Natural Gas Production = 4<sup>th</sup>  
Total Produced Water Volume = 9<sup>th</sup>

### 5.13.2 Production and Produced Water Data

When compared to previous GWPC studies (2012, 2017), produced water volumes increased 7.64% from 2012 (927,635,000) to 2017 (998,519,062), however, volumes decreased from 2017 to 2021 (796,655,259) by ~20%. The number of producing wells also decreased by 2,135 wells or by 5.12%, from 2017 to 2021.

### 5.13.3 Produced Water Management Practices

Based on 2021 LOC data, the largest produced water management method by volume is injection for disposal by operator (704,851,022 bbls) or 88.48%. Other methods include EOR injection (6.06%) and injection at commercial facilities (5.46%) (refer to **Table 5-26**). The state did not report any beneficial reuse of produced water in 2021.

<sup>14</sup> SONRIS data Portal, <https://sonlite.dnr.state.la.us/pls/apex/f?p=108:2:13433454763203:::> Accessed August 2022

Table 5-25: Oil and Gas Production for Louisiana by Development Method - 2021

| Type of Hydrocarbon  | Number of Wells Producing | Total Volume of Produced Water Brought to Surface (bbl/year) | Volume of Hydrocarbon Produced       |
|--|---------------------------|--|--------------------------------------|
| <b>Conventional Formations</b>   |                           |  |                                      |
| Crude oil  | 21,627                    | 0  | 27,866,065 bbl                       |
| Natural gas  | 20,102                    | 0  | 33,793,904.66 Mmcf                   |
| Other (Condensate, etc.)   | 0                         | 0  | 6,858,420 bbl                        |
| <b>Unconventional Formations</b>   |                           |  |                                      |
| Crude oil  | 0                         | 0  | 0                                    |
| Natural gas  | 0                         | 0  | 0                                    |
| Other (Condensate, etc.)   | 0                         | 0  | 0                                    |
| <b>Total</b>   | 41,729                    | 796,655,259  | 34,724,485 bbl<br>33,793,904.66 Mmcf |
| <b>Note:</b> Total volume of produced water represents reported total volume of produced water by management practice. |                           |  |                                      |

Table 5-26: Produced Water Management Practices for Louisiana - 2021

| Management Practice   | Total Volume of Produced Water Managed by that Practice (bbl/year) | Percentage of Produced Water Managed by that Practice |
|---|--|---|
| Injection for Enhanced Recovery   | 48,292,239   | 6.06%   |
| Injection for Disposal (By Operator)  | 704,851,022  | 88.48%  |
| Injection for Disposal (Commercial / Offsite)<br>(3rd Party Managed Produced Water) | 43,511,998   | 5.46%   |
| Surface Water Discharge<br>(Ocean, Lake, Pond, Stream)                              | 0  | 0%  |
| Surface Discharge (Land Application)  | 0  | 0%  |
| Evaporation (Lined Sump)  | 0  | 0%  |
| Evaporation / Infiltration (Unlined Sump)   | 0  | 0%  |
| Sale / Transfer – Domestic Use  | 0  | 0%  |
| Sale / Transfer – Other Oil & Gas Operator  | 0  | 0%  |
| Reuse Within the Oil & Gas Industry   | 0  | 0%  |
| Reuse Outside the Oil & Gas Industry  | 0  | 0%  |
| Other   | 0  | 0%  |
| <b>Total</b>  | 796,655,259  | 100%  |

## 5.14 Mississippi

### 5.14.1 Introduction

The Mississippi State Oil and Gas Board (MOGB) oversees oil and gas operations in the state and provides regulations specific to oil and gas development under Title 53, (Oil, Gas and Other Minerals) Chapter 1 (MOGB). Below is a list of key considerations developed after questionnaire data compilation and assessment. **Tables 5-27** and **5-28** present 2021 production data.

- **Production:** The state reported 2,900 hydrocarbon wells that produced 12,931,012 bbls of crude oil; 27,028,025 Mmcf of natural gas; and 0 bbls of condensate.
- **Combined BOE:** 4,517,601,845.33
- **Produced Water:** Total produced water volume for the state was 15,712,999 bbls.
- **Water Management Practice:** The largest volume of produced water managed by practice was injection for disposal by operator with 114,265,647 bbls, or 78.21%.
- **Ratios:**
  - Combined WOR = 1.1; WGR = 75.4
  - Conventional WOR = 1.04, WGR = 0.1
  - Unconventional WOR = 1.4, WGR = 0.024
- **State Ranking:** Total Crude Oil and Condensate = 16<sup>th</sup>  
 Total Natural Gas Production = 22<sup>nd</sup>  
 Total Produced Water Volume = 23<sup>rd</sup>

### 5.14.2 Production and Produced Water Data

When compared to previous GWPC studies (2012, 2017), produced water volumes decreased 26% from 2012 (231,236,000 bbls) to 2017 (171,145,175 bbls), and 91% between 2017 and 2021 (15,712,999 bbls). The number of producing wells decreased by 10.5% from 2017 to 2021, with 340 wells removed from producing status.

The percentage of water produced from the total crude oil production accounted for approximately 87% while the remaining 13% of water originated from conventional and unconventional natural gas wells (refer to **Table 5-27**). The percentage of water produced from conventional development (~95%) accounted for most of the total produced water volume; whereas, most of the water volume from unconventional development arose from crude oil development, or 5.26% of the total produced water volume.

### 5.14.3 Produced Water Management Practices

Based on 2021 MOGB data, 31,834,517 bbls (21.79%) of produced water was injected for EOR projects and 114,265,647 bbls (78.21%) injected for disposal by operator (refer to **Table 5-28**). The state did not report any beneficial reuse of produced water in 2021.

**Table 5-27: Oil and Gas Production for Mississippi by Development Method - 2021**

| Type of Hydrocarbon              | Number of Wells Producing | Total Volume of Produced Water Brought to Surface (bbl/year) | Volume of Hydrocarbon Produced    |
|----------------------------------|---------------------------|--|-----------------------------------|
| <b>Conventional Formations</b>   |                           |  |                                   |
| Crude oil                        | 1536                      | 12,847,991   | 12,344,707 bbl                    |
| Natural gas                      | 1297                      | 2,024,960  | 26,440,674 Mmcf                   |
| Other (Condensate, etc.)         | 0                         | 0  | 0                                 |
| <b>Unconventional Formations</b> |                           |  |                                   |
| Crude oil                        | 63                        | 825,805  | 586,305 bbl                       |
| Natural gas                      | 4                         | 14,243   | 587,351 Mmcf                      |
| Other (Condensate, etc.)         | 0                         | 0  | 0                                 |
| <b>Total</b>                     | 2,900                     | 15,712,999   | 12,931,012 bbl<br>27,028,025 Mmcf |

**Table 5-28: Produced Water Management Practices for Mississippi - 2021**

| Management Practice   | Total Volume of Produced Water Managed by that Practice (bbl/year) | Percentage of Produced Water Managed by that Practice |
|---|--|---|
| Injection for Enhanced Recovery   | 31,834,517   | 21.79%  |
| Injection for Disposal (By Operator)  | 114,265,647  | 78.21%  |
| Injection for Disposal (Commercial / Offsite)<br>(3rd Party Managed Produced Water) | 0  | 0%  |
| Surface Water Discharge<br>(Ocean, Lake, Pond, Stream)                              | 0  | 0%  |
| Surface Discharge (Land Application)  | 0  | 0%  |
| Evaporation (Lined Sump)  | 0  | 0%  |
| Evaporation / Infiltration (Unlined Sump)   | 0  | 0%  |
| Sale / Transfer – Domestic Use  | 0  | 0%  |
| Sale / Transfer – Other Oil & Gas Operator  | 0  | 0%  |
| Reuse Within the Oil & Gas Industry   | 0  | 0%  |
| Reuse Outside the Oil & Gas Industry  | 0  | 0%  |
| Other   | 0  | 0%  |
| <b>Total</b>  | 146,100,164  | 100%  |

## 5.15 Missouri

### 5.15.1 Introduction

The Missouri Department of Natural Resources (MDNR) oversees oil and gas drilling and production while the Missouri Geological Survey (MGS) is responsible in part for activities associated with the exploration, production and subsurface storage of oil and gas. MDNR did not differentiate hydrocarbon production and produced water data between unconventional and conventional development, and only water volumes associated with crude oil development were provided. Below is a list of key considerations developed after questionnaire data compilation and assessment. **Tables 5-29** and **5-30** present 2021 production data.

- **Production:** The state reported 911 hydrocarbon wells that produced 59,579.36 bbls of crude oil; 493 Mmcf of natural gas; and 0 bbls of condensate.
- **Combined BOE:** 141,746.03
- **Produced Water:** Total produced water volume for the state was 1,156,481 bbls.
- **Water Management Practice:** 1,065,749 bbls (92.15%) of produced water is disposed of via Injection for enhanced recovery.
- **Ratios:** WOR = 19.4; WGR = insufficient data
- **State Ranking:** Total Crude Oil and Condensate = 30<sup>th</sup>  
Total Natural Gas Production = 30<sup>th</sup>  
Total Produced Water Volume = 28<sup>th</sup>

### 5.15.2 Production and Produced Water Data

When compared to previous GWPC studies (2012, 2017), produced water volumes increased by 31% from 2012 (2,103,000 bbls) to 2017 (2,763,613 bbls), but decreased 58% from 2017 to 2021 (1,156,481 bbls). Despite the decrease in water volumes, producing wells increased 107%, or 471 wells, from 2017 to 2021.

Produced water from total crude oil production accounted for 100% of the total volume. Produced water from conventional development was 100% of the total produced water volume, although it is important to note data from 2017 indicated nearly 95% of produced water was from the unconventional development of crude oil (refer to **Table 5-29**). The disparity in water volumes by reservoir type may be attributed to reporting discrepancies by the state.

### 5.15.3 Produced Water Management Practices

Based on 2021 MDNR data, 1,065,749 bbls (92.15%) of produced water was injected for EOR projects and 90,732 bbls (7.85%) for disposal by operator (refer to **Table 5-30**). The state did not report any beneficial reuse of produced water in 2021.



**Table 5-29: Oil and Gas Production for Missouri by Development Method - 2021**

| Type of Hydrocarbon  | Number of Wells Producing | Total Volume of Produced Water Brought to Surface (bbl/year) | Volume of Hydrocarbon Produced |
|--|---------------------------|--|--------------------------------|
| <b>Conventional Formations</b>   |                           |  |                                |
| Crude oil  | 895                       | 1,156,481  | 59,579 bbl                     |
| Natural gas  | 16                        | 0  | 493 Mmcf                       |
| Other (Condensate, etc.)   | 0                         | 0  | 0                              |
| <b>Unconventional Formations</b>   |                           |  |                                |
| Crude oil  | 0                         | 0  | 0                              |
| Natural gas  | 0                         | 0  | 0                              |
| Other (Condensate, etc.)   | 0                         | 0  | 0                              |
| <b>Total</b>   | 911                       | 1,156,481  | 59,579 bbl<br>493 Mmcf         |
| Note: For 2017, MDNR reported 381 unconventional and 59 conventional crude oil wells. No unconventional wells were reported in 2021 by MDNR. |                           |  |                                |

**Table 5-30: Produced Water Management Practices for Missouri - 2021**

| Management Practice   | Total Volume of Produced Water Managed by that Practice (bbl/year) | Percentage of Produced Water Managed by that Practice |
|---|--|---|
| Injection for Enhanced Recovery   | 1,065,749  | 92.15%  |
| Injection for Disposal (By Operator)  | 90,732   | 7.85%   |
| Injection for Disposal (Commercial / Offsite)<br>(3rd Party Managed Produced Water) | 0  | 0%  |
| Surface Water Discharge<br>(Ocean, Lake, Pond, Stream)                              | 0  | 0%  |
| Surface Discharge (Land Application)  | 0  | 0%  |
| Evaporation (Lined Sump)  | 0  | 0%  |
| Evaporation / Infiltration (Unlined Sump)   | 0  | 0%  |
| Sale / Transfer – Domestic Use  | 0  | 0%  |
| Sale / Transfer – Other Oil & Gas Operator  | 0  | 0%  |
| Reuse Within the Oil & Gas Industry   | 0  | 0%  |
| Reuse Outside the Oil & Gas Industry  | 0  | 0%  |
| Other   | 0  | 0%  |
| <b>Total</b>  | 1,156,481  | 100%  |

## 5.16 Montana

### 5.16.1 Introduction

The Montana Board of Oil and Gas Conservation (BOGC) administers the Montana oil and gas conservation laws and regulates oil and gas exploration and production activities in the state. The Board is a quasi-judicial body attached to the Department of Natural Resources and Conservation for administrative purposes. Below is a list of key considerations developed after questionnaire data compilation and assessment. **Tables 5-31** and **5-32** present 2021 production data.

- **Production:** The state reported 9,461 hydrocarbon wells that produced 18,920,372 bbls of crude oil; 41,823 Mmcf of natural gas; and 0 bbls of condensate.
- **Combined BOE:** 15,684,174
- **Produced Water:** Total produced water volume for the state was 147,897,041 bbls.
- **Water Management Practice:** 79,072,420 bbls (53.46%) of produced water is disposed of via enhance recovery projects.
- **Ratios:**
  - Combined WOR = 7.0; WGR = 21.8
  - Conventional WOR = 13.59, WGR = Insufficient Data
  - Unconventional WOR = 1.4, WGR = Insufficient Data
- **State Ranking:** Total Crude Oil and Condensate = 13<sup>th</sup>  
Total Natural Gas Production = 21<sup>st</sup>  
Total Produced Water Volume = 15<sup>th</sup>

### 5.16.2 Production and Produced Water Data

When compared to previous GWPC studies (2012, 2017), produced water volumes decreased by 22.5% from 2012 (182,833,000) to 2017 (141,733,134 bbls), and increased by 4.35% from 2017 to 2021 (147,897,041 bbls) or 6,163,907 bbls (refer to **Table 5-31**). The number of producing wells decreased by 5.70%, or 571 wells, from 2017 to 2021.

Produced water from the total crude oil production accounted for approximately 90% of the total volume while the remaining 10% originated from conventional natural gas development. Of the 90% produced water from crude oil production, conventional development accounted for much of the total volume (90%), while the remaining water was associated with unconventional development.

### 5.16.3 Produced Water Management Practices

Based on 2021 BOGC data, 79,072,420 bbls (53.46 %) of produced water was injected for EOR projects and 51,885,041 bbls (35.08%) for disposal by operator. In addition, the state reported 10,805,134 bbls or 7.31% of the produced water is managed by evaporation.

BOGC noted they have no way to distinguish between lined/unlined evaporation pits, so the reported water volume for evaporation was lumped into the “lined” category. Also, the volume of water BOGC reported in the “other” category represents the remaining water unaccounted for from evaporation pits and injection, which could be disposed of in any combination of the remaining categories (refer to **Table 5-32**). The state did not report any beneficial reuse of produced water in 2021.

Table 5-31: Oil and Gas Production for Montana by Development Method - 2021

| Type of Hydrocarbon  | Number of Wells Producing | Total Volume of Produced Water Brought to Surface (bbl/year) | Volume of Hydrocarbon Produced        |
|--|---------------------------|--|---------------------------------------|
| <b>Conventional Formations</b>   |                           |  |                                       |
| Crude oil  | 3,067                     | 118,386,245  | 8,713,695 bbl                         |
| Natural gas  | 5,158                     | 911,945  | 41,823 Mmcf                           |
| Other (Condensate, etc.)   | 36                        | 14,076,112   | 0                                     |
| <b>Unconventional Formations</b>   |                           |  |                                       |
| Crude oil  | 1,200                     | 14,522,739   | 10,206,677 bbl                        |
| Natural gas  | 0                         | 0  | 0                                     |
| Other (Condensate, etc.)   | 0                         | 0  | 0                                     |
| <b>Total</b>   | <b>9,461</b>              | <b>147,897,041</b>   | <b>18,920,372 bbl<br/>41,823 Mmcf</b> |
| <b>Note:</b> The BOGC reported natural gas production from crude oil wells (20,073 Mmcf) was included in the total natural gas production. |                           |  |                                       |

Table 5-32: Produced Water Management Practices for Montana - 2021

| Management Practice   | Total Volume of Produced Water Managed by that Practice (bbl/year) | Percentage of Produced Water Managed by that Practice |
|---|--|---|
| Injection for Enhanced Recovery   | 79,072,420   | 53.46%  |
| Injection for Disposal (By Operator)  | 51,885,041   | 35.08%  |
| Injection for Disposal (Commercial / Offsite)<br>(3rd Party Managed Produced Water) | 0  | 0%  |
| Surface Water Discharge<br>(Ocean, Lake, Pond, Stream)                              | 0  | 0%  |
| Surface Discharge (Land Application)  | 0  | 0%  |
| Evaporation (Lined Sump)  | 10,805,134   | 7.31%   |
| Evaporation / Infiltration (Unlined Sump)   | 0  | 0%  |
| Sale / Transfer – Domestic Use  | 0  | 0%  |
| Sale / Transfer – Other Oil & Gas Operator  | 0  | 0%  |
| Reuse Within the Oil & Gas Industry   | 0  | 0%  |
| Reuse Outside the Oil & Gas Industry  | 0  | 0%  |
| Other   | 6,134,446  | 4.15%   |
| <b>Total</b>  | <b>147,897,041</b>   | <b>100%</b>   |

## 5.17 Nebraska

### 5.17.1 Introduction

The Nebraska Oil and Gas Conservation Commission's (NOGCC) mission is to permit the development of the state's oil and natural gas resources with focus on maximizing efficient production while promoting the health, safety, and environment of Nebraska residents. In response to the questionnaire, the state did not differentiate hydrocarbon production and produced water data between unconventional and conventional development. Below is a list of key considerations developed after questionnaire data compilation and assessment. **Tables 5-33** and **5-34** present 2021 production data.

- **Production:** The state reported 1,579 hydrocarbon wells that produced 1,705,559 bbls of crude oil; 321 Mmcf of natural gas; and 0 bbls of condensate.
- **Combined BOE:** 55,197,225.67
- **Produced Water:** Total produced water volume for the state was 42,968,415 bbls.
- **Water Management Practice:** The largest volume of produced water managed by practice was 23,312,800 bbls (48%) for enhanced recovery projects and 23,798,500 (49%) for disposal by operator.
- **Ratios:** WOR = 24.4; WGR = 4362.1
- **State Ranking:** Total Crude Oil and Condensate = 22<sup>nd</sup>  
Total Natural Gas Production = 31<sup>st</sup>  
Total Produced Water Volume = 190<sup>th</sup>

### 5.17.2 Production and Produced Water Data

When compared to previous GWPC studies (2012, 2017), produced water volumes decrease ~15% from 2012 (58,641,000 bbls) to 2017 (50,069,495 bbls), and decreased an additional 15% between 2017 and 2021 (42,968,415) (refer to **Table 5-33**). Inversely, the number of hydrocarbon producing wells from 2017 to 2021 increased by 79 wells, or 5.3%.

Produced water from total crude oil production accounted for 97% of the total while the remaining 3% was derived from the development of conventional natural gas wells. As NOGCC reported, the percentage of water produced from conventional development accounted for 100% of the total produced water volume for the state.

### 5.17.3 Produced Water Management Practices

Based on 2021 NOGCC data, 23,312,800 bbls (48%) of produced water was injected for EOR projects and 23,798,500 bbls (49%) for disposal by operator. Other produced water management practices include commercial disposal by injection (0.50%), surface water discharge (0.50%), and evaporation (lined/unlined) (~3%) (refer to **Table 5-34**). NOGCC reported 3,500 bbls of water beneficially re-used outside of the oil and gas industry.

Table 5-33: Oil and Gas Production for Nebraska by Development Method - 2021

| Type of Hydrocarbon              | Number of Wells Producing | Total Volume of Produced Water Brought to Surface (bbl/year) | Volume of Hydrocarbon Produced |
|----------------------------------|---------------------------|--|--------------------------------|
| <b>Conventional Formations</b>   |                           |  |                                |
| Crude oil                        | 1,405                     | 41,568,415   | 1,705,559 bbl                  |
| Natural gas                      | 174                       | 1,400,000  | 321 Mmcf                       |
| Other (Condensate, etc.)         | 0                         | 0  | 0                              |
| <b>Unconventional Formations</b> |                           |  |                                |
| Crude oil                        | 0                         | 0  | 0                              |
| Natural gas                      | 0                         | 0  | 0                              |
| Other (Condensate, etc.)         | 0                         | 0  | 0                              |
| <b>Total</b>                     | 1,579                     | 42,968,415   | 1,705,559 bbl<br>321 Mmcf      |

Table 5-34: Produced Water Management Practices for Nebraska - 2021

| Management Practice   | Total Volume of Produced Water Managed by that Practice (bbl/year) | Percentage of Produced Water Managed by that Practice |
|---|--|---|
| Injection for Enhanced Recovery   | 23,312,800   | 48%   |
| Injection for Disposal (By Operator)  | 23,798,500   | 49%   |
| Injection for Disposal (Commercial / Offsite)<br>(3rd Party Managed Produced Water) | 112,000  | 0.50%   |
| Surface Water Discharge<br>(Ocean, Lake, Pond, Stream)                              | 29,615   | 0.50%   |
| Surface Discharge (Land Application)  | 0  |   |
| Evaporation (Lined Sump)  | 12,000   | >1  |
| Evaporation / Infiltration (Unlined Sump)   | 1,300,000  | 2%  |
| Sale / Transfer – Domestic Use  | 0  | 0%  |
| Sale / Transfer – Other Oil & Gas Operator  | 0  | 0%  |
| Reuse Within the Oil & Gas Industry   | 0  | 0%  |
| Reuse Outside the Oil & Gas Industry  | 3,500  | >1  |
| Other   | 0  | 0%  |
| <b>Total</b>  | 48,568,415   | 100%  |

## 5.18 Nevada

### 5.18.1 Introduction

The Nevada Division of Minerals (NDOM) is responsible for the exploration and production of minerals, oil, gas, and geothermal energy, and to provide public safety by identifying, ranking, and securing dangerous conditions at mines no longer operating. The agency also collects and disseminates information on exploration, production, and related topics. In response to the questionnaire, the state did not differentiate hydrocarbon production and produced water data between unconventional and conventional development. In addition, the NDOM reported it does not track or audit produced water volumes but instead relies on operators to self-report any volumes. Below is a list of key considerations developed after questionnaire data compilation and assessment. **Tables 5-35** and **5-36** present 2021 production data.

- **Production:** The state reported 60 hydrocarbon wells that produced 223,232 bbls of crude oil; 410 Mmcf of natural gas; and 0 bbls of condensate.
- **Combined BOE:** 223,916.70
- **Produced Water:** Total produced water volume for the state was 4,779,403 bbls.
- **Water Management Practice:** The largest volume of produced water managed by practice includes 23,312,800 bbls (48%) for enhanced recovery projects and 4,813,446 bbls (99.49%) injection for disposal by operator.
- **Ratios:** WOR = 21.4; WGR = insufficient data.
- **State Ranking:** Total Crude Oil and Condensate = 28<sup>th</sup>  
Total Natural Gas Production = 34<sup>th</sup>  
Total Produced Water Volume = 26<sup>th</sup>

### 5.18.2 Production and Produced Water Data

When compared to previous GWPC studies (2012, 2017), produced water volumes decreased 11% from 2012 (5,865,000 bbls) to 2017 (6,510,029 bbls), and an additional ~27% from 2017 to 2021 (4,779,403 bbls) (refer to **Table 5-35**). The number of hydrocarbon producing wells decreased by one well from 2017 to 2021.

Produced water from crude oil production (conventional) accounted for 100% of the state's total produced water volume.

### 5.18.3 Produced Water Management Practices

Based on 2021 NDOM data, 4,813,446 bbls (99.49%) of produced water was injected for disposal by operator, while the remaining 0.51% of water was used for EOR. NDOM only tracks total disposal volumes by injection and does not segregate commercial disposal volumes from volumes disposed of by operator (refer to **Table 5-36**). The state did not report any beneficial reuse of produced water in 2021.

Table 5-35: Oil and Gas Production for Nevada by Development Method - 2021

| Type of Hydrocarbon   | Number of Wells Producing | Total Volume of Produced Water Brought to Surface (bbl/year) | Volume of Hydrocarbon Produced |
|---|---------------------------|--|--------------------------------|
| <b>Conventional Formations</b>  |                           |  |                                |
| Crude oil   | 54                        | 4,779,403  | 223,232 bbl                    |
| Natural gas   | 6                         | 0  | 4.10 Mmcf                      |
| Other (Condensate, etc.)  | 0                         | 0  | 0                              |
| <b>Unconventional Formations</b>  |                           |  |                                |
| Crude oil   | 0                         | 0  | 0                              |
| Natural gas   | 0                         | 0  | 0                              |
| Other (Condensate, etc.)  | 0                         | 0  | 0                              |
| <b>Total</b>  | 60                        | 4,779,403  | 223,232 bbls<br>4.10 Mmcf      |
| <b>Note:</b> NDOM does not track produced water volumes and rely on operators to self-report produced water volumes monthly. The data is not audited by the agency. |                           |  |                                |

Table 5-36: Produced Water Management Practices for Nevada - 2021

| Management Practice   | Total Volume of Produced Water Managed by that Practice (bbl/year) | Percentage of Produced Water Managed by that Practice |
|---|--|---|
| Injection for Enhanced Recovery   | 24,897   | 0.51%   |
| Injection for Disposal (By Operator)  | 4,813,446  | 99.49%  |
| Injection for Disposal (Commercial / Offsite)<br>(3rd Party Managed Produced Water) | 0  | 0%  |
| Surface Water Discharge<br>(Ocean, Lake, Pond, Stream)                              | 0  | 0%  |
| Surface Discharge (Land Application)  | 0  | 0%  |
| Evaporation (Lined Sump)  | 0  | 0%  |
| Evaporation / Infiltration (Unlined Sump)   | 0  | 0%  |
| Sale / Transfer – Domestic Use  | 0  | 0%  |
| Sale / Transfer – Other Oil & Gas Operator  | 0  | 0%  |
| Reuse Within the Oil & Gas Industry   | 0  | 0%  |
| Reuse Outside the Oil & Gas Industry  | 0  | 0%  |
| Other   | 0  | 0%  |
| <b>Total</b>  | 4,838,343  | 100%  |

## 5.19 New Mexico

### 5.19.1 Introduction

The New Mexico Oil Conservation Division (OCD) regulates oil and gas activity in New Mexico and gathers well production data, permits new wells, enforces the division's rules and the state's oil and gas statutes, and ensures the state's land is responsibly restored. OCD does not differentiate between unconventional and conventional production; therefore, volume of produced water and hydrocarbons developed from unconventional formations is not discrete. Below is a list of key considerations developed after questionnaire data compilation and assessment. **Tables 5-37** and **5-38** present 2021 production data.

- **Production:** The state reported 62,045 hydrocarbon wells that produced 451,085,590 bbls of crude oil; 2,421,424 Mmcf of natural gas, to include coalbed methane; and 0 bbls of condensate.
- **Combined BOE:** 854,656,256.67
- **Produced Water:** Total produced water volume for the state was 1,600,878,600 bbls.
- **Water Management Practice:** The largest volume of produced water managed by practice is injection for disposal by operator with 717,435,541 bbls (79.61%) reported.
- **Ratios:** WOR = 0.4; WGR = 173.1.
- **State Ranking:** Total Crude Oil and Condensate = 3<sup>rd</sup>  
Total Natural Gas Production = 7<sup>th</sup>  
Total Produced Water Volume = 5<sup>th</sup>

### 5.19.2 Production and Produced Water Data

When compared to previous GWPC studies (2012, 2017), produced water volumes increased 13% from 2012 (775,930,000 bbls) to 2017 (879,740,841 bbls), and another 82% from 2017 to 2021 (1,600,878,600 bbls) (refer to **Table 5-37**). OCD did not report the number of hydrocarbon producing wells for 2017 and thus a comparative analysis with 2021 was impossible.

Produced water from crude oil production accounted for approximately 74% of the total produced water in the state while the remaining 26% was from conventional natural gas wells. Produced water from conventional development accounted for 100% of the total produced water volume, although OCD noted conventional versus unconventional water production was distinct.

### 5.19.3 Produced Water Management Practices

Based on 2021 OCD data, most of the state's produced water is injected for disposal by operator (79.61%) or reused (20.19%) within the oil and gas industry for drilling, well work, well stimulation, or other facility uses. OCD noted total injection volumes for EOR wells are derived from multiple sources (*i.e.*, brackish groundwater, produced water, municipal effluent, etc.) and are not tracked; consequently, volumes of water used for EOR are unknown (refer to **Table 5-36**). OCD provided the following produced water management data:

- Evaporation (lined) produced water volumes located at surface waste management facilities are likely higher as operator-reported volumes are only provided when upon OCD request.
- Produced water leaving New Mexico to Texas (sale transfer) is not gauged.
- Surface discharge, evaporation (unlined), sale/transfer (domestic use) and reuse outside of the oil and gas industry is not allowed in the state.
- The *other* category represents the volume of produced water that was spilled and not recovered.



**Table 5-37: Oil and Gas Production for New Mexico by Development Method - 2021**

| Type of Hydrocarbon   | Number of Wells Producing | Total Volume of Produced Water Brought to Surface (bbl/year) | Volume of Hydrocarbon Produced    |
|---|---------------------------|--|-----------------------------------|
| <b>Conventional Formations</b>  |                           |  |                                   |
| Crude oil   | 34,063                    | 1,181,651,249  | 451,085,590 bbl                   |
| Natural gas   | 28,342                    | 419,227,351  | 2,421,424 Mmcf                    |
| Other (Condensate, etc.)  | 0                         | 0  | 0                                 |
| <b>Unconventional Formations</b>  |                           |  |                                   |
| Crude oil   | 0                         | 0  | 0                                 |
| Natural gas   | 0                         | 0  | 0                                 |
| Other (Condensate, etc.)  | 0                         | 0  | 0                                 |
| <b>Total</b>  | 62,405                    | 1,600,878,600  | 451,085,590 bbl<br>2,421,424 Mmcf |
| <b>Note:</b> Volume of natural gas reported by the OCD includes coalbed methane production. |                           |  |                                   |

**Table 5-38: Produced Water Management Practices for New Mexico - 2021**

| Management Practice   | Total Volume of Produced Water Managed by that Practice (bbl/year) | Percentage of Produced Water Managed by that Practice |
|---|--|---|
| Injection for Enhanced Recovery   | 0  | 0   |
| Injection for Disposal (By Operator)  | 717,435,541  | 79.61%  |
| Injection for Disposal (Commercial / Offsite)<br>(3rd Party Managed Produced Water) | 0  | 0   |
| Surface Water Discharge<br>(Ocean, Lake, Pond, Stream)                              | 0  | 0   |
| Surface Discharge (Land Application)  | 0  | 0   |
| Evaporation (Lined Sump)  | 1,762,644  | 0.20%   |
| Evaporation / Infiltration (Unlined Sump)   | 0  | 0   |
| Sale / Transfer – Domestic Use  | 0  | 0   |
| Sale / Transfer – Other Oil & Gas Operator  | 0  | 0   |
| Reuse Within the Oil & Gas Industry   | 181,970,412  | 20.19%  |
| Reuse Outside the Oil & Gas Industry  | 0  | 0   |
| Other   | 29,225   | <0.01%  |
| <b>Total</b>  | 901,197,822  | 100%  |

## 5.20 New York

### 5.20.1 Introduction

The New York State Department of Environmental Conservation (NYDEC) Division of Mineral Resources objective is to ensure the environmentally sound, economic development of the state's non-renewable energy and mineral resources. In response to the questionnaire, the state did not differentiate hydrocarbon production and produced water data between unconventional and conventional development. Below is a list of key considerations developed after questionnaire data compilation and assessment. **Tables 5-39** and **5-40** present 2021 production data.

- **Production:** The state reported 10,610 hydrocarbon wells that produced 265,592 bbls of crude oil; 9,735.40 Mmcf of natural gas; and 0 bbls of condensate.
- **Combined BOE:** 1,888,157.83
- **Produced Water:** Total produced water volume for the state was 186,637 bbls.
- **Water Management Practice:** The largest volume of produced water managed by practice in 2021 was the reuse of the water outside the oil and gas Industry (*e.g.*, domestic sewer, irrigation, cooling water, etc.) with 90,031 reported bbls, or 48.24% of the total water volume.
- **Ratios:** WOR = 0.5; WGR = 4.7
- **State Ranking:** Total Crude Oil and Condensate = 27<sup>th</sup>  
Total Natural Gas Production = 24<sup>th</sup>  
Total Produced Water Volume = 29<sup>th</sup>

### 5.20.2 Production and Produced Water Data

When compared to previous GWPC studies (2012, 2017), produced water volumes decreased from 2012 (510,000) to 2017 (189,746), nearly 63%. From 2017 to 2021 (186,637), reported water volumes slightly decrease 3,109 bbls, or 1.64% (refer to **Table 5-39**). The number of hydrocarbon producing wells increased from 2017 to 2021 (1.76%)

Produced water from crude oil production accounted for approximately 76% of the total produced water in the state, while the remaining 24% came from conventional natural gas wells. Produced water from conventional development accounted for 100% of the total produced water volume, although the state does not differentiate produced water volumes of conventional and unconventional development.

### 5.20.3 Produced Water Management Practices

Based on 2021 NYEC data, 63,668 bbls (34.11%) was sent to commercial disposal, whereas only 6,913 bbls (3.70%) was injected for disposal by operator. The only water management practices not represented include "sale/transfer," although the surface water discharge and evaporation (line/unlined) categories account for less than one percent of the total volume of water management practices (refer to **Table 5-40**). As previously stated, of the most common produced water management practice was reuse outside of the oil and gas Industry with 90,031 reported bbls, or 48.24% of the total water volume. Water in this category is used for dust control and to de-ice roadways.

**Table 5-39: Oil and Gas Production for New York by Development Method - 2021**

| Type of Hydrocarbon              | Number of Wells Producing | Total Volume of Produced Water Brought to Surface (bbl/year) | Volume of Hydrocarbon Produced |
|----------------------------------|---------------------------|--|--------------------------------|
| <b>Conventional Formations</b>   |                           |  |                                |
| Crude oil                        | 3,985                     | 140,920  | 265,592 bbl                    |
| Natural gas                      | 6,625                     | 45,717   | 9,735 Mmcf                     |
| Other (Condensate, etc.)         | 0                         | 0  | 0                              |
| <b>Unconventional Formations</b> |                           |  |                                |
| Crude oil                        | 0                         | 0  | 0                              |
| Natural gas                      | 0                         | 0  | 0                              |
| Other (Condensate, etc.)         | 0                         | 0  | 0                              |
| <b>Total</b>                     | 10,610                    | 186,637  | 265,592 bbl<br>9,735 Mmcf      |

**Table 5-40: Produced Water Management Practices for New York - 2021**

| Management Practice   | Total Volume of Produced Water Managed by that Practice (bbl/year) | Percentage of Produced Water Managed by that Practice |
|---|--|---|
| Injection for Enhanced Recovery   | 17,255   | 9.25%   |
| Injection for Disposal (By Operator)  | 6,913  | 3.70%   |
| Injection for Disposal (Commercial / Offsite)<br>(3rd Party Managed Produced Water) | 63,668   | 34.11%  |
| Surface Water Discharge<br>(Ocean, Lake, Pond, Stream)                              | 53   | 0.03%   |
| Surface Discharge (Land Application)  | 7,826  | 4.19%   |
| Evaporation (Lined Sump)  | 210  | 0.11%   |
| Evaporation / Infiltration (Unlined Sump)   | 37   | 0.02%   |
| Sale / Transfer – Domestic Use  | 0  | 0%  |
| Sale / Transfer – Other Oil & Gas Operator  | 0  | 0%  |
| Reuse Within the Oil & Gas Industry   | 644  | 0.35%   |
| Reuse Outside the Oil & Gas Industry  | 90,031   | 48.24%  |
| Other   | 0  | 0%  |
| <b>Total</b>  | 186,637  | 100%  |

## 5.21 North Dakota

### 5.21.1 Introduction

The North Dakota Industrial Commission (NDIC), Oil and Gas Division, regulates the drilling and production of oil and gas in the state and does so by encouraging and promoting the development, production, and utilization of oil and gas while preventing waste and maximizing economic recovery. Below is a list of key considerations developed after questionnaire data compilation and assessment. **Tables 5-41** and **5-42** present 2021 production data.

- **Production:** The state reported 18,163 hydrocarbon wells that produced 405,127,827 bbls of crude oil; 1,075,358 Mmcf of natural gas; and 0 bbls of condensate.
- **Combined BOE:** 584,354,160
- **Produced Water:** Total produced water volume for the state was 643,154,596 bbls.
- **Water Management Practice:** The largest volume of produced water managed by practice includes injection for disposal either by the operator (41.53%) or at a commercial facility (41.17%).
- **Ratios:**
  - Combined WOR = 1.6; WGR = 0.02
  - Conventional WOR = 11.49, WGR = Insufficient data
  - Unconventional WOR = 1.3, WGR = Insufficient data
- **State Ranking:** Total Crude Oil and Condensate = 4<sup>th</sup>  
Total Natural Gas Production = 12<sup>th</sup>  
Total Produced Water Volume = 10<sup>th</sup>

### 5.21.2 Production and Produced Water Data

When compared to previous GWPC studies (2012, 2017), produced water volume increased nearly 74% from 2012 (291,147,000 bbls) to 2017 (505,828,554 bbls), and an additional increase of 27% between 2017 and 2021 (643,154,596 bbls) (refer to **Table 4-41**). The number of producing wells in the state increased ~20% from 2017 to 2021, or 2,999 wells.

Produced water from crude oil production accounted for ~21% of the total produced water in the state, while the remaining 79% came from conventional and unconventional natural gas wells. Produced water from unconventional development accounted for 80% of the total produced water volume, primarily due to the development of natural gas.

### 5.21.3 Produced Water Management Practices

Based on 2021 NDIC data, most of the produced water in the state is injected for disposal by operator (41.53%) or at a commercial facility (41.17%). An additional 110,377,405 bbls (17.30%) of water were used for EOR projects (refer to **Table 5-42**). According to the NDIC, produced water is reused within the oil and gas industry although the agency does not track specific volumes.

**Table 5-41: Oil and Gas Production for North Dakota by Development Method - 2021**

| Type of Hydrocarbon  | Number of Wells Producing | Total Volume of Produced Water Brought to Surface (bbl/year) | Volume of Hydrocarbon Produced            |
|--|---------------------------|--|---|
| <b>Conventional Formations</b>   |                           |  |   |
| Crude oil  | 22,580                    | 132,996,244  | 11,571,847 bbl                            |
| Natural gas  | 161                       | 21,155   | 61,405 Mmcf                               |
| Other (Condensate, etc.)   | 0                         | 0  | 0   |
| <b>Unconventional Formations</b>   |                           |  |   |
| Crude oil  | 15,744                    | 510,137,197  | 393,555,980 bbl                           |
| Natural gas  | 0                         | 0  | 1,013,953 Mmcf                            |
| Other (Condensate, etc.)   | 0                         | 0  | 0   |
| <b>Total</b>   | <b>18,163</b>             | <b>643,154,596</b>   | <b>405,127,827 bbl<br/>1,075,538 Mmcf</b> |
| Note: NDIC reported the unconventional gas is collected from the unconventional oil wells. |                           |  |   |

**Table 5-42: Produced Water Management Practices for North Dakota - 2021**

| Management Practice   | Total Volume of Produced Water Managed by that Practice (bbl/year) | Percentage of Produced Water Managed by that Practice |
|---|--|---|
| Injection for Enhanced Recovery   | 110,377,405  | 17.30%  |
| Injection for Disposal (By Operator)  | 264,960,745  | 41.53%  |
| Injection for Disposal (Commercial / Offsite)<br>(3rd Party Managed Produced Water)   | 262,672,129  | 41.17%  |
| Surface Water Discharge<br>(Ocean, Lake, Pond, Stream)  | 0  | 0%  |
| Surface Discharge (Land Application)  | 0  | 0%  |
| Evaporation (Lined Sump)  | 0  | 0%  |
| Evaporation / Infiltration (Unlined Sump)   | 0  | 0%  |
| Sale / Transfer – Domestic Use  | 0  | 0%  |
| Sale / Transfer – Other Oil & Gas Operator  | 0  | 0%  |
| Reuse Within the Oil & Gas Industry   | Unknown  | Unknown   |
| Reuse Outside the Oil & Gas Industry  | 0  |   |
| Other   | 0  | 0%  |
| <b>Total</b>  | <b>638,010,279</b>   | <b>100%</b>   |
| Note: NDIC reported they do not track the volume of water that is reused within the oil and gas industry although they are aware reuse occurs in this category. |  |   |

## 5.22 Ohio

### 5.22.1 Introduction

The Ohio Department of Natural Resources, Division of Oil and Gas Resources Management (DOGRM) regulates the state's oil and natural gas industry and protects the environment while ensuring the state's natural resources are managed and developed responsibly. Below is a list of key considerations developed after questionnaire data compilation and assessment. **Tables 5-43** and **5-44** present 2021 production data.

- **Production:** The state reported 36,970 hydrocarbon wells that produced 18,777,412 bbls of crude oil; 2,256,484 Mmcf of natural gas; and 0 bbls of condensate (*reported as oil*).
- **Combined BOE:** 394,858,037
- **Produced Water:** Total produced water volume for the state was 32,332,672 bbls.
- **Water Management Practice:** The largest volume of produced water managed by practice includes injection for disposal by the operator with 35,036,096 reported bbls, or 98.75% of the total management practice water volume.
- **Ratios:**
  - Combined WOR = 0.2; WGR = 12.4
  - Conventional WOR = 0.64, WGR = 28.1
  - Unconventional WOR = 0.2, WGR = 12.2
- **State Ranking:** Total Crude Oil and Condensate = 14<sup>th</sup>  
                                     Total Natural Gas Production = 8<sup>th</sup>  
                                     Total Produced Water Volume = 22<sup>nd</sup>

### 5.22.2 Production and Produced Water Data

When compared to previous GWPC studies (2012, 2017), produced water volumes increased nearly 336% from 2012 (5,542,000 bbls) to 2017 (24,142,988 bbls), and an additional ~34% between 2017 and 2021 (32,332,672 bbls) (refer to **Table 5-43**). Inversely, the number of producing wells decreased by 10,342 wells, or ~22%.

Produced water from crude oil accounted for approximately 13% of the total produced water in the state, while the remaining 87% came from conventional and unconventional natural gas wells. Produced water from unconventional development accounted for nearly 92% of the total produced water volume, primarily due to the development of natural gas.

### 5.22.3 Produced Water Management Practices

Based on 2021 DOGRM data, most of the produced water in the state is injected for disposal by operators (98.75%); however, this percentage represents total injection as injection of produced water at commercial facilities is not tracked (refer to **Table 5-44**). According to the DOGRM, 47,338 bbls (0.13%) of produced water is reused outside of the oil and gas industry to include brine to aggregate piles (2,207 bbls) and brine spreading on private roads (19,429 bbls) and county roads (25,702 bbls). Lastly, in the 2017 report, it was reported 48% of the produced water in Ohio was received from other states, to include Pennsylvania and West Virginia; volumes of water received from other states was not reported in the questionnaire spreadsheet tables provided with the 2021 data; however, the difference between produced water generated and managed is ~3,148,000 bbls.

Table 5-43: Oil and Gas Production for Ohio by Development Method - 2021

| Type of Hydrocarbon  | Number of Wells Producing | Total Volume of Produced Water Brought to Surface (bbl/year) | Volume of Hydrocarbon Produced           |
|--|---------------------------|--|--|
| <b>Conventional Formations</b>   |                           |  |  |
| Crude oil  | 9,101                     | 1,528,280  | 2,385,245 bbl                            |
| Natural gas  | 25,011                    | 986,388  | 35,106 Mmcf                              |
| Other (Condensate, etc.)   | 0                         | 0  | 0  |
| <b>Unconventional Formations</b>   |                           |  |  |
| Crude oil  | 493                       | 2,820,462  | 16,392,167 bbl                           |
| Natural gas  | 2,365                     | 26,997,542   | 2,221,378 Mmcf                           |
| Other (Condensate, etc.)   | 0                         | 0  | 0  |
| <b>Total</b>   | <b>36,970</b>             | <b>32,332,672</b>  | <b>18,777,412 bbl<br/>2,256,484 Mmcf</b> |
| <b>Note:</b> DOGRM reported condensate production is included with crude oil production volumes. |                           |  |  |

Table 5-44: Produced Water Management Practices for Ohio - 2021

| Management Practice   | Total Volume of Produced Water Managed by that Practice (bbl/year) | Percentage of Produced Water Managed by that Practice |
|---|--|---|
| Injection for Enhanced Recovery   | 397,235  | 1.12%   |
| Injection for Disposal (By Operator)  | 35,036,096   | 98.75%  |
| Injection for Disposal (Commercial / Offsite)<br>(3rd Party Managed Produced Water) | 0  | 0%  |
| Surface Water Discharge<br>(Ocean, Lake, Pond, Stream)                              | 0  | 0%  |
| Surface Discharge (Land Application)  | 0  | 0%  |
| Evaporation (Lined Sump)  | 0  | 0%  |
| Evaporation / Infiltration (Unlined Sump)   | 0  | 0%  |
| Sale / Transfer – Domestic Use  | 0  | 0%  |
| Sale / Transfer – Other Oil & Gas Operator  | 0  | 0%  |
| Reuse Within the Oil & Gas Industry   | 0  | 0%  |
| Reuse Outside the Oil & Gas Industry  | 47,338   | 0.13%   |
| Other   | 0  | 0%  |
| <b>Total</b>  | <b>35,480,669</b>  | <b>100%</b>   |

## 5.23 Oklahoma

### 5.23.1 Introduction

The Oklahoma Corporation Commission (OCC) has regulatory authority over oil and gas activities in the state while the Oklahoma Tax Commission (OTC) is responsible for reporting oil and gas related production data from associated operator tax records. OCC did not provide oil and gas production data for 2021 via completion of the questionnaire. Instead, production data for 2021 was obtained from the OTC based on operator gross production tax records. The data obtained from the OTC did not differentiate hydrocarbon production and produced water data between unconventional and conventional development. The OCC does however track produced water volumes and did report the total produced water volume by management practice for 2021, which was used to approximate the total volume of produced water for the state. Below is a list of key considerations developed after questionnaire data compilation and assessment. **Tables 5-45** and **5-46** present 2021 production data.

- **Production:** The state reported 48,942 hydrocarbon wells that produced 148,337,394 bbls of crude oil; 2,544,913 Mmcf of natural gas; and 0 bbls of condensate.
- **Combined BOE:** 572,489,560
- **Produced Water:** Total produced water volume for the state was 1,744,894,591 bbls (*total water volume approximated from volumes reported for produced water management practices*).
- **Water Management Practice:** The largest volume of produced water managed by practice was injection for enhanced recovery projects with 975,571,994 reported bbls, or 55.91% of total volume of managed practices.
- **Ratios:** WOR = insufficient data; WGR = insufficient data.
- **State Ranking:** Total Crude Oil and Condensate = 7<sup>th</sup>  
Total Natural Gas Production = 6<sup>th</sup>  
Total Produced Water Volume = 4<sup>th</sup>

### 5.23.2 Production and Produced Water Data

When compared to previous GWPC studies (2012, 2017), produced water volumes increased from 2012 (2,325,153,000) to 2017 (2,844,485,617) or 22%; whereas water volumes decreased considerably (~39%) when comparing data from 2017 and 2021 (1,744,894,591) (refer to **Table 5-45**). The number of hydrocarbon producing wells decreased (73%) or 128,508 from 2017 to 2021. Data reporting errors may explain the large discrepancy in producing well numbers between the two reporting years.

### 5.23.3 Produced Water Management Practices

Based on 2021 OCD data, 975,571,994 (55.91%) of the produced water was used for EOR projects, while the remaining water volume was injected for disposal by operators (30.07%) or at commercial facilities (14.01%) (refer to **Table 5-46**). The state did not report any beneficial reuse of produced water in 2021.



**Table 5-45: Oil and Gas Production for Oklahoma by Development Method - 2021**

| Type of Hydrocarbon   | Number of Wells Producing | Total Volume of Produced Water Brought to Surface (bbl/year) | Volume of Hydrocarbon Produced            |
|---|---------------------------|--|---|
| <b>Conventional Formations</b>  |                           |  |   |
| Crude oil   | 23,756                    | 0  | 148,337,394 bbl                           |
| Natural gas   | 24,736                    | 0  | 2,544,913 Mmcf                            |
| Other (Condensate, etc.)  | 0                         | 0  | 0   |
| <b>Unconventional Formations</b>  |                           |  |   |
| Crude oil   | 0                         | 0  | 0   |
| Natural gas   | 0                         | 0  | 0   |
| Other (Condensate, etc.)  | 0                         | 0  | 0   |
| <b>Total</b>  | <b>48,492</b>             | <b>1,744,894,591</b>   | <b>148,337,393 bbl<br/>2,544,913 Mmcf</b> |
| <b>Note:</b> Production numbers were obtained by the OTC based on operator gross production tax records. The total volume of produced water is approximated based on the reported total volume of produced water by management practices. |                           |  |   |

**Table 5-46: Produced Water Management Practices for Oklahoma - 2021**

| Management Practice   | Total Volume of Produced Water Managed by that Practice (bbl/year) | Percentage of Produced Water Managed by that Practice |
|---|--|---|
| Injection for Enhanced Recovery   | 975,571,994  | 55.91%  |
| Injection for Disposal (By Operator)  | 524,776,441  | 30.07%  |
| Injection for Disposal (Commercial / Offsite)<br>(3rd Party Managed Produced Water) | 244,546,156  | 14.01%  |
| Surface Water Discharge<br>(Ocean, Lake, Pond, Stream)                              | 0  | 0%  |
| Surface Discharge (Land Application)  | 0  | 0%  |
| Evaporation (Lined Sump)  | 0  | 0%  |
| Evaporation / Infiltration (Unlined Sump)   | 0  | 0%  |
| Sale / Transfer – Domestic Use  | 0  | 0%  |
| Sale / Transfer – Other Oil & Gas Operator  | 0  | 0%  |
| Reuse Within the Oil & Gas Industry   | 0  | 0%  |
| Reuse Outside the Oil & Gas Industry  | 0  | 0%  |
| Other   | 0  | 0%  |
| <b>Total</b>  | <b>1,744,894,591</b>   | <b>100%</b>   |

## 5.24 Pennsylvania

### 5.24.1 Introduction

The Pennsylvania Department of Environment Protection (PADEP), Office of Oil and Gas Management, is responsible for statewide oil and gas conservation and environmental programs to facilitate the safe exploration, development, recovery of the state's oil and gas reservoirs in a manner that will protect resources and the environment. Below is a list of key considerations developed after questionnaire data compilation and assessment. **Tables 5-47** and **5-48** present 2021 production data.

- **Production:** The state reported 77,190 hydrocarbon wells that produced 863,097 bbls of crude oil; 7,656,814 Mmcf of natural gas; and 5,396,909 bbls of condensate.
- **Combined BOE:** 1,282,395,742
- **Produced Water:** Total produced water volume for the state was 36,779,076 bbls.
- **Water Management Practice:** The largest water management practice reported by the state was reuse within the oil and gas industry (*i.e.*, drilling, well work, well stimulation, other facility uses, etc.) with 34,970,964 bbls, or 49.93%.
- **Ratios:**
  - Combined WOR = 0.1; WGR = 4.7
  - Conventional WOR = 0.78, WGR = 2.8
  - Unconventional WOR = 0.001, WGR = 4.7
- **State Ranking:** Total Crude Oil and Condensate = 18<sup>th</sup>  
 Total Natural Gas Production = 2<sup>nd</sup>  
 Total Produced Water Volume = 21<sup>st</sup>

#### 5.24.2 Production and Produced Water Data

When compared to previous GWPC studies (2012, 2017), produced water volumes increased 62% from 2012 (34,089,000 bbls) and 2017 (55,321,026 bbls), but decreased 33.5% from 2017 to 2021 (36,779,076.62 bbls) (refer to **Table 5-47**). The number of hydrocarbon producing wells decreased from 2017 to 2021 to 4,594 producing wells, or a 5.6% decrease.

Produced water from crude oil production accounted for less than one percent of the total produced water in the state, while 98% came from conventional and unconventional natural gas wells. The remaining percentage of produced water (~2%) was associated with condensate production. Produced water from unconventional development accounted for nearly 98% of the state's total produced water volume, primarily due to the development of natural gas.

### 5.24.3 Produced Water Management Practices

Based on 2021 PADEP data, most of the produced water in the state is reused by operators within the oil and gas industry (49.93%), while 7.05% was reused outside of the industry and 6.05% was injected for disposal by operator (refer to **Table 5-48**). The state also reported 25,446,885.60 bbls or 36.33% of the produced water was managed in the *other* category, with specific uses unspecified.

Table 5-47: Oil and Gas Production for Pennsylvania by Development Method - 2021

| Type of Hydrocarbon              | Number of Wells Producing | Total Volume of Produced Water Brought to Surface (bbl/year) | Volume of Hydrocarbon Produced          |
|----------------------------------|---------------------------|--|---|
| <b>Conventional Formations</b>   |                           |  |   |
| Crude oil                        | 15213                     | 319,351  | 778,873 bbl                             |
| Natural gas                      | 43385                     | 228,841  | 82,346 Mmcf                             |
| Other (Condensate, etc.)         | 6329                      | 290,588  | 2,579 bbl                               |
| <b>Unconventional Formations</b> |                           |  |   |
| Crude oil                        | 1                         | 0  | 84,225 bbl                              |
| Natural gas                      | 12174                     | 35,934,060   | 7,574,469 Mmcf                          |
| Other (Condensate, etc.)         | 88                        | 6,237  | 5,394,331 bbl                           |
| <b>Total</b>                     | <b>77,190</b>             | <b>36,779,077</b>  | <b>6,260,007 bbl<br/>7,656,814 Mmcf</b> |

Table 5-48: Produced Water Management Practices for Pennsylvania - 2021

| Management Practice   | Total Volume of Produced Water Managed by that Practice (bbl/year) | Percentage of Produced Water Managed by that Practice |
|---|--|---|
| Injection for Enhanced Recovery   | 0  | 0%  |
| Injection for Disposal (By Operator)  | 4,551,759  | 6.50%   |
| Injection for Disposal (Commercial / Offsite)<br>(3rd Party Managed Produced Water) | 0  | 0%  |
| Surface Water Discharge<br>(Ocean, Lake, Pond, Stream)                              | 125,525  | 0.18%   |
| Surface Discharge (Land Application)  | 14,733   | 0.02%   |
| Evaporation (Lined Sump)  | 0  | 0%  |
| Evaporation / Infiltration (Unlined Sump)   | 0  | 0%  |
| Sale / Transfer – Domestic Use  | 0  | 0%  |
| Sale / Transfer – Other Oil & Gas Operator  | 0  | 0%  |
| Reuse Within the Oil & Gas Industry   | 34,970,964   | 49.93%  |
| Reuse Outside the Oil & Gas Industry  | 4,935,594  | 7.05%   |
| Other   | 25,446,886   | 36.33%  |
| <b>Total</b>  | <b>70,045,460</b>  | <b>99.64%</b>   |

## 5.25 South Dakota

### 5.25.1 Introduction

The South Dakota Department of Environment and Natural Resources (DENR), Minerals and Mining Program regulates mineral exploration, mining, and oil and gas development in the state, and ensures mineral exploration and development is conducted in a manner that minimizes environmental impact, and that affected lands are reclaimed and useable after the resources have been extracted. The state does not differentiate hydrocarbon production and produced water data between unconventional and conventional development. Below is a list of key considerations developed after questionnaire data compilation and assessment. **Tables 5-49** and **5-50** present 2021 production data.

- **Production:** The state reported 195 hydrocarbon wells that produced 1,028,395 bbls of crude oil; 3,353 Mmcf of natural gas; and 0 bbls of condensate.
- **Combined BOE:** 1,587,160
- **Produced Water:** Total produced water volume for the state was 6,855,975 bbls.
- **Water Management Practice:** Injection for enhanced recovery represented the largest water management practice in the state with 6,340,452 bbls, or 79.48% of the total reported water volume
- **Ratios:** WOR = 6.7; WGR = 0.1
- **State Ranking:** Total Crude Oil and Condensate = 26<sup>th</sup>  
Total Natural Gas Production = 27<sup>th</sup>  
Total Produced Water Volume = 24<sup>th</sup>

### 5.25.2 Production and Produced Water Data

When compared to previous GWPC studies (2012, 2017), produced water volumes from 2012 (5,296,000 bbls) and 2017 (6,924,285 bbls) increased by nearly 31%, and then decreased slightly by ~1% from 2017 to 2021. The number of hydrocarbon producing wells from 2017 to 2021 decreased by one well.

Produced water from conventional crude oil production accounted for nearly 100% of the total produced water in the state, while less than one percent came from conventional natural gas wells. Since the state does not differentiate between conventional and unconventional production the produced water from unconventional development could not be estimated (refer to **Table 5-49**).

### 5.25.3 Produced Water Management Practices

Based on 2021 DENR data, produced water in the state is used for EOR projects (79.48%) or injected for disposal by operators (20.52%) (refer to **Table 5-50**). DENR tracks bbls injected for disposal, however, water volumes used for EOR are supplemented by ground water obtained through water supply wells, and the agency is not able to differentiate those amounts within the injection data. Also, the agency reported one county in the state uses small volumes of produced water for dust suppression on gravel roads or stores it in unlined pits for evaporation. DENR does not track volumes of produced water utilized for these purposes. As such, the state did not report any beneficial reuse of produced water in 2021.

**Table 5-49: Oil and Gas Production for South Dakota by Development Method - 2021**

| Type of Hydrocarbon              | Number of Wells Producing | Total Volume of Produced Water Brought to Surface (bbl/year) | Volume of Hydrocarbon Produced |
|----------------------------------|---------------------------|--|--------------------------------|
| <b>Conventional Formations</b>   |                           |  |                                |
| Crude oil                        | 152                       | 6,855,702  | 1,028,395 bbl                  |
| Natural gas                      | 43                        | 273  | 3,353 Mmcf                     |
| Other (Condensate, etc.)         | 0                         | 0  | 0                              |
| <b>Unconventional Formations</b> |                           |  |                                |
| Crude oil                        | 0                         | 0  | 0                              |
| Natural gas                      | 0                         | 0  | 0                              |
| Other (Condensate, etc.)         | 0                         | 0  | 0                              |
| <b>Total</b>                     | 195                       | 6,855,975  | 1,028,395 bbl<br>3,353 Mmcf    |

**Table 5-50: Produced Water Management Practices for South Dakota - 2021**

| Management Practice   | Total Volume of Produced Water Managed by that Practice (bbl/year) | Percentage of Produced Water Managed by that Practice |
|---|--|---|
| Injection for Enhanced Recovery   | 6,340,452  | 79.48%  |
| Injection for Disposal (By Operator)  | 1,636,555  | 20.52%  |
| Injection for Disposal (Commercial / Offsite)<br>(3rd Party Managed Produced Water) | 0  | 0%  |
| Surface Water Discharge<br>(Ocean, Lake, Pond, Stream)                              | 0  | 0%  |
| Surface Discharge (Land Application)  | 0  | 0%  |
| Evaporation (Lined Sump)  | 0  | 0%  |
| Evaporation / Infiltration (Unlined Sump)   | 0  | 0%  |
| Sale / Transfer – Domestic Use  | 0  | 0%  |
| Sale / Transfer – Other Oil & Gas Operator  | 0  | 0%  |
| Reuse Within the Oil & Gas Industry   | 0  | 0%  |
| Reuse Outside the Oil & Gas Industry  | 0  | 0%  |
| Other   | 0  | 0%  |
| <b>Total</b>  | 7,977,007  | 100%  |

## 5.26 Tennessee

### 5.26.1 Introduction

The Tennessee Department of Environment and Conservation (TDEC), Oil and Gas Division, issues permit for persons or businesses who drill, deepen, or reopen oil and gas wells in the state. In response to the questionnaire, TDEC did not differentiate hydrocarbon production and produced water data between unconventional and conventional development. In addition, the state does not track produced water volumes. The TDEC did report the total produced water volume by management practice and this value was used to approximate the total volume of produced water for the state. Below is a list of key considerations developed after questionnaire data compilation and assessment. **Tables 5-51 and 5-52** present 2021 production data.

- **Production:** The state reported 1,751 hydrocarbon wells that produced 151,633 bbls of crude oil; 3,602 Mmcf of natural gas; and 0 bbls of condensate.
- **Combined BOE:** 751,987
- **Produced Water:** Total produced water volume for the state was 143,767 bbls (*total water volume approximated from volumes reported for produced water management practices*).
- **Water Management Practice:** Injection for enhanced recovery represented the largest water management practice in the state with 6,340,452 bbls, or 79.48% of the total reported water volume.
- **Ratios:** WOR = Insufficient data; WGR = Insufficient data.
- **State Ranking:** Total Crude Oil and Condensate = 29<sup>th</sup>  
Total Natural Gas Production = 26<sup>th</sup>  
Total Produced Water Volume = 30<sup>th</sup>

### 5.26.2 Production and Produced Water Data

When compared to previous GWPC studies (2012, 2017), produced water volumes from 2012 (1,480,000 bbls) and 2017 (44,163 bbls) decreased substantially by 97%, and then increased by ~226% from 2017 to 2021 (143,766.61 bbls). The number of hydrocarbon producing wells decreased from 2017 to 2021 by 309 wells, or 15%.

### 5.26.3 Produced Water Management Practices

Based on 2021 TDEC data, produced water in the state is used for EOR projects (96.46%) or is injected for disposal by operators (3.54%) (refer to **Table 5-52**). The state did not report any beneficial reuse of produced water in 2021.

Table 5-51: Oil and Gas Production for Tennessee by Development Method - 2021

| Type of Hydrocarbon   | Number of Wells Producing | Total Volume of Produced Water Brought to Surface (bbl/year) | Volume of Hydrocarbon Produced |
|---|---------------------------|--|--------------------------------|
| <b>Conventional Formations</b>  |                           |  |                                |
| Crude oil   | 805                       | 0  | 151,633 bbl                    |
| Natural gas   | 946                       | 0  | 3,602 Mmcft                    |
| Other (Condensate, etc.)  | 0                         | 0  | 0                              |
| <b>Unconventional Formations</b>  |                           |  |                                |
| Crude oil   | 0                         | 0  | 0                              |
| Natural gas   | 0                         | 0  | 0                              |
| Other (Condensate, etc.)  | 0                         | 0  | 0                              |
| <b>Total</b>  | 1,751                     | 143,767  | 151,633 bbl<br>3,602 Mmcft     |
| <b>Note:</b> Total volume of produced water represents reported total volume of produced water by management practices. |                           |  |                                |

Table 5-52: Produced Water Management Practices for Tennessee - 2021

| Management Practice   | Total Volume of Produced Water Managed by that Practice (bbl/year) | Percentage of Produced Water Managed by that Practice |
|---|--|---|
| Injection for Enhanced Recovery   | 138,675  | 96.46%  |
| Injection for Disposal (By Operator)  | 5,092  | 3.54%   |
| Injection for Disposal (Commercial / Offsite)<br>(3rd Party Managed Produced Water) | 0  | 0%  |
| Surface Water Discharge<br>(Ocean, Lake, Pond, Stream)                              | 0  | 0%  |
| Surface Discharge (Land Application)  | 0  | 0%  |
| Evaporation (Lined Sump)  | 0  | 0%  |
| Evaporation / Infiltration (Unlined Sump)   | 0  | 0%  |
| Sale / Transfer – Domestic Use  | 0  | 0%  |
| Sale / Transfer – Other Oil & Gas Operator  | 0  | 0%  |
| Reuse Within the Oil & Gas Industry   | 0  | 0%  |
| Reuse Outside the Oil & Gas Industry  | 0  | 0%  |
| Other   | 0  | 0%  |
| <b>Total</b>  | 143,767  | 100%  |

## 5.27 Texas

### 5.27.1 Introduction

The Railroad Commission of Texas (RRC) regulates the oil and gas industry and serves to protect the environment and community while supporting enhanced development and economic vitality for the state. Although the state does not track produced water volume data, the RRC did report the total produced water volume by management practices. This volume was used to approximate the total volume of produced water for Texas. Below is a list of key considerations developed after questionnaire data compilation and assessment. **Tables 5-53** and **5-54** present 2021 production data.

- **Production:** The state reported 203,207 hydrocarbon wells that produced 1,459,827,134 bbls of crude oil; 10,741,016 Mmcf of natural gas; and 264,574,972 bbls of condensate.
- **Combined BOE:** 3,514,571,494
- **Produced Water:** Total produced water volume for the state was 8,107,645,550 bbls (*total water volume approximated from volumes reported for produced water management practices*).
- **Water Management Practice:** The largest water management practice reported by the state injection for disposal by operators with 3,541,581,140 bbls, or 43.68%.
- **Ratios:** WOR = Insufficient data; WGR = Insufficient data.
- **State Ranking:** Total Crude Oil and Condensate = 1<sup>st</sup>  
Total Natural Gas Production = 1<sup>st</sup>  
Total Produced Water Volume = 1<sup>st</sup>

### 5.27.2 Production and Produced Water Data

When compared to previous GWPC studies (2012, 2017), produced water volumes increased from 2012 (7,435,659,000 bbls) to 2017 (9,895,084,619 bbls) by 62%, and then decreased by ~33.5% between 2017 and 2021 (8,107,645,550 bbls) (refer to **Table 5-53**). As previously mentioned in **Chapter 4**, the reduction in injection volume or the difference between the 2017 and 2021 produced water total, some -1,787,439,000 bbls that was not injected, could represent the reuse and recycling industry as there has been a big push to recycle in the Permian. The number of hydrocarbon producing wells from 2017 to 2021 decreased by 4,594 wells, or 5.6%. Production and well counts are based on field designation as "unconventional fracture treated" (UFT), a designation RRC adopted in 2016. This designation may not be inclusive of all fields currently classifiable as unconventional because many fields predate this adoption. It is possible some of the production currently attributed to "conventional" wells may in fact be unconventional but not classified as such.

### 5.27.3 Produced Water Management Practices

Based on 2021 RRC data, most of the produced water in the state is injected for disposal by operators (3,541,581,140 bbls, or 43.68% of the total water volume). Injection for EOR (32.14%) and disposal at commercial facilities (24.18%) are the remaining water management methods (refer to **Table 5-54**). The state did not report any beneficial reuse of produced water in 2021.



**Table 5-53: Oil and Gas Production for Texas by Development Method - 2021**

| Type of Hydrocarbon  | Number of Wells Producing | Total Volume of Produced Water Brought to Surface (bbl/year) | Volume of Hydrocarbon Produced               |
|--|---------------------------|--|--|
| <b>Conventional Formations</b>   |                           |  |  |
| Crude oil  | 126,631                   | 8,107,645,550  | 1,303,394,874 bbl                            |
| Natural gas  | 24075                     | 0  | 8,970,804 Mmcf                               |
| Other (Condensate, etc.)   | 0                         | 0  | 246,972,563 bbl                              |
| <b>Unconventional Formations</b>   |                           |  |  |
| Crude oil  | 36,700                    | 0  | 156,432,260 bbl                              |
| Natural gas  | 15,801                    | 0  | 1,770,213 Mmcf                               |
| Other (Condensate, etc.)   | 0                         | 0  | 17,602,409 bbl                               |
| <b>Total</b>   | <b>203,207</b>            | <b>8,107,645,550</b>   | <b>1,724,402,106 bbl<br/>10,741,016 Mmcf</b> |
| <b>Note:</b> Total volume of produced water was approximated based on the reported total volume of produced water by management practices. |                           |  |  |

**Table 5-54: Produced Water Management Practices for Texas - 2021**

| Management Practice   | Total Volume of Produced Water Managed by that Practice (bbl/year) | Percentage of Produced Water Managed by that Practice |
|---|--|---|
| Injection for Enhanced Recovery   | 2,605,715,654  | 32.14%  |
| Injection for Disposal (By Operator)  | 3,541,581,140  | 43.68%  |
| Injection for Disposal (Commercial / Offsite)<br>(3rd Party Managed Produced Water) | 1,960,348,756  | 24.18%  |
| Surface Water Discharge<br>(Ocean, Lake, Pond, Stream)                              | 0  | 0%  |
| Surface Discharge (Land Application)  | 0  | 0%  |
| Evaporation (Lined Sump)  | 0  | 0%  |
| Evaporation / Infiltration (Unlined Sump)   | 0  | 0%  |
| Sale / Transfer – Domestic Use  | 0  | 0%  |
| Sale / Transfer – Other Oil & Gas Operator  | 0  | 0%  |
| Reuse Within the Oil & Gas Industry   | 0  | 0%  |
| Reuse Outside the Oil & Gas Industry  | 0  | 0%  |
| Other   | 0  | 0%  |
| <b>Total</b>  | <b>8,107,645,550</b>   | <b>100%</b>   |

## 5.28 Utah

### 5.28.1 Introduction

The Utah Department of Natural Resources Division of Oil, Gas, and Mining (DOGM), regulates oil and gas natural resources in the state and ensures the resources are developed in an environmentally responsible manner. DOGM does not differentiate between unconventional and conventional production, so hydrocarbon and produced water volumes developed from unconventional formations are not distinct. In addition, total produced water by reservoir type was not reported but rather given as a cumulative volume. Below is a list of key considerations developed after questionnaire data compilation and assessment. **Tables 5-55** and **5-56** present 2021 production data.

- **Production:** The state reported 11,531 hydrocarbon wells that produced 35,513,708 bbls of crude oil; 265,882 Mmcf of natural gas, which includes 25,957 Mmcf from coalbed methane development; and 0 bbls of condensate.
- **Combined BOE:** 79,827,332
- **Produced Water:** Total produced water volume for the state was 36,779,077 bbls.
- **Water Management Practice:** Injection for disposal by operators represented the largest produced water management practice in the state with 77,421,870 bbls, or 53.38% of the total reported water volume.
- **Ratios:** WOR = insufficient data; WGR = insufficient data.
- **State Ranking:** Total Crude Oil and Condensate = 10<sup>th</sup>  
Total Natural Gas Production = 14<sup>th</sup>  
Total Produced Water Volume = 14<sup>th</sup>

### 5.28.2 Production and Produced Water Data

When compared to previous GWPC studies (2012, 2017), produced water volumes decreased from 2012 (166,945,000 bbls) to 2017 (155,047,940) by ~7%, and decreased again 3.5% between 2017 and 2021 (149,548,608 bbls). The number of hydrocarbon producing wells decreased by 234 wells from 2017 to 2021.

### 5.28.3 Produced Water Management Practices

Based on 2021 DOGM data, produced water in the state is used for EOR projects (46.62%) or injected for disposal by operators (53.38%) (refer to **Table 5-56**). The state did not report any beneficial reuse of produced water in 2021.

Table 5-55: Oil and Gas Production for Utah by Development Method - 2021

| Type of Hydrocarbon  | Number of Wells Producing | Total Volume of Produced Water Brought to Surface (bbl/year) | Volume of Hydrocarbon Produced          |
|--|---------------------------|--|---|
| <b>Conventional Formations</b>   |                           |  |   |
| Crude oil  |                           |  |   |
| Natural gas  |                           |  |   |
| Other (Condensate, etc.)   |                           |  |   |
| <b>Unconventional Formations</b>   |                           |  |   |
| Crude oil  | 5,086                     | -  | 35,513,708 bbl                          |
| Natural gas  | 6,445                     | -  | 239,924 Mmcf                            |
| Other (Coalbed Methane)  | -                         | -  | 25,957 Mmcf                             |
| <b>Total</b>   | <b>11,531</b>             | <b>149,548,608</b>   | <b>35,513,708 bbls<br/>265,882 Mmcf</b> |
| <b>Note:</b> DOGM does not differentiate between unconventional and conventional production, although the agency did report they consider most development in the state to occur from unconventional formations. |                           |  |   |

Table 5-56: Produced Water Management Practices for Utah - 2021

| Management Practice   | Total Volume of Produced Water Managed by that Practice (bbl/year) | Percentage of Produced Water Managed by that Practice |
|---|--|---|
| Injection for Enhanced Recovery   | 67,626,647   | 46.62%  |
| Injection for Disposal (By Operator)  | 77,421,870   | 53.38%  |
| Injection for Disposal (Commercial / Offsite)<br>(3rd Party Managed Produced Water) | 0  | 0%  |
| Surface Water Discharge<br>(Ocean, Lake, Pond, Stream)                              | 0  | 0%  |
| Surface Discharge (Land Application)  | 0  | 0%  |
| Evaporation (Lined Sump)  | 0  | 0%  |
| Evaporation / Infiltration (Unlined Sump)   | 0  | 0%  |
| Sale / Transfer – Domestic Use  | 0  | 0%  |
| Sale / Transfer – Other Oil & Gas Operator  | 0  | 0%  |
| Reuse Within the Oil & Gas Industry   | 0  | 0%  |
| Reuse Outside the Oil & Gas Industry  | 0  | 0%  |
| Other   | 0  | 0%  |
| <b>Total</b>  | <b>145,048,517</b>   | <b>100%</b>   |

## 5.29 Virginia

### 5.29.1 Introduction

The Virginia Department of Mines, Minerals, and Energy (DMME) regulates coal and mineral mining sites as well as natural gas sites for safety and environmental protection. In response to the questionnaire, DMME did not provide produced water volumes associated with the production of crude oil. Below is a list of key considerations developed after questionnaire data compilation and assessment. **Tables 5-57** and **5-58** present 2021 production data.

- **Production:** The state reported 8,033 hydrocarbon wells that produced 4,097 bbls of crude oil; 96,044 Mmcf of natural gas; and 0 bbls of condensate.
- **Combined BOE:** 16,011,355
- **Produced Water:** Total produced water volume for the state was 1,660,599 bbls.
- **Water Management Practice:** Injection for disposal by operators represented the largest produced water management practice in the state with 1,572,793.72, or 96.65% of the total reported water volume.
- **Ratios:**
  - Combined WOR = Insufficient data; WGR = 17.3.
  - Conventional WOR = Insufficient data, WGR = 0.7
  - Unconventional WOR = Insufficient data, WGR = 20.5
- **State Ranking:** Total Crude Oil and Condensate = 33<sup>rd</sup>  
 Total Natural Gas Production = 18<sup>th</sup>  
 Total Produced Water Volume = 27<sup>th</sup>

### 5.29.2 Production and Produced Water Data

When compared to previous GWPC studies (2012, 2017), produced water volumes decreased from 2012 (3,232,000 bbls) to 2017 (2,156,931), by ~33%, and another 23% from 2017 to 2021 (1,660,599 bbls). Consistent with produced water volumes, the number of hydrocarbon producing wells also decreased by 224 wells from 2017 to 2021.

### 5.29.3 Produced Water Management Practices

Based on 2021 DMME data, produced water in the state is injected for disposal either by operators (96.65%), or to a much lesser extent by commercial disposal (3.35%) (refer to **Table 5-58**). The state did not report any beneficial reuse of produced water in 2021.

Table 5-57: Oil and Gas Production for Virginia by Development Method - 2021

| Type of Hydrocarbon   | Number of Wells Producing | Total Volume of Produced Water Brought to Surface (bbl/year) | Volume of Hydrocarbon Produced |
|---|---------------------------|--|--------------------------------|
| <b>Conventional Formations</b>  |                           |  |                                |
| Crude oil   | 2                         | 0  | 4,097 bbl                      |
| Natural gas   | 1,961                     | 10,085   | 15,449 Mmcf                    |
| Other (Condensate, etc.)  | 0                         | 0  | 0                              |
| <b>Unconventional Formations</b>  |                           |  |                                |
| Crude oil   | 0                         | 0  | 0                              |
| Natural gas   | 6,070                     | 1,650,514  | 80,595 Mmcf                    |
| Other (Coalbed Methane)   | 0                         | 0  | 0                              |
| <b>Total</b>  | 8,033                     | 1,660,599  | 4,097 bbls<br>96,044 Mmcf      |
| <b>Note:</b> As reported by the DMME, 42 natural gas wells also produced oil, which was included in the crude oil production total. |                           |  |                                |

Table 5-58: Produced Water Management Practices for Virginia - 2021

| Management Practice   | Total Volume of Produced Water Managed by that Practice (bbl/year) | Percentage of Produced Water Managed by that Practice |
|---|--|---|
| Injection for Enhanced Recovery   | 0  | 0%  |
| Injection for Disposal (By Operator)  | 1,572,794  | 96.65%  |
| Injection for Disposal (Commercial / Offsite)<br>(3rd Party Managed Produced Water) | 54,445   | 3.35%   |
| Surface Water Discharge<br>(Ocean, Lake, Pond, Stream)                              | 0  | 0%  |
| Surface Discharge (Land Application)  | 0  | 0%  |
| Evaporation (Lined Sump)  | 0  | 0%  |
| Evaporation / Infiltration (Unlined Sump)   | 0  | 0%  |
| Sale / Transfer – Domestic Use  | 0  | 0%  |
| Sale / Transfer – Other Oil & Gas Operator  | 0  | 0%  |
| Reuse Within the Oil & Gas Industry   | 0  | 0%  |
| Reuse Outside the Oil & Gas Industry  | 0  | 0%  |
| Other   | 0  | 0%  |
| <b>Total</b>  | 1,627,239  | 100%  |

## 5.30 West Virginia

### 5.30.1 Introduction

The West Virginia Department of Environmental Protection (WVDEP), Office of Oil and Gas, is responsible for monitoring and regulating all actions related to the exploration, drilling, storage and production of oil and natural gas. Below is a list of key considerations developed after questionnaire data compilation and assessment. **Tables 5-59** and **5-60** present 2021 production data.

- **Production:** The state reported 56,637 hydrocarbon wells that produced 17,961,149 bbls of crude oil; 2,675,208 Mmcf of natural gas; and 0 bbls of condensate.
- **Combined BOE:** 463,829,149
- **Produced Water:** Total produced water volume for the state was 46,654,984 bbls.
- **Water Management Practice:** Reuse within the oil and gas industry (*i.e.*, for drilling, well work, well stimulation, etc.) represented the largest produced water management practice in the state with 35,408,655 bbls or 75.89% of the total reported water volume.
- **Ratios:** WOR = 0.026; WGR = 15.72
- **State Ranking:** Total Crude Oil and Condensate = 15<sup>th</sup>  
Total Natural Gas Production = 5<sup>th</sup>  
Total Produced Water Volume = 18<sup>th</sup>

### 5.30.2 Production and Produced Water Data

When compared to previous GWPC studies (2012, 2017), produced water volumes increased from 2012 (13,772,000 bbls) to 2017 (26,650,935), a substantial increase of ~94%. Volumes increased another 75% from 2017 to 2021 (46,654,984.40 bbls). During that time, the state documented a loss of 8,189 hydrocarbon producing wells, or 12.6% of the total.

WVDEP noted it considers condensate to be liquid hydrocarbons stripped off at the wellhead and reported in the oil production data. In addition, the state characterizes a well to be a gas well when the ratio of the volume of gas produced (mcf) to the volume of oil produced (bbl) is greater than 6.0. For this reason, an oil well may produce natural gas and vice versa, and even though the state does not technically have any unconventional wells, 17,288,737 bbls of oil were reported under this reservoir type.

Produced water produced from crude oil production was <1% of the total produced water in the state, while the remaining volumes were associated with natural gas (90%) and condensate (~8.8%) production. Produced water from conventional development was just under 10% of the state's total produced water volume. The unconventional development of natural gas provided the remaining produced water volume, or 90% of the total water volume (refer to **Table 5-59**).

### 5.30.3 Produced Water Management Practices

Based on 2021 WVDEP data, produced water in the state is primarily reused by operators (75.89%), injected for disposal by operators (12.54%), or injected for EOR projects (7.84%). A smaller volume of water (3.48%) is injected in commercial disposal wells (refer to **Table 5-60**). WVDEP does not currently tabulate the volume of water used for EOR. The reported volume for this management practice (3,660,000 bbls) was estimated in the 2012 report and reused in the 2017 report, and in this report. Lastly, WVDEP noted that under the "reuse within the oil and gas" category, 31,461,735 bbls of the reported total is estimated to be used in well stimulation activities.

Table 5-59: Oil and Gas Production for West Virginia by Development Method - 2021

| Type of Hydrocarbon  | Number of Wells Producing | Total Volume of Produced Water Brought to Surface (bbl/year) | Volume of Hydrocarbon Produced            |
|--|---------------------------|--|---|
| <b>Conventional Formations</b>   |                           |  |   |
| Crude oil  | 3,440                     | 470,688  | 672,412 bbl                               |
| Natural gas  | 48,860                    | 0  | 121,204 Mmcf                              |
| Other (Condensate, etc.)   | 0                         | 4,120,936  | 0   |
| <b>Unconventional Formations</b>   |                           |  |   |
| Crude oil  | 0                         | 0  | 17,288,737 bbl                            |
| Natural gas  | 4,337                     | 42,063,360   | 2,554,004 Mmcf                            |
| Other (Condensate, etc.)   | 0                         | 0  | 0   |
| <b>Total</b>   | <b>56,637</b>             | <b>46,654,984</b>  | <b>17,961,149 bbls<br/>2,675,208 Mmcf</b> |
| <b>Note:</b> To organize data, the WVDEP defines unconventional development to coincide with horizontal drilling techniques as applied to shale formations. Produced water production from unconventional wells was reported exclusively by the 2,656 wells permitted under W. Va. Code §22-6A. An additional 114,380 bbl produced water was added based on the same assumption made in 2017 that the WGR equals 22.5 bbl/Mmcf. CBM wells are tracked by the state but not tabulated; reported production for these wells by the WVDEP was 5,320 Mmcf. |                           |  |   |

Table 5-60: Produced Water Management Practices for West Virginia - 2021

| Management Practice   | Total Volume of Produced Water Managed by that Practice (bbl/year) | Percentage of Produced Water Managed by that Practice |
|---|--|---|
| Injection for Enhanced Recovery   | 3,660,000  | 7.84%   |
| Injection for Disposal (By Operator)  | 5,850,365  | 12.54%  |
| Injection for Disposal (Commercial / Offsite)<br>(3rd Party Managed Produced Water)   | 1,621,584  | 3.48%   |
| Surface Water Discharge<br>(Ocean, Lake, Pond, Stream)  | 0  | 0%  |
| Surface Discharge (Land Application)  | 114,380  | 0.25%   |
| Evaporation (Lined Sump)  | 0  | 0%  |
| Evaporation / Infiltration (Unlined Sump)   | 0  | 0%  |
| Sale / Transfer – Domestic Use  | 0  | 0%  |
| Sale / Transfer – Other Oil & Gas Operator  | 0  | 0%  |
| Reuse Within the Oil & Gas Industry   | 35,408,655   | 75.89%  |
| Reuse Outside the Oil & Gas Industry  | 0  | 0%  |
| Other   | 0  | 0%  |
| <b>Total</b>  | <b>46,654,984</b>  | <b>100%</b>   |
| <b>Note:</b> Produced water data from horizontal H6A (i.e., horizontal Marcellus/Utica wells) is not collected. However, the state estimates 10,487,245 bbl of water is disposed of at Class 2D facilities and that 8,280,296 bbl of this water is transported to Ohio. |  |   |

## 5.31 Wyoming

### 5.31.1 Introduction

Wyoming Oil and Gas Conservation Commission (WOGCC) regulates oil and gas activities in the state and does so in a manner that ensures responsible development and management of oil and gas resources and provides appropriate environmental stewardship for its citizens. Below is a list of key considerations developed after questionnaire data compilation and assessment. **Tables 5-61** and **5-62** present 2021 production data.

- **Production:** The state reported 27,171 hydrocarbon wells that produced 78,900,632 bbls of crude oil; 1,081,393 Mmcf of natural gas; and 6,389,501 bbls of condensate.
- **Combined BOE:** 265,522,317
- **Produced Water:** Total produced water volume for the state was 1,559,881,944 bbls.
- **Water Management Practice:** Injection for enhanced recovery represented the largest produced water management practice in the state with 1,220,556,814 bbls, or 85.41% of the total reported water volume.
- **Ratios:**
  - Combined WOR = 15.1; WGR = 251.7
  - Conventional WOR = 38.4, WGR = 212.4
  - Unconventional WOR = 2.3, WGR = 12483.9
- **State Ranking:** Total Crude Oil and Condensate = 9<sup>th</sup>  
                                     Total Natural Gas Production = 10<sup>th</sup>  
                                     Total Produced Water Volume = 6<sup>th</sup>

### 5.31.2 Production and Produced Water Data

When compared to previous GWPC studies (2012, 2017), produced water volumes decreased from 2012 (2,178,065,000 bbls) to 2017 (1,705,309,511 bbls) by ~22%, and decreased another 14% between 2017 and 2021 (1,459,320,828 bbls). Additionally, the state documented a loss of 6,401 hydrocarbon producing wells from 2017 to 2021, or a decrease of 19%.

Produced water from crude oil production accounted for 88% of the total produced water in the state, while the remaining 12% of volumes were associated with natural gas production. Produced water from conventional development accounted for most of the states total produced water volume (95%). The unconventional development of hydrocarbons produced the remaining 5%, with most of this being associated with crude oil development (refer to **Table 5-61**).

### 5.31.3 Produced Water Management Practices

Based on 2021 WOGCC data, produced water in the state is either used for EOR projects (85.41%) or injected for disposal by operators (14.59%) (refer to **Table 5-62**). The state also reported produced water is managed in other ways, but either WOGCC does not track that information (*i.e.*, evaporation in pits and/or reservoirs) or the Wyoming Department of Environmental Quality is responsible for the regulation of the practice (*i.e.*, discharge into surface water). The state further reported if the produced water is not injected for disposal or enhanced recovery, then it is likely discharged to the surface. WOGCC did not report water reused within the oil and gas industry or outside of the industry.



Table 5-61: Oil and Gas Production for Wyoming by Development Method - 2021

| Type of Hydrocarbon              | Number of Wells Producing | Total Volume of Produced Water Brought to Surface (bbl/year) | Volume of Hydrocarbon Produced           |
|----------------------------------|---------------------------|--|--|
| <b>Conventional Formations</b>   |                           |  |  |
| Crude oil                        | 7,057                     | 1,159,342,111  | 23,827,883 bbl                           |
| Natural gas                      | 17,582                    | 228,909,681  | 1,077,926 Mmcf                           |
| Other (Condensate, etc.)         | 0                         | 0  | 6,389,501 bbl                            |
| <b>Unconventional Formations</b> |                           |  |  |
| Crude oil                        | 2,350                     | 128,348,565  | 55,072,749 bbl                           |
| Natural gas                      | 182                       | 43,281,587   | 3,467 Mmcf                               |
| Other (Condensate, etc.)         | 0                         | 0  | 0  |
| <b>Total</b>                     | <b>27,171</b>             | <b>1,559,881,944</b>   | <b>85,290,133 bbl<br/>1,081,393 Mmcf</b> |
|                                  |                           |  |  |

Table 5-62: Produced Water Management Practices for Wyoming - 2021

| Management Practice   | Total Volume of Produced Water Managed by that Practice (bbl/year) | Percentage of Produced Water Managed by that Practice |
|---|--|---|
| Injection for Enhanced Recovery   | 1,220,556,814  | 85.41%  |
| Injection for Disposal (By Operator)  | 208,502,298  | 14.59%  |
| Injection for Disposal (Commercial / Offsite)<br>(3rd Party Managed Produced Water) | 0  | 0%  |
| Surface Water Discharge<br>(Ocean, Lake, Pond, Stream)                              | 0  | 0%  |
| Surface Discharge (Land Application)  | 0  | 0%  |
| Evaporation (Lined Sump)  | 0  | 0%  |
| Evaporation / Infiltration (Unlined Sump)   | 0  | 0%  |
| Sale / Transfer – Domestic Use  | 0  | 0%  |
| Sale / Transfer – Other Oil & Gas Operator  | 0  | 0%  |
| Reuse Within the Oil & Gas Industry   | 0  | 0%  |
| Reuse Outside the Oil & Gas Industry  | 0  | 0%  |
| Other   | 0  | 0%  |
| <b>Total</b>  | <b>1,429,059,112</b>   | <b>100%</b>   |

## 5.32 Other States

A few other states were sent the questionnaire as they might have initiated some oil and gas production since the last assessment in 2017. The states contacted and their responses are as follows:

- **Georgia:** The Georgia Department of Natural Resources explaining that there is no production either onshore or offshore.
- **Maryland:** The Maryland Department of the Environment replied to the questionnaire but only provided data regarding conventional natural gas production at 4.91 Mmcf/year without the number of wells or any produced water data. The volume of natural gas from Maryland places it in 33<sup>rd</sup> position in our state rankings. The information provided was minimal and therefore a separate discussion was not included in **Chapter 5**.
- **Michigan:** The Michigan Department of Environment, Great Lakes, and Energy – Oil, Gas, and Minerals Division was unable to respond due to lack of staff during the pandemic to collate and enter the data; however, their hydrocarbon production numbers were obtained from EIA sources. Michigan ranked 19<sup>th</sup> in both natural gas and crude oil production with 72,301 Mmcf and 4,338,000 bbls, respectively.
- **North Carolina:** The North Carolina Geological Survey reported their situation is unchanged as there are no commercial oil or gas wells in the state.
- **South Carolina:** The South Carolina Department of Health & Environmental Control did not respond to our questionnaire but reported that there is no oil or natural gas development within the state.
- **Washington:** The Washington Geological Survey stated that there is no production of oil or gas in Washington State currently.

## 6 Federal and Native American Production

The objective of this chapter is to summarize hydrocarbon production and produced water volumes on federal lands to include onshore, offshore, and on tribal land. Federal onshore oil and gas operations are managed by the U.S. Department of the Interior (DOI) Bureau of Land Management (BLM) and the U.S. Department of Agriculture (USDA) Forest Service.

The BLM currently manages approximately 700 million acres of onshore subsurface minerals that are held by the BLM and Forest Service; BLM also manages some aspects of the oil and gas development for Native Americans from the tribal mineral estate.<sup>15</sup> Based on published statistics from BLM for the fiscal year 2021, there are 88,887 well bores that are located in 28 states with the most well bores being located in New Mexico (30,100), Wyoming (28,800) and Utah (8,101).<sup>16</sup> The total number of well bores reported in 2021 represented the lowest number of reported wells per year since 2009 (85,330). The Forest Service manages access to, and development of, federal oil and natural gas resources on approximately one-third of the over 150 National Forests and Grasslands.<sup>17</sup> Based on the Forest Service's fiscal year budget for 2020, approximately 2.7% of the lands administered by the Forest Service are leased for oil and gas operations, coal, and geothermal uses with 4,000 active wells.<sup>18</sup>

The DOI Office of Natural Resources Revenue (ONRR) is responsible for management of all revenues associated with mineral leases on federal onshore, federal offshore (outer continental shelf), and on tribal lands. Oil and gas related production information that is published by the ONRR represents relevant data that is received from operators on Form ONRR-4054-B (Oil and Gas Operations Report, Part B). Oil and gas production data for the 2021 calendar year was obtained from the agency's website via download of the production by year spreadsheet.

DOI's Bureau of Ocean Energy Management (BOEM) manages the oil and gas leasing on the Outer Continental Shelf. Its sister agency, Bureau of Safety and Environmental Enforcement (BSEE), maintains production data from offshore leases, to include oil and gas production data from Alaska, the Pacific Region, and the Gulf of Mexico. Oil and gas production data, as well as produced water volume data for the 2021 calendar year was downloaded via BSEE's data center.

### 6.1 Onshore Federal and Native American Production

The ONRR oil and gas production data for onshore leases located on federal and Native American lands was tabulated for the 2021 calendar year. Currently, produced water volumes are not tracked by the ONRR; however, produced water values (and oil and gas production) are assumed to be included in the total volumes provided by the state agencies for those states in which the federal and tribal lands are located.

Provided below in **Table 6-1** is a comparative summary of federal onshore oil and gas production for the calendar years 2017 and 2021, to include Native American Lands and "Mixed Exploratory", which is a BLM term that describes a temporary jurisdictional unit that is used until production is proven on that location. When compared to the ONRR oil (191,184,056 bbl) and gas (3,242,790 Mmcf) production data for 2017, observed oil and gas volumes for 2021 have increased by 429% and ~26%, respectively.

<sup>15</sup> BLM. About the BLM Oil and Gas Program. <https://www.blm.gov/programs/energy-and-minerals/oil-and-gas/about>. Accessed on September 30, 2022.

<sup>16</sup> BLM. Oil and Gas Statistics. Fiscal Year 2021 Statistics. <https://www.blm.gov/programs-energy-and-minerals-oil-and-gas-oil-and-gas-statistics>. Accessed on September 29, 2022.

<sup>17</sup> USDA. Federal Oil and Gas Resource Management. <https://www.fs.usda.gov/managing-land/natural-resources/geology/minerals/energy-minerals/oil-gas>. Accessed on September 30, 2022.

<sup>18</sup> USDA, Forest Service. 2019. FY 2020 Budget Justification.

Conversely, oil and gas production on Native American lands has decreased. From 2018 data, oil has dropped by 2,042,455 bbls (2.51%) and gas production has decreased by 9,801 Mmcf (2.81%).

**Table 6-1: Onshore Production on Federal and Native American Lands – 2017 and 2021**

| Region                               | 2021                 | 2017               |
|--------------------------------------|----------------------|--------------------|
| <b>Onshore Oil Production (bbls)</b> |                      |                    |
| Federal                              | 1,010,997,815        | 191,184,056        |
| Native                               | 79,052,393           | 81,094,848         |
| Mixed Exploratory                    | 31,207,523           | 0                  |
| <b>Total</b>                         | <b>1,121,257,731</b> | <b>272,278,904</b> |
| <b>Onshore Gas Production (Mmcf)</b> |                      |                    |
| Federal                              | 4,075,557.24         | 3,242,790          |
| Native                               | 339,351.77           | 349,153            |
| Mixed Exploratory                    | 159,696.95           | 0                  |
| <b>Total</b>                         | <b>4,574,606</b>     | <b>3,591,943</b>   |

## 6.2 Federal Offshore Production

Production volumes for federal offshore oil and gas operations was obtained from the BSEE based on Oil and Gas Operation Reports that were submitted by offshore operators to the ONRR. This data included oil and gas production data for Alaska, the Pacific Region, and the Gulf of Mexico. Additionally, produced water data for the Gulf of Mexico (OGOR-A Well Production Database) and the Pacific region was downloaded from the BSEE website via ASCII files for further compilation and evaluation, and included total water volume by well status (*i.e.*, gas injection, well injection, producing oil and gas, etc.) and total water injected by well status. Although produced water and injected volumes from the BSEE were not available for Alaska, the state did report these water values and the end disposition of the water in the questionnaire spreadsheet that was submitted to oil and gas producing states as part of this report; these values are presented in **Chapter 5**.

### 6.2.1 Offshore Oil and Gas Production

For comparative purposes, oil and gas production data for 2017 and 2021 for offshore operations was compiled and summarized in **Table 6-2**, to include total values from Alaska, the Gulf of Mexico, and the Pacific. Overall, offshore crude oil production has slightly increased by 7,748,524 bbls (1.24%) due to higher production values observed in the Gulf of Mexico. Crude oil production in Alaska and the Pacific, however, have decreased when compared to 2017 by ~15% and 43%, respectively. The Gulf of Mexico continues to be the largest offshore producer of crude oil with 622,850,485 bbls.

Unlike crude oil production, offshore natural gas production trends continue to decrease as an overall ~36% reduction in Mmcf was observed between 2017 and 2021. The largest decrease in natural gas production was observed in the Pacific with a loss in value of nearly 42%, although it is important to note that the natural gas from the Pacific represents less than one percent of the overall offshore production. The Gulf of Mexico continues to have the largest offshore natural gas production with 622,850,485 Mmcf, though this is a decrease by 27% compared to 2017.

**Table 6-2: Offshore Production in Alaska, Gulf of Mexico, and the Pacific – 2017 and 2021**

| Region  | 2021               | 2017               |
|---|--------------------|--------------------|
| <b>Offshore Oil Production (bbls)</b>   |                    |                    |
| Alaska  | 449,679            | 517,002            |
| Gulf of Mexico  | 622,850,485        | 613,313,372        |
| Pacific   | 3,991,793          | 5,713,059          |
| <b>Total</b>  | <b>627,291,957</b> | <b>619,543,433</b> |
| <b>Offshore Gas Production (Mmcf)</b>   |                    |                    |
| Alaska  | 24,547             | 29,056             |
| Gulf of Mexico  | 791,913            | 1,078,644          |
| Pacific   | 2,784              | 3,950              |
| <b>Total</b>  | <b>819,244</b>     | <b>1,111,650</b>   |
| <b>Note:</b> Production data for 2017 was taken from production charts that were prepared by the BSSE and presented in the 2017 Volumes Report. |                    |                    |

### 6.2.2 Offshore Produced Water Volumes

Tabulation of the offshore produced water data obtained from the BSEE shows oil and gas operations in the Gulf of Mexico and the Pacific region produced 355,824,302 bbls and 46,772,970 bbls of water, respectively, or a collective volume of 402,597,272 bbls (refer to **Table 6-3**). The data also indicates the two regions injected considerable volumes of water: The Gulf of Mexico injected a total of 119,224,348 bbls, or ~34% of the regions total produced water volume; whereas, the Pacific injected a larger portion of the regions produced water with 35,083,883 reported bbls, or 75%.

The discharge of produced water into the ocean via the EPA's NPDES program is an additional water management practice that is conducted within both offshore regions. Based on BSSE offshore data, the volumes of produced water *not* injected in the Gulf of Mexico and the Pacific was 236,599,954 bbls and 11,689,087 bbls, respectively. These remaining volumes likely represent the amount of water that was treated and discharged to the ocean by operators from offshore wells.

Data from the BSSE also included water volume information based on well status (*i.e.*, the physical status of a well completion) and is provided below in **Table 6-3**. Based on this data, crude oil production accounted for 90% of the total water volume in the Gulf of Mexico and 99.9% in the Pacific Region. Producing gas wells contributed much less to these two regions: 8.62% of the Gulf of Mexico's total water volume and less than one percent in the Pacific Region.

**Table 6-3: Offshore Produced Water in the Gulf of Mexico and Pacific Region - 2021**

| Well Status  | Gulf of Mexico      |                         | Pacific             |                         |
|--|---------------------|-------------------------|---------------------|-------------------------|
|  | Water Volume (bbls) | Injection Volume (bbls) | Water Volume (bbls) | Injection Volume (bbls) |
| Gas Injection  | 485,976             | 313,774                 | 0                   | 0                       |
| Water Injection  | 0                   | 118,798,155             | 0                   | 35,083,883              |
| Water Source   | 7,307,100           | 0                       | 0                   | 0                       |
| Producing Oil  | 317,053,165         | 111,086                 | 46,771,460          | 0                       |
| Producing Gas  | 30,707,576          | 0                       | 1,510               | 0                       |
| Non-Producing Oil  | 0                   | 1,333                   | 0                   | 0                       |
| <b>Total</b>   | <b>355,824,302</b>  | <b>119,224,348</b>      | <b>46,772,970</b>   | <b>35,083,883</b>       |
| <b>Note:</b> Produced water data associated with producing oil from Gas lift or load oil was compiled into one category, "Producing Oil." Not all BSEE well status categories reported associated produced water and are not listed above. |                     |                         |                     |                         |

## 7 Findings and Conclusions

### 7.1 Findings

#### 7.1.1 Produced Water Volume

This is the fourth edition of this study to estimate the total volume of produced water generated from oil and gas production in the United States in a full year and characterized the ways in which that water was managed. The previous studies looked at calendar years, 2007, 2012, and 2017, while this study focuses on 2021. The volumes and comparisons in this report are based on datasets gathered from various state oil and gas and environmental agencies representing 33 states as well as from several federal agency's websites with data available online. The 2021 estimated total volume of produced water increased by 6.02% or nearly 1.5 billion bbls from 2017 to 25.86 billion bbls, or ~70.85 million bbls/day.

There were eight states that reported over 1 billion bbls of produced water in 2021 (TX, IL, CA, OK, NM, WY, AK, KS) up three states from 2017. Texas retained the top spot with roughly 8.1 billion bbls produced for the year; however, this was a decline of ~1.8 billion bbls compared to 2017, the difference most likely was unaccounted reuse water for hydraulic fracturing operations. The states with produced water volumes in excess of 1 billion bbls and their percentage of the national total are Texas (31.4%), Illinois (17.8%), California (11.9%), Oklahoma (6.7%), New Mexico (6.2%), Wyoming (6.0%), Alaska (4.0%) and Kansas (3.9%). Illinois made the largest move up the rankings coming from 13<sup>th</sup> in 2017, to grab 2<sup>nd</sup> in 2021, with ~4.6 billion bbls. This was attributed to revised data for their EOR operations which reflected a substantial increase, the revised data for 2017 would have had them in 2<sup>nd</sup> place as well.

Texas again produced the highest volumes of oil and gas to go along with their number one ranking for produced water. The remaining billion bbl/year water-producing states were not all represented in the top ten for oil and gas production, although Alaska, Oklahoma, New Mexico, and Wyoming appeared in the top ten for both crude oil and natural gas.

The production of crude oil, natural gas, and produced water all increased between 2017 and 2021. The percentage increases from 2017 to 2021 as compared to the percentage increases from 2012 to 2017 are as follows:

- **Crude Oil:** 20.18% (2021 vs. 2017) – 50.41% (2017 vs. 2012)
- **Natural Gas:** 17.21% (2021 vs. 2017) – 17.73% (2017 vs. 2012)
- **Produced Water:** 6.02% (2021 vs. 2017) – 15.16% (2017 vs. 2012)

Natural gas increased at about the same rate for this four-year period versus the early five-year period. Both crude oil and produced water each slowed down their rate of increase; however, the percentage increase in produced water as compared to the increase in crude oil appears to have remained consistent with a near 3.3 fold relationship in their percent increases.

The reliable observation is that water production again increased at a slower rate than oil and gas production consistent with the 2017 and 2012 findings.

#### 7.1.2 Produced Water Management Practices

This report compiled data regarding the management practices employed by oil and gas producers to handle produced water in 2021. Consistent with the 2017 and 2012 findings, the vast majority of produced water was injected, ~95.74% (23,841,387,000 bbls). Of that amount ~48.3% (12,038,534,000 bbls) was injected for EOR, ~37.3% (9,284,329,000 bbls) was injected for disposal by operators, and ~10.1% (2,518,524,000 bbls) was injected for disposal at 3<sup>rd</sup> party commercial operations.

The remaining volume was either discharged, evaporated, transferred, or reused. Approximately 1.2% was discharged as reported by seven states and the federal offshore assets, ~0.2% was evaporated mainly by several western states, ~1.2% was sold or transferred for reuse in California, and ~1.4% was beneficially reused within and outside of the oil and gas industry.

### 7.1.3 Data Availability and Quality

As noted in prior iterations of this study, produced water volumes are not reported or documented in a consistent or regular manner from state to state. The rules and regulations vary from state to state and can cover monitoring and reporting produced water volumes from each well or make no mention of it at all, hence we are left with a mixed bag of information. However, most states responses to the questionnaire and provided insights to their data reliability and completeness.

Unlike past efforts, most states (26) had data on water production and injection for EOR or disposal and provided that information via responses to the questionnaire. It was the other management or reuse categories that were left blank or only a hand full of states had data to complete those classifications. In only a few cases did we need to make assumptions or extrapolate volumes based on partial data provided. One of the other more common limitation was that the injection volume represented the total as many states do not track commercial disposal versus operator disposal.

In the cases where states did not have or were unable to provide the data, we consulted the EIA website to fill hydrocarbon production blanks. As for produced water volumes in these cases they were left blank as no other agency solicits or collects such data on a consistent and reliable basis. The assumptions, data sets, and analyses used to develop the estimates are described separately for each state in **Chapter 5**.

Almost all states provided water volume data to the individual bbl. However, the accuracy of this data could not be confirmed; therefore, the summary tables in **Chapter 4** depict rounded total volumes – these are the national totals that should be cited. There are functional issues prominent to ambiguities and imprecision of the agency supplied data (see discussion in **Chapter 4**).

## 7.2 Conclusions

This study documents the most recent and comprehensive data concerning the volume of produced water generated from oil and gas development in the United States and its disposition. It was conducted using a similar approach as the previous studies conducted for 2007, 2012, and 2017 data years. Various methods and evaluation techniques were amended and updated as explained for this report.

The aggregate produced water volume for 2021 increased by 6.02% over the total volume generated in 2017. This growth should be looked at through a lens that acknowledges the parallel increases in oil (20.18%) and gas (17.21%) volumes from 2017 to 2021. This same pattern of oil and gas volumes increasing faster than water volumes was observed in 2017 and 2012, albeit at a slower rate from 2017 to 2021 than the prior study period. Since the types of wells and formations used to produce hydrocarbons remained consistent, i.e., unconventional, the explanation must lie with the increased number of wells and the amount of produced water initially generated.

The feedback regarding volumes per management practices has not shifted substantially from the 2017 as the majority of onshore produced water was injected; however, an increase in the amount of offshore produced water injected versus treated and discharged to the ocean was observed. The percentages for each management practice were altered marginally from 2017, but the trends continue to be similar.

As with the previous studies there still is no simple method to gather this information regarding produced water generation and management estimates. The data offered took months of communication, and frequent follow-up email reminders and clarifications with state agencies.

However, more states were able to reply to the questionnaire and provide adequate information than in previous efforts. With regards to federal data collection, a bit more information was available regarding offshore injection than in previous studies, but no standard form exists for tracking produced water volumes.



## APPENDIX A

## Produced Water Volumes and Management Practices in 2021

| State       | Oil & Gas Agency  | Comments  |
|-------------|---|---|
| Alabama     | Oil and Gas Board of Alabama  | Replies to the questionnaire, CBM water to the Black Warrior River under the auspices of NPDES permits  |
| Alaska      | Alaska Oil and Gas Conservation Commission  | Replied to the questionnaire.   |
| Arizona     | Arizona Oil and Gas Conservation Commission   | AZOGCC replied that they did not have compiled data to complete the questionnaire. To obtain monthly production data the ADEQ Records Management Center was contacted and records were requested. |
| Arkansas    | Arkansas Oil and Gas Commission   | Replied to the questionnaire with produced water generation and management data, but used tables from 2017 questionnaire.   |
| California  | California Department of Conservation<br>Geologic Energy Management Division - Formerly<br>Division of Oil, Gas, and Geothermal Resources | Replied to the questionnaire.   |
| Colorado    | Colorado Oil and Gas Conservation Commission  | Replied to the questionnaire.   |
| Florida     | Florida Department of Environmental Protection (FDEP)<br>Oil and Gas Program  | FDEP Oil and Gas Program website. Electronic Document Management System (OCULUS) for each of the operating fields in the state, on monthly Form 10A reports.                                      |
| Georgia     | Georgia DNR   | Received email explaining that there is NO PRODUCTION either onshore or offshore in Georgia   |
| Idaho       | Idaho Department of Lands, Oil and Gas Division   | Replied to the questionnaire.   |
| Illinois    | Illinois Department of Natural Resources,<br>Office of Oil and Gas Resource Management  | Replied to the questionnaire.   |
| Indiana     | Indiana Department of Natural Resources<br>Division of Oil and Gas  | Replies to the questionnaire  |
| Kansas      | Kansas Corporation Commission - Conservation Division   | Replies to the questionnaire  |
| Kentucky    | Kentucky Department of Natural Resources<br>Division of Oil and Gas   | Replied to the questionnaire.   |
| Louisiana   | Louisiana Department of Natural Resources<br>Office of Conservation   | Replied to the questionnaire and provided link to online databases (SONRIS) with access permission for oil and gas and produced water data.   |
| Maryland    | Maryland Department of the Environment - Land and<br>Materials Administration - Mining Program  | Replied to Questionnaire with hydrocarbon production data only.   |
| Michigan    | Michigan Department of Environment, Great Lakes, and<br>Energy - Oil, Gas, and Minerals Division  | Could not reply to the questionnaire provided, production data obtained from EIA.   |
| Mississippi | Mississippi State Oil and Gas Board   | Replied to the questionnaire provided produced water generation and management information.   |
| Missouri    | Missouri Department of Natural Resources and<br>Missouri Geological Survey  | Replied to questionnaire with produced water generation and management information.   |
| Montana     | Montana DNR - Board of Oil and Gas Conservation   | Replied to the questionnaire and provided produced water generation, crude oil and natural gas data as well as water management information.  |

## Produced Water Volumes and Management Practices in 2021

| State          | Oil & Gas Agency   | Comments  |
|----------------|--|---|
| Nebraska       | Nebraska Oil and Gas Conservation Commission   | Provided both water production and management information via questionnaire reply.  |
| Nevada         | Nevada Division of Minerals  | Replied to questionnaire.   |
| New Mexico     | New Mexico Energy, Minerals, and Natural Resources Department - Oil Conservation Division            | Provided information on produced water volume and management practices as well as hydrocarbon production information via questionnaire responses.   |
| New York       | New York State Department of Environmental Conservation (NYDEC) Division of Mineral Resources        | Replied to questionnaire with oil, gas, and water production information.   |
| North Carolina | North Carolina Geological Survey   | Replied to email and confirmed No production in state.  |
| North Dakota   | North Dakota Industrial Commission (NDIC) Oil and Gas Division                                       | Provided information on produced water volume and management practices as well as hydrocarbon production information via questionnaire responses. Several follow-ups to confirm various sources of natural gas production, conventional, unconventional casinghead gas.                       |
| Ohio           | Ohio Department of Natural Resources, Division of Oil and Gas Resources Management                   | Provided oil, gas, and water production information and produced water management information via Questionnaire responses.  |
| Oklahoma       | Oklahoma Corporation Commission  | Received data from OCC regarding UIC data was for 2021 while O&G and Surface Water discharge was for 1/1/2022-6/21/2022 - I requested a clarification and production and discharge data for 2021. Obtained crude oil and natural gas production totals from Oklahoma Tax Commission for 2021. |
| Pennsylvania   | Pennsylvania Department of Environment Protection  | Provided information on produced water volume and management and hydrocarbon production by replying to the questionnaire.   |
| South Carolina | South Carolina Department of Health & Environmental Control - Division of Mining & Solid Waste Mgmt. | Replied via email that they do not have any commercial production.  |
| South Dakota   | South Dakota Department of Agriculture and Natural Resources, Minerals and Mining Program            | Provided information on production and management of produced water related to oil and gas activities as well as oil and gas production totals.   |
| Tennessee      | Tennessee Department of Environment and Conservation, Office of Energy Programs                      | Oil and Gas Program provided information about oil and gas production. Division of Water Resources provided the injection volume for several Class II wells, both via questionnaire replies.  |
| Texas          | Railroad Commission of Texas   | Responded to questionnaire with complete information on produced water and hydrocarbon production.  |
| Utah           | Utah Department of Natural Resources Division of Oil, Gas, and Mining                                | Provided data on oil, gas, and water production and on how the produced water was managed via questionnaire responses. Well counts were obtained from Online Data Explore.  |
| Virginia       | Virginia Department of Mines, Minerals, and Energy<br>Virginia Department of Energy, Gas and Oil     | Provided oil, gas, and water production information as well as produced water management information on questionnaire tables.   |
| Washington     | Washington Department of Natural Resources   | Replied via email that there is no production within the state.   |
| West Virginia  | West Virginia Department of Environmental Protection (WVDEP) Office of Oil and Gas                   | Responded to questionnaire with information on production activities and produced water management.   |
| Wyoming        | Wyoming Oil and Gas Conservation Commission  | WOGCC provided data on produced water injection and hydrocarbon production via a populated table 1 and 2 from the questionnaire.  |

June 06, 2022

RE: **U.S. Produced Water Volumes and Management Practices in 2021**

Dear State Oil and Gas Director:

As Executive Director of the Ground Water Protection Council (GWPC) it is my pleasure to engage you once again in our ongoing efforts to gather data and draft the Fourth Edition of the *U.S. Produced Water Volumes and Management Practices Report*. As you know, this series of reports (2007, 2012, & 2017) have summarized the volume of produced water generated by all oil and gas producers in the United States by state and describes the primary ways in which produced water was managed. Copies of previous reports can be found at <https://www.gwpc.org/research> and <https://publications.anl.gov/anlpubs/2009/07/64622.pdf>. To that end, the GWPC has recently contracted ALL Consulting to update this often-cited series, with a fourth edition based on 2021 production data.

This new report, which will look at produced water volumes and the changing management practices which occurred in 2021, will represent the fourth set of comparable data collected at routine intervals. These are valuable reference documents for the oil and gas, and water industries, as no other comparable comprehensive sources of produced water data are available. The new report will be highly anticipated and contribute to the nation's knowledge of produced water management.

As with previous efforts, we plan to rely heavily on state agency data resources as we undertake this study. GWPC and ALL Consulting request your assistance in providing information on produced water and / or pointing us to existing data management resources that you already use. The attached questionnaire describes the types of information we hope to get from each agency.

We recognize that state agencies are very busy and often under-staffed. Nevertheless, we request that you provide us with your responses within three to four weeks. This is a very important GWPC initiative, and we hope to complete the project in a timely manner. If you are unable to provide all the requested information, please provide as much of it as possible and/ or guide us to the individuals in your agency or state who may have the information. Thank you in advance for your assistance.

Responses should be sent by email to Jon Seekins at [JSeekins@all-llc.com](mailto:JSeekins@all-llc.com) . If you have any questions or concerns regarding your responses to the questionnaire or would prefer to provide information in a different format, please contact Mr. Seekins at 918.382.7581.

Earnestly,

Ground Water Protection Council

Dan Yates  
Executive Director

## GWPC Produced Water Questionnaire – 2021 Data

Three (3) previous studies have estimated the total volume of produced water generated in the United States in a full year and characterized the ways in which that water was managed. The previous studies looked at calendar years, 2007, 2012, and 2017. The Ground Water Protection Council (GWPC) recently engaged ALL Consulting to prepare a fourth edition to this important research series by updating the study with data for target year 2021. This questionnaire serves as the primary mechanism to collect information on produced water from each of the agencies overseeing oil and gas operations in producing states

In this study we consider produced water to include water brought to the surface along with oil and gas production. This includes water that flows back to the surface from wells that were recently fractured as well as any ongoing water production from the wells over time. It includes natural groundwater in formations that produce oil and gas as well as any water that has been injected into those formations to aid in producing more oil and gas. The key point is that the water comes to the surface along with oil and gas.

Over the past 20+ years, the U.S. oil and gas production has evolved from nearly all wells producing from conventional formations to an increasing number of wells producing from unconventional formations. Water production profiles often are quite different in conventional and unconventional formations.

The U.S. Department of Energy's Energy Information Administration (DOE EIA) defines unconventional oil and natural gas production as: *"an umbrella term for oil and natural gas that is produced by means that do not meet the criteria for conventional production."* EIA defines conventional oil and natural gas production as: *"crude oil and natural gas that is produced by a well drilled into a geologic formation in which the reservoir and fluid characteristics permit the oil and natural gas to readily flow to the wellbore."* The boundaries between conventional and unconventional production have changed over time and may differ among users of the terms. However, production of the following types of hydrocarbon resources are generally considered to be unconventional (coalbed methane, shale gas, shale oil, tight oil, tight gas sands). Other hydrocarbon types less common in the United States but considered as unconventional production include oil shale, oil/tar sands, extra heavy oil, natural bitumen, and gas hydrates.

**Table 1** below seeks oil, water, and gas production information separately for conventional vs. unconventional formations. We recognize that some agencies do not track production separately by formation type. To the extent possible, with your agency's geological knowledge of the formations that produce in your state, please try to provide information separately for conventional and unconventional production. If you are unable to make that distinction, we greatly appreciate any relevant produced water data you can provide.

### Part I – Produced Water Volume

Please provide information on the volume of produced water generated in your state for calendar year 2021. If you do not have fully compiled data for 2021, please provide data from the next most recent year for which you do have full data. These data should be entered into **Table 1**, or you can indicate how we can access your state's electronic data management system.

Even if you do not have information on the volume generated, but you do have information on the volume reinjected (assuming that most produced water from your state is reinjected), that is valuable information too, and should be entered in **Table 1** with a notation that the figure represents injected volumes. To the extent possible, we would like to see the produced water volume estimates broken down by the type of hydrocarbon produced by the well as shown in **Table 1**. This helps in calculating water/oil and water/gas ratios. If you do not have quantitative information on the volume of produced

water generated, please give us your educated “best estimate” of the volume either in absolute volume or in percentages.

Additionally, this year’s report will attempt to breakdown the data by basin, so if any data regarding location, such as county or actual basin is available, we would appreciate access to those files electronically. We understand that the analyses will take some time, so that is why we are asking for the raw data and will have our analysts perform the breakdown.

Please provide information on the annual volume of each type of hydrocarbon produced in your state for 2021 or the next most recent year. This information should be entered into the last column of **Table 1**. Please express natural gas production in Mmcf (million cubic feet) per year and note including casinghead gas in this quantity is appropriate. Crude oil, condensate, and water should be expressed in bbl (barrels) per year.

If your agency does not keep track of water volumes, please let us know, so we can find another way to estimate produced water volumes for your state.

**Note:** **Table 1** below is an example, a blank spreadsheet modeled after **Tables 1 and 2** is attached for your use.

**Table 1 – Produced Water Volume Information**

| Type of Hydrocarbon   | Number of Producing Wells (Hydrocarbon & Type Specific) | Total Volume of Produced Water Brought to Surface (bbl/year) | Volume of Hydrocarbon Produced (bbl/year or Mmcf/year) |
|---|---|--|--|
| <b>Conventional Formations</b>  |   |  |  |
| Crude Oil   | 171   | 8,595,678.43   | 1,619,240.24   |
| Natural Gas   | 55  | 634.5  | 9,578.21   |
| Other (Condensate, etc.)  | 0   | 0  | 0  |
| <b>Conventional Totals (Number, bbls, BOE)</b>  | 226   | 8,596,312.93   | 1,620,836.61   |
| <b>Unconventional Formations</b>  |   |  |  |
| Crude Oil   | 45  | 28,715,006.25  | 4,254,075.00   |
| Natural Gas   | 23  | 281.25   | 2,728.37   |
| Other (Condensate, etc.)  | 0   | 0  | 0  |
| <b>Unconventional Totals (Number, bbls, BOE)</b>  | 68  | 28,715,287.50  | 4,709,804.17   |
| Agency does not keep track of water volumes, explanation of alternative estimate method provided in email:<br>YES <input type="checkbox"/> NO <input type="checkbox"/> N/A <input type="checkbox"/> |   |  |  |

## Part II – Produced Water Management

Please provide information on how produced water was disposed of or otherwise managed in your state for calendar year 2021 or the next most recent year. This information should be entered into **Table 2**. If you do not have quantitative information on produced water management practices, please give us your educated “best estimate” of the percentage of produced water that is handled by each management practice.

In the 2017 data set, less than three percent of all produced water was reported as being beneficially reused (note that this does not include water injected into producing formations to augment production – that is tallied separately). This is about a two percent increase over the 2012 data, however in many cases, this low percentage is the result of the fact that companies were not typically required to report on water reuse. Therefore, while agencies suspected produced water was being reused, they had no quantitative data to characterize those practices. We believe that there is a reuse trend and more produced water was reused in 2021 than in 2017, and request that you provide as much information as you can (quantitative or qualitative).

Note, in the 2017 report, we made no distinction in terminology between *recycle*, *use*, or *reuse*. When using those terms, we referred to managing produced water that has come to the surface by putting it to a secondary use (e.g., makeup water for drilling and frac jobs, cooling water, irrigation water, and others). For this year's report we have updated the reuse categories to better match the state's data where reuse reporting is required. Please describe in your email reply, to the best of your knowledge, the ways in which produced water is being reused in your state.

**Table 2 – Produced Water Management Practices**

| Management Practice   | Total Volume of Produced Water Managed by That Practice (bbl/year) | Percentage of Produced Water Managed by That Practice |
|---|--|---|
| Injection for Enhanced Recovery   | 4,180,191.31   | 48.63%  |
| Injection for Disposal (By Operator)  | 2,743,752  | 31.92%  |
| Injection for Disposal (Commercial / Offsite)<br>(Paid 3 <sup>rd</sup> Party to Manage Produced Water)                            | 554,689  | 6.45%   |
| Surface Water Discharge<br>(Ocean, Lake, Pond, Stream)  | 0  | 0.00%   |
| Surface Discharge (Land Application)  | 0  | 0.00%   |
| Evaporation (Lined Sump)  | Unknown  | 0.00%   |
| Evaporation / Infiltration (Unlined Sump)   | 0  | 0%  |
| Sale / Transfer – Domestic Use  | 100,000  | 1.16%   |
| Sale / Transfer – Other Oil & Gas Operator  | 758,734  | 8.83%   |
| Reuse Within the Oil & Gas Industry<br>(By Operator for Drilling, Well Work, Well Stimulation, Other Facility Use)                | 256,886  | 2.99%   |
| Reuse Outside the Oil & Gas Industry<br>(Please Specify, e.g., Domestic Sewer, Irrigation, Cooling water, Dust Suppression, etc.) | 1,425 - Dust Suppression   | 0.02%   |
| Other   | 0  | 0.00%   |

If your state has significant hydrocarbon production in more than one of the categories shown in **Table 1**, and you believe that the produced water from one production type is managed differently from another production type, please complete separate versions of **Table 2 - Produced Water Management Practices** for each of those production types.

Please provide the name and contact information for a person representing your agency or another agency in your state if produced water data management is not part of your agency. We may need to contact that person to clarify the data submittal or ask additional questions. A table has been included in the attached spreadsheet (**Agency Contacts**) to collect this information.

Responses should be sent by email to Jon Seekins at [jseekins@all-llc.com](mailto:jseekins@all-llc.com). If you have any questions on how to respond or provide data to the questionnaire or would prefer to provide information in a different format, please contact Mr. Seekins at 918.382.7581.

We recognize that state agencies are very busy and often under-staffed, nevertheless, we request that you provide us with your responses within three weeks. This is a very important GWPC initiative, and we hope to complete the project in a timely manner. If you are unable to provide all the requested information, please provide as much of it as possible. Thank you in advance for your assistance.