Datasets associated with investigating the potential for beneficial reuse of produced water from oil and gas extraction outside of the energy sector

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\textbf{A B S T R A C T}

The data in this report are associated with \url{https://doi.org/10.1016/j.scitotenv.2020.137085} [4] and include data on water volumes and water quality related to the major unconventional oil and gas plays in the U.S. The data include volumes of water co-produced with oil and gas production, county-level estimates of annual water use volumes by various sectors, including hydraulic fracturing water use, and the quality of produced water. The data on volumes of produced water and hydraulic fracturing water volumes were obtained from the IHS Enerdeq and FracFocus databases. Water use in other sectors was obtained from the U.S. Geological Survey water use database. Data on produced water quality were obtained from the USGS produced waters database.

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# Specifications table

| Subject | Water Science and Technology |
|---------|------------------------------|
| Specific subject area | The water budget related to unconventional oil and gas production and water quality of produced water from major unconventional energy plays in the U.S. |
| Type of data | Table |
| How data were acquired | All data were acquired from on-line databases using standard configuration PC hardware and internet browser software. |
| Data format | Raw Analysed Filtered |
| Parameters for data collection | No collection parameters were applied |
| Description of data collection | The data represent the analyses of water demand for hydraulic fracturing and produced water volumes from the IHS Enerdeq proprietary database that were collated by this group from State records. Produced water chemistry data and water use by various sectors were collected and processed by approved United States Geological Survey methods. |
| Data source location | Data were downloaded from static United States Geological Survey and IHS Enerdeq Database web servers. |
| Data accessibility | In a public repository Repository name: Mendeley Data Data identification number: 10.17632/jjjy5mtflflk:2 Direct URL to data: [https://data.mendeley.com/datasets/jjjy5mtflflk/2](https://data.mendeley.com/datasets/jjjy5mtflflk/2) |
| Related research article | Scanlon, B.R., Reedy, R.C., Xu, P., Engle, M., Nicot, J.P., Yoxtheimer, D., Yang, Q., and Ikonnikova, S., Can we beneficially reuse produced water from oil and gas extraction in the U.S.?, Science of the Total Environment, In Press |

# Value of the data

- These data provide the basis for the comparison of chemistry and volumes of produced water between the major unconventional oil and gas plays in the Continental U.S. and for comparison with sector water users in those areas.
- Beneficiaries of these data include researchers, engineers, water resource managers, or others concerned with the large-scale management of energy sector produced water.
- These data form a starting point for maintaining perspective on current and future water management issues as they relate to produced water from the energy sector.

## 1. Data description

The data are contained in a Microsoft Excel workbook “Water Volume and Chemistry Data Summaries.xlsx” that includes seven tabs:

- “1 PW Notes” includes a listing of the column headings and their descriptions and units for Tabs 2, 3, 4, and 5, all of which are subsets of data for the various U.S. unconventional energy plays from the USGS Produced Waters database [1].
- “2 PW, SWD, HF, Sector Uses” includes (1) the USGS water use database [2,3] total sector water use volumes for 2015 for the Irrigation, Municipal, Domestic, Livestock, Industrial, Recirculating Cooling, and Mining sectors at the county level and (2) IHS database total volumes for 2017 of produced water (PW), saltwater disposal (SWD) and hydraulic fracturing (HF), also at the county level. Table 1 is a representative table showing water use in the Permian Basin by County. Same water volume tables for other oil and gas plays are in the Microsoft Excel workbook (tab: 2 PW, SWD, HF, Sector Use).
- “3 PW TDS” includes total dissolved solids (TDS) concentrations in mg/L units.
- “4 PW Chem” includes major ion chemistry, including Calcium (Ca), Magnesium (Mg), Sodium (Na), Potassium (K), Sulphate (SO₄), Chloride (Cl), and Bicarbonate (HCO₃) concentrations in mg/L units.
Table 1
Energy industry and sector water use in the Permian Basin by county. Permian total represents the sum of the Delaware and Midland basins and does not include use in conventional production areas. All values are in billion litre (BL) units.

| Basin     | County | FIPS | PW | SWD | HF | Irrigation | Municipal | Domestic | Livestock | Industrial | Mining |
|-----------|--------|------|----|-----|----|------------|-----------|----------|-----------|------------|--------|
| Delaware  | Eddy   | 35,015 | 22.4 | 12.3 | 5.0 | 189.9       | 18.6      | 10.9     | 0.4       | 1.3        | 13.7   |
|          | Lea    | 35,025 | 32.7 | 31.1 | 11.0 | 204.7       | 14.1      | 9.5      | 0.5       | 0.1        | 101.0  |
|          | Culberson | 48,109 | 27.3 | 35.7 | 15.0 | 56.3       | 1.1       | 0.7      | –         | –          | 5.0    |
|          | Loving | 48,301 | 3.7  | 15.1 | 5.4  | 0.0        | 0.0       | 0.0      | –         | –          | 19.8   |
|          | Pecos  | 48,371 | 42.9 | 63.7 | 32.8 | 191.0       | 6.0       | 3.3      | –         | 0.2        | 33.5   |
|          | Reeves | 48,389 | 8.5  | 16.5 | 6.0  | 60.8       | 5.0       | 2.1      | 0.1        | 0.5        | 35.5   |
|          | Ward   | 48,475 | 23.6 | 32.7 | 13.2 | 4.1        | 7.2       | 2.1      | –         | –          | 25.2   |
|          | Winkler| 48,495 | 10.3 | 18.4 | 15.5 | 2.0        | 2.0       | 1.5      | –         | 0.1        | 17.4   |
|          | Total  | 264.4 | 378.6 | 210.2 | 84.1 | 65.0       | 81.5      | 0.9     | 3.0        | 648.5      |        |
| Midland  | Andrews | 48,003 | 3.1  | 2.0  | 3.6  | 18.0       | 3.3       | 2.6      | –         | –          | 76.6   |
|          | Crane  | 48,103 | 3.2  | 10.5 | 2.6  | 2.0        | 0.7       | 0.3      | –         | 0.3        | 31.1   |
|          | Crockett | 48,105 | 10.3 | 20.1 | 3.8  | 0.0        | 1.3       | 0.6      | –         | –          | 15.5   |
|          | Ector  | 48,135 | 2.2  | 3.7  | 0.0  | 0.9        | 0.9       | 19.1     | –         | 0.2        | 88.9   |
|          | Glasscock | 48,173 | 1.9  | 6.5  | 3.2  | 31.2       | –         | 0.2      | –         | 0.0        | 27.9   |
|          | Howard | 48,227 | 3.9  | 8.0  | 0.8  | 4.6        | 0.0       | 5.7      | –         | 0.4        | 40.4   |
|          | Irion  | 48,235 | 6.5  | 11.8 | 10.7 | 0.8        | 0.1       | 0.2      | –         | –          | 6.1    |
|          | Martin | 48,317 | 10.4 | 20.7 | 17.1 | 43.8       | 2.0       | 0.7      | –         | –          | 24.4   |
|          | Midland | 48,329 | 14.5 | 24.3 | 16.8 | 0.9        | 1.4       | 20.6     | –         | 0.2        | 26.4   |
|          | Reagan | 48,383 | 25.2 | 30.2 | 33.7 | 24.8       | –         | 0.4      | –         | 0.3        | 27.8   |
|          | Upton  | 48,461 | 12.0 | 15.2 | 14.3 | 8.0        | –         | 0.6      | –         | 0.1        | 32.5   |
|          | Total  | 171.4 | 225.7 | 103.7 | 708.7 | 54.0      | 30.1      | 0.9     | 1.7        | 251.0      |        |
| Permian Total | 93.1 | 152.9 | 106.5 | 133.0 | 11.3 | 91.4       | –         | 1.3      | 397.5      |            |        |

Table 2
Permian Basin unconventional produced water summary statistics.

| Parameter | Unit | TDS mg/L | Ca mg/L | Mg mg/L | Na mg/L | K mg/L | SO4 mg/L | Cl mg/L | HCO3 mg/L | Ba mg/L | Ra pCi/L |
|-----------|------|-----------|---------|---------|---------|--------|----------|---------|-----------|---------|----------|
| Mean      |      | 147,464   | 6627    | 1311    | 51,520  | 841    | 1024     | 95,820  | 440       | 133     | 591      |
| Min       |      | 1157      | 26      | 6.0     | 316     | 17     | 1.7      | 1405    | 70        | 0.1     | 58       |
| Max       |      | 430,392   | 46,500  | 18,145  | 134,652 | 14,649 | 7851     | 216,575 | 6346      | 1136    | 1542     |
| 0.01      |      | 5747      | 393     | 78      | 4029    | 24     | 17       | 7688    | 28        | 0.1     | 58       |
| 0.05      |      | 27,936    | 758     | 154     | 13,585  | 61     | 88       | 24,189  | 61        | 0.1     | 59       |
| 0.10      |      | 50,256    | 1218    | 288     | 23,995  | 95     | 211      | 41,929  | 84        | 0.3     | 78       |
| 0.25      |      | 98,762    | 2572    | 528     | 39,053  | 183    | 425      | 72,500  | 122       | 1.1     | 214      |
| 0.50      |      | 154,289   | 4915    | 967     | 55,107  | 392    | 675      | 99,748  | 232       | 4.6     | 535      |
| 0.75      |      | 193,912   | 9179    | 1681    | 65,439  | 980    | 1260     | 121,637 | 492       | 197     | 880      |
| 0.90      |      | 226,695   | 12,415  | 2425    | 73,787  | 1379   | 2637     | 136,836 | 1041      | 453     | 1176     |
| 0.95      |      | 251,022   | 17,360  | 3571    | 79,046  | 2113   | 3116     | 152,847 | 1466      | 695     | 1269     |
| 0.99      |      | 295,212   | 29,961  | 6167    | 86,625  | 7822   | 4486     | 181,846 | 2913      | 998     | 1487     |

- “5 PW Barium” includes Barium concentrations in mg/L units.
- “6 PW Radium” includes Radium concentrations in pCi/L units.
- “7 WQ Tables” includes statistical summaries by oil and gas play area of the concentration data listed in Tabs 2, 3, 4, and 5. Table 2 is a representative table showing summary statistics of water quality data in the Permian Basin. Same summary tables for other oil and gas plays are in the Microsoft Excel workbook (tab: 7 WQ Tables).

2. Experimental design, materials, and methods

The USGS Produced Waters database [1] contains samples collected from oil and gas wells throughout the U.S. An initial filtering of the data removed all samples that did not have well latitude/longitude coordinates, TDS concentrations, non-oil or -gas wells, those with notes indicating that a sample did not represent produced water (i.e., frac water, flowback, and drilling pit samples), or wells located outside the oil and gas play region boundaries of interest.
A large subset of the remaining wells had multiple samples. In order to remove as much bias as possible, average values were calculated for TDS and major cation/anion concentrations for these wells. Repeat sampled wells were identified as those having either the same API number or, where no API number was listed, wells having the same unique location identifier constructed using the play, state, well type, and coordinate location. All values of TDS, Barium, and Radium were included in their respective final datasets. However, only samples with ionic charge balances ≤15% were used in the final major cation/anion dataset.

The USGS Water Use [2,3] in the United States database is updated every five years, with the latest iteration occurring in 2015. Water volumes are stored in the database with a variety of English units that were converted to billion litres per year for this dataset. This dataset includes water withdrawal totals for the following sectors: Irrigation, Municipal, Domestic, Livestock, Industrial, Recirculating Cooling, and Mining in the counties located within the unconventional oil and gas plays.

The IHS Enerdeq database is privately owned and available only through subscription. The data are collected by IHS from the various state regulatory and reporting agencies responsible for maintaining oil and gas production and water disposal data. This dataset includes 2017 total volumes for produced water, saltwater disposal, and hydraulic fracturing water for unconventional oil and gas wells located within the play boundaries [4].

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Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] USGS Produced Water Database: https://www.sciencebase.gov/catalog/item/59d25d63e4b05fe04cc235f90.
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