Supporting Information

Water Issues Related to Transitioning from Conventional to Unconventional Oil Production in the Permian Basin

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Table of Contents

Water Issues Related to Transitioning from Conventional to Unconventional Oil Production in the Permian Basin S1
List of Figures S2
List of Tables S3
Section 1. Methods and Data Sources S4
Section 2. Decline Curve Analyses and Estimated Ultimate Recovery S6
Section 3. Implications of Hydraulic Fracturing Intensity on Transportation S7
Section 4. Water Costs for the Permian Basin S7
References S80

List of Figures

Fig. S1a. Oil well density in the Permian Basin S8
Fig. S2. Location map of the Permian Basin S11
Fig. S3 Cross section of geologic units from the Delaware to the Midland basins S12
Fig. S4. Stratigraphic column of the geologic units in the Permian Basin S13
Fig. S5. Historical oil production in the US, Permian Basin and Texa S14
Fig. S6. Tight oil production in the US and different producing units of the Permian Basin S15
Fig. S7. Regional 30-yr mean annual precipitation in the Permian Basin region S16
Fig. S8. Lateral extents of major and minor aquifers in the Permian Basin region S17
Fig. S9. Land use/land cover in the Permian Basin and subregions within the Permian Basin S18
Fig. S10. Methods flow chart S19
Fig. S11. Permian Basin total production of oil and water from 2005 – 2015 ..... S20
Fig. S12. Historical oil and produced water and injected water and CO_2 for the Wasson Field S22
Fig. S13. Permian Basin unconventional vertical well completions during the period 2005-2015 ..... S24
Fig. S14. Midland Basin unconventional horizontal wells completions during the period 2000-2015 .... S25
Fig. S15. Delaware Basin unconventional horizontal wells completions during the period 2000-2015. . S26
Fig. S16. Distribution of HF water use per well for unconventional horizontal wells S27
Fig. S17. Distribution of HF water use unit lateral length for unconventional horizontal wells S28
Fig. S18. Total annual irrigation and municipal water use in the Texas portion of the Permian Basin S29
Fig. S19. Permian Basin oil and water production during the period 1980-2015 ..... S30
Fig. S20. Decline curves for produced oil, water, and gas S31
Fig. S21. Midland Basin and Delaware Basin PW from unconventional horizontal wells S32
Fig. S22. Midland Basin and Delaware Basin oil production from unconventional horizontal wells S33
Fig. S23. Midland Basin and Delaware Basin oil+gas production from unconventional horizontal wells S34

Fig. S24. Comparison of per well cumulative oil and PW for unconventional horizontal wells S35
Fig. S25. Evolution of water cut for wells completed from 2011-2015 ..... S36
Fig. S26. Comparison between PW and injected water volumes in the Permian Basin S37
Fig. S27. Locations of EOR and SWD wells S38
Fig. S28. Active SWD wells in the Permian Basin S39
Fig. S29. Spatial distribution of SWD volumes, water demand for HF, and the ratio of SWD to HF S41
Fig. S30. Distribution of produced water total dissolved solids S42
Fig. S31. Schematic of pipeline system being installed by Pioneer Water Management Company. S43

List of Tables

Table S1. Selected values for the Permian Basin S44
Table S2. Selected ratios between HF, PW, produced oil, produced oil and gas, and EUR S45
Table S3. Numbers and types of wells completed S46
Table S4. Numbers of conventional and unconventional producing wells S47
Table S5. Annual total oil, gas, and PW volumes S49
Table S6. Permian Basin number of unconventional wells and associated HF water use S51
Table S7. Median HF water use for unconventional vertical and horizontal wells S52
Table S8. Unconventional horizontal well depths, lateral length, and HF water use distributions S53
Table S9. Unconventional well proppant loading and distributions S56
Table S10. Numbers of hydraulic fracturing stages and stage lengths S59
Table S11. Total regional water use by category S61
Table S12. First 12 months of produced oil, gas, and PW for unconventional horizontal wells S63
Table S13. EUR for oil, gas, and PW from unconventional horizontal wells S65
Table S14. Midland Basin conventional and unconventional oil, gas, and PW S67
Table S15. Delaware Basin conventional and unconventional oil, gas, and PW S69
Table S16. HF water intensity relative to oil production S71
Table S17. PW intensity relative to oil production and water cut S72
Table S18. SWD and EOR water injection volumes S74
Table S19. Volumetric ratios PW to HF water use for unconventional vertical and horizontal wells S77
Table S20. Regional 2014 total HF water use, total SWD, and ratios between these values. S78
Table S21. Ratios between 2014 total SWD and HF for selected counties areas S79

Section 1. Methods and Data Sources

Distinguishing Oil Wells from Gas Wells

We employ the Railroad Commission of Texas statutory definition (Statewide Rule 79), which states that a gas well is one that has a Gas-Oil Ratio (GOR) as reported at initial completion which exceeds 100,000 cubic feet (cf) of natural gas to each barrel of oil produced at standard pressure and temperature conditions. The oil so produced may be oil and/or condensate.

Distinguishing between Well Types

Well classification with regard to conventional versus unconventional or vertical vs horizontal well types is not an explicit well attribute in the IHS Enerdeq database. The Permian Basin is generally unique in that in addition to having unconventional wells that are completed using newer horizontal drilling techniques, there are also a significant number of unconventional wells that have been completed using traditional vertical drilling. As such, we were required to make certain assumptions in order to distinguish between these well classifications. We used a combination of database attributes including direction, down-hole survey data, treatment (hydraulic fracturing) water volumes, and proppant amounts.

Well Orientation

The IHS database has a "Direction" attribute which includes vertical, directional, or horizontal. A fourth category, pinnate, rarely occurs and is not discussed here. Vertical wells are generally close to being straight and are essentially truly vertical in direction. Directional wells are generally wells that were drilled straight but off-vertical by some generally consistent angle. Horizontal wells have two general sub-categories, including those that are not truly horizontal by current definition and those that are. We define the former as "False" and the latter as "True" horizontals.

False horizontals are wells that were generally completed following past practices and tend to follow arcuate paths through the target formation(s). False horizontals may or may not actually have a horizontal section over some length beginning at or very near the bottom end of the borehole.

By contrast, true horizontals are a relatively recent completion practice and tend to have generally vertical top sections that transition sharply to a nearly horizontal sections within the target formation. The horizontal sections are generally at least several hundreds and more commonly several thousands of feet in length.

Down-hole Well Surveys

We used the down-hole survey data to distinguish between false and true horizontals. The survey data consist of a series of distance and directional offset values that can be used to construct a 3-D model of the well borehole. We defined the horizontal lateral section of a borehole as beginning at the point where the angle between the horizontal plan and two successive survey points is less than 2.5˚ and continuing to the end of the well bore. The lateral depth was defined as the average true vertical depth along this horizontal well bore interval. Horizontal wells that have short (<500 ft, 150 m) horizontal lengths were classified as false horizontals and were grouped for analysis along with vertical and directional wells. Horizontal wells with horizontal sections ≥500 ft (150 m) were classified as true horizontals.

Conventional vs Unconventional Wells

Treatment data in the IHS database were the primary source of information used to distinguish between conventional and unconventional well completions. Modern unconventional well completions generally require much larger water volumes and proppant amounts as compared with traditional conventional

well completions. We examined the distributions of both water use and of proppant amounts for all wells with such data that were completed in the Permian Basin between 2005 and 2015. We found a bi-modal distribution for water use with a local minimum occurring at about 400,000 gallons (~100,000 bbl; 1500 m^3). Accordingly, we used that value as a cut-off between conventional completions (<400,000 gal) and unconventional completions (≥400,000 gal). A similar proppant use value of 400,000 lb (180,000 kg) was also used because the average proppant loading in the Permian Basin is about 1 lb/gal. Because there is a continuum in terms of water use and proppant amount from conventional to unconventional wells, this definition provides an approach for subdividing these well classes for purposes of discussion.

Thus, four classes of wells were distinguished in the Permian Basin, including conventional verticals, conventional horizontals (minor category), unconventional verticals, and unconventional horizontals.

Data Sources

Water and Proppant Use Data

Water and proppant use for individual wells are available from two sources, the FracFocus database and the IHS Enerdeq database. Reporting of hydraulic fracturing water use and chemicals became mandatory for wells completed in Texas beginning in February 2012 and was voluntary for wells completed prior to that time. The IHS database contains information primarily related to total fluid and acid volumes used in well completions and agreement is generally very good between IHS and FracFocus. In fact, many recent water use data entries in the IHS database were obtained from FracFocus as indicated by reference notations in the IHS database. Proppant amounts are also reported in both database, though we used only the IHS database because it directly indicates the proppant mass amount while the FracFocus database expresses the proppant only as a percentage of the total volume.

There is a reporting issue for some wells in the FracFocus database, generally for wells completed in 2013 or earlier. Data for many of these wells were originally reported using an older data format that is not properly reported using the current database query routines. The result is that water volumes in particular that were used for those wells are not being reported. However, a third-party source (SkyTruth, www.skytruth.org) maintains a database of FracFocus data that contains data we were able to acquire for wells completed through May 2013. We have found this database to be useful in filling in gaps in the current FracFocus database.

Data Quality Review

The IHS database has some quality control issues related primarily to inaccurate units reporting by operators. We examined the data for inconsistencies by calculating water use and proppant use per unit of lateral length and proppant use per unit volume of water to identify outliers. We resolved improper units where identifiable. Wells with unresolvable outlying water use values were flagged and median values were calculated based on annual median gal/ft values multiplied by the outlying well's lateral length.

Allocated Production Data

Monthly production for oil wells are reported to the Texas Railroad Commission as aggregated totals at the lease level. IHS uses a proprietary algorithm to retroactively assign monthly production values to individual wells for leases with more than one well. As a result, individual oil well production data may not be accurate, but aggregated totals should match those for the lease. Production data for gas wells, however, are reported at the well level.

Produced water volumes are not reported by operators but are estimated by IHS based on annual production capacity tests.

Section 2. Decline Curve Analyses and Estimated Ultimate Recovery

The following methodology was also applied to analysis of data in the Bakken Shale Play and is described in Supporting Information in Scanlon et al. (2016)[1] and reproduced here with modifications on the well data at the end of the description. We used two parameter decline curves to determine the estimated ultimate recovery (EUR) of oil, gas, and produced water in the Midland and Delaware basins. Typically decline curves are used to assess oil and gas production, but we can also apply the same methodology to water production. The EUR values for oil and gas were used to estimate the water intensities of energy production both in terms of water use for hydraulic fracturing (HF) and produced water (PW) generated per unit of oil and gas production.

The decline analysis method we used in this study was originally developed for gas production from shales[2], then modified to describe slightly compressible fluid production from shales (slightly compressible fluids include water and oil)[3]. The basis of the approach is assuming one dimensional Darcy flow into regularly spaced fractures from the matrix. This configuration leads to the conclusion that there are two primary stages of flow for each well: infinite-acting flow and boundary-dominated flow.

During infinite-acting flow, the fracture network produces from an ever-expanding area of investigation. Once pressure pulses from adjacent hydrofractures meet, the area of investigation has reached its maximum size, and the well drains fluid from a fixed volume. In the first stage, a well's production rate follows the square-root of time, and in the second, it falls exponentially.

Our model captures this behavior through a one-dimensional model where the fracture face is set at x=0 and there is a no-flow boundary at x=1, the point midway between adjacent fractures. Fluid properties taken from pressure, volume, temperature (PVT) reports are used as inputs to our model. The two parameters for fitting the model to field data are the time to boundary dominated flow and the total mass of fluid contacted by the well.

We use a segregated flow model that allows oil, gas, and water to flow as if they were a single phase. In effect, each fluid follows its own static pathways to the fracture. This behavior can be achieved in multiphase-flow models through assuming viscosity dominated flow with capillary pressures equivalent between the different phases. The original concept of segregated flow[4] has recently been applied to analyze the behavior of some water floods[5] [6].

Given this parallel flow model, we developed recovery factor curves which work similarly to the curves popularized by Fetkovich (1980)[7], with two fitting parameters. Curves were generated for several initial reservoir pressures and fluid maturity levels using a custom Python one-dimensional finite differences solver. For each well, cumulative oil, gas, and water production were fitted to the Fetkovich-style curves, using SciPy's least squares curve fitting library. The total amount of fluid in place and the time to boundary dominated flow were fit for each fluid in each well.

Using this methodology, we determined the EUR and forecast monthly oil, gas, and water production for ~9,800 unconventional horizontal wells and ~22,500 unconventional vertical wells having at least 12 months of production history and assuming a 20 year well lifetime.

The resulting mean values of 20-year EUR for unconventional vertical wells throughout the Permian Basin for the period 2005-2015 are 154×10^6 ft^3 (4.36×10^6 m^3) for gas, 43,000 bbl (6,800 m^3) for oil, and 96,000 bbl (15,300 m^3) for produced water (PW) (Fig. S20a).The resulting mean values of 20-year EUR for

unconventional horizontal wells throughout the Permian Basin for the period 2005-2015 are 443×10^6 ft^3 (12.5×10^6 m^3) for gas, 118,000 bbl (18,800 m^3) for oil, and 316,000 bbl (50,200 m^3) for produced water (PW) (Fig. S20b).

Separate mean 20-year EUR values were also determined for unconventional horizontal wells completed each from 2005 to 2015 in the Midland Basin and the Delaware Basin. The resulting mean values of 20-year EUR for unconventional horizontal wells it the Midland Basin completed during 2015 are 330×10^6 ft^3 (9.3×10^6 m^3) for gas, 121,000 bbl (19,200 m^3) for oil, and 216,000 bbl (34,300 m^3) for produced water (PW) (Table S13a).The resulting mean values of 20-year EUR for unconventional horizontal wells in the Delaware Basin completed during 2015 are 600×10^6 ft^3 (17.0×10^6 m^3) for gas, 156,000 bbl (24,800 $m^3$for oil, and 413,000 bbl (65,700 m^3) for produced water (PW) (Table S13c).

Section 3. Implications of Hydraulic Fracturing Intensity on Transportation

Increasing intensity of hydraulic fracturing in terms of water use and proppant loading has important implications for truck traffic. Typical trucks used to transport water of proppant are 18 wheelers which can be up to 80,000 lb (36,300 kg). Subtracting the weight of the truck provides capacity for ~150 bbl of water (6,300 gal, ~24 m^3) or 50,000 lbs (23,000 kg). The median water use per horizontal well in the Midland Basin in 2015 is 250,000 bbl ($10.5x10^6$ gal, 40,000 m^3). Therefore, an average well would require ~1,700 truckloads of water. Proppant loading is ~ 1 lb/gal (0.1 kg/L). Therefore, proppant requirements for HF would be ~$10.5x10^6$ lbs (~$5x10^6$ kg) requiring ~200 truckloads of sand.

Section 4. Water Costs for the Permian Basin

Operators indicate that low costs to obtain fresh or brackish groundwater and lay flat pipe to transport water to the site act as a deterrent to reuse/recycling of PW. For example, University Lands (managing ~10% of Midland and Delaware basins) reports a water cost of $0.35 per bbl for fresh or brackish groundwater (http://www.utlands.utsystem.edu/). Multiplying this cost by the median water volume for HF in the Midland Basin (250,000 bbl/well, 2015) would result in ~ 0.1 million $ (M$) for purchasing water with total well costs ranging from 6.6 to 7.8 M$ (EIA, 2016). Estimated disposal costs range from $0.5 without transportation to ~$2/bbl, including transportation. Multiplying $0.5/bbl to $2/bbl by the range from 66,000 to 124,000 bbl/well for 12 month production in the Midland and Delaware basins (Table 1), respectively, results 0.03 M$ to 0.25 M$. Considering the corresponding 12 mo. oil production (~50,000 bbl) at $50/bbl ($2.5M$) indicates that sourcing and disposing of water represents 5 – 15% of the oil price.

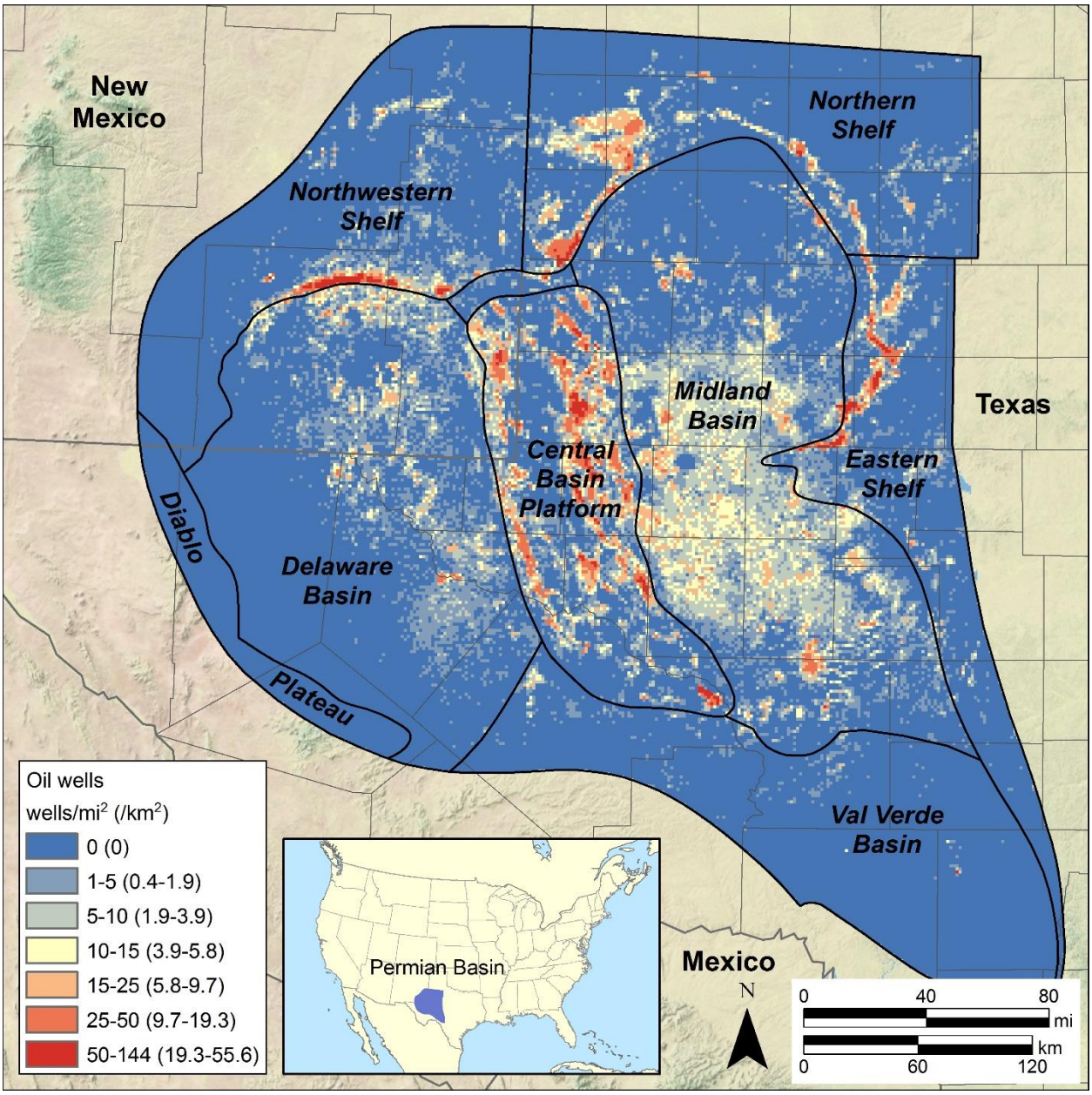

Fig. S1a. Oil well density in the Permian Basin based on ~162,000 producing wells during the 2005-2015 period (Table S4a). High densities around the margins of the Midland and Delaware basins and in the Central Basin Platform reflect primarily conventional reservoirs. Low densities in the Midland and Delaware basin floors represent mostly unconventional wells. The Permian Basin occupies 65,000 mi^2 (168,000 km^2). The primary areas of unconventional oil production are the Midland Basin (14,100 mi^2, 36,500 km^2) and the Delaware Basin (12,200 mi^2, 31,600 km^2) which together represent about 40% of the Permian Basin area. Original map image created in ESRI ArcGIS version 10.3.1.

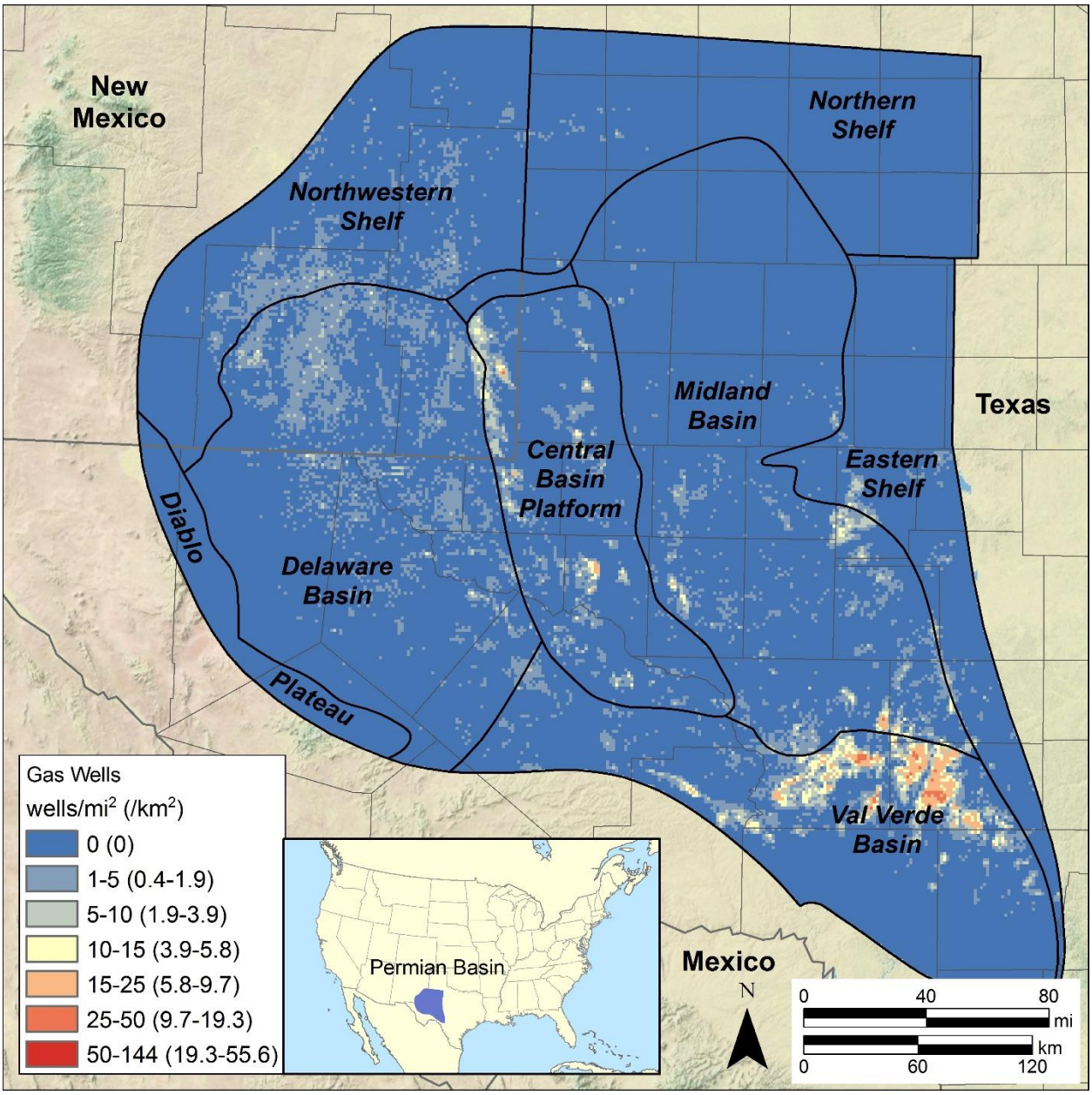

Fig. S1b. Gas well density in the Permian Basin based on 31,000 producing wells during the 2005-2015 period. Most gas well activity is concentrated in the Val Verde Basin. Original map image created in ESRI ArcGIS version 10.3.1.

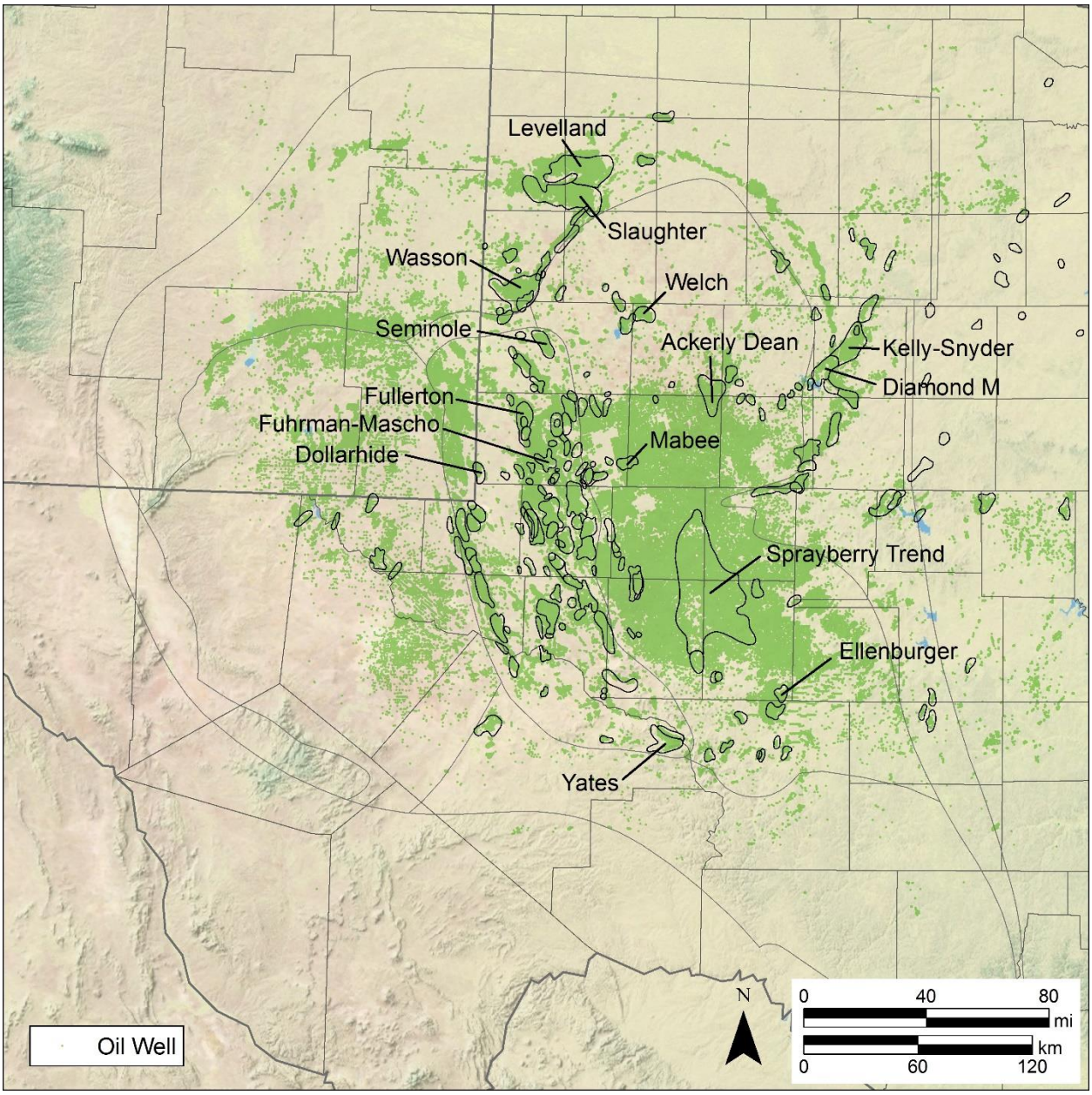

Fig. S1c. Oil and gas wells in conventional fields along with names of large fields. Green points are oil and gas well locations. Original map image created in ESRI ArcGIS version 10.3.1.

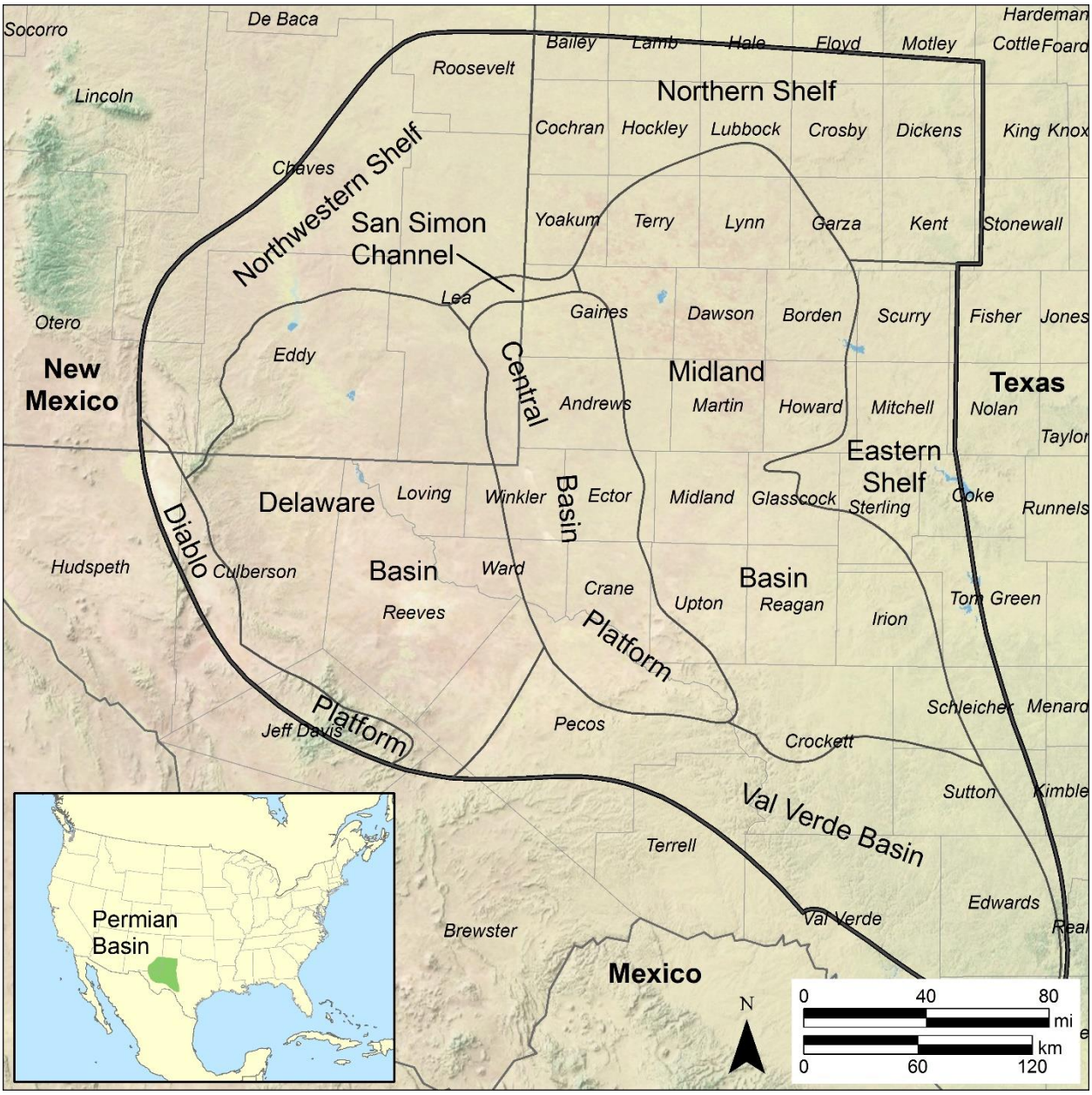

Fig. S2. Location map of the Permian Basin. Subregion names and county names are shown. Original map image created in ESRI ArcGIS version 10.3.1.

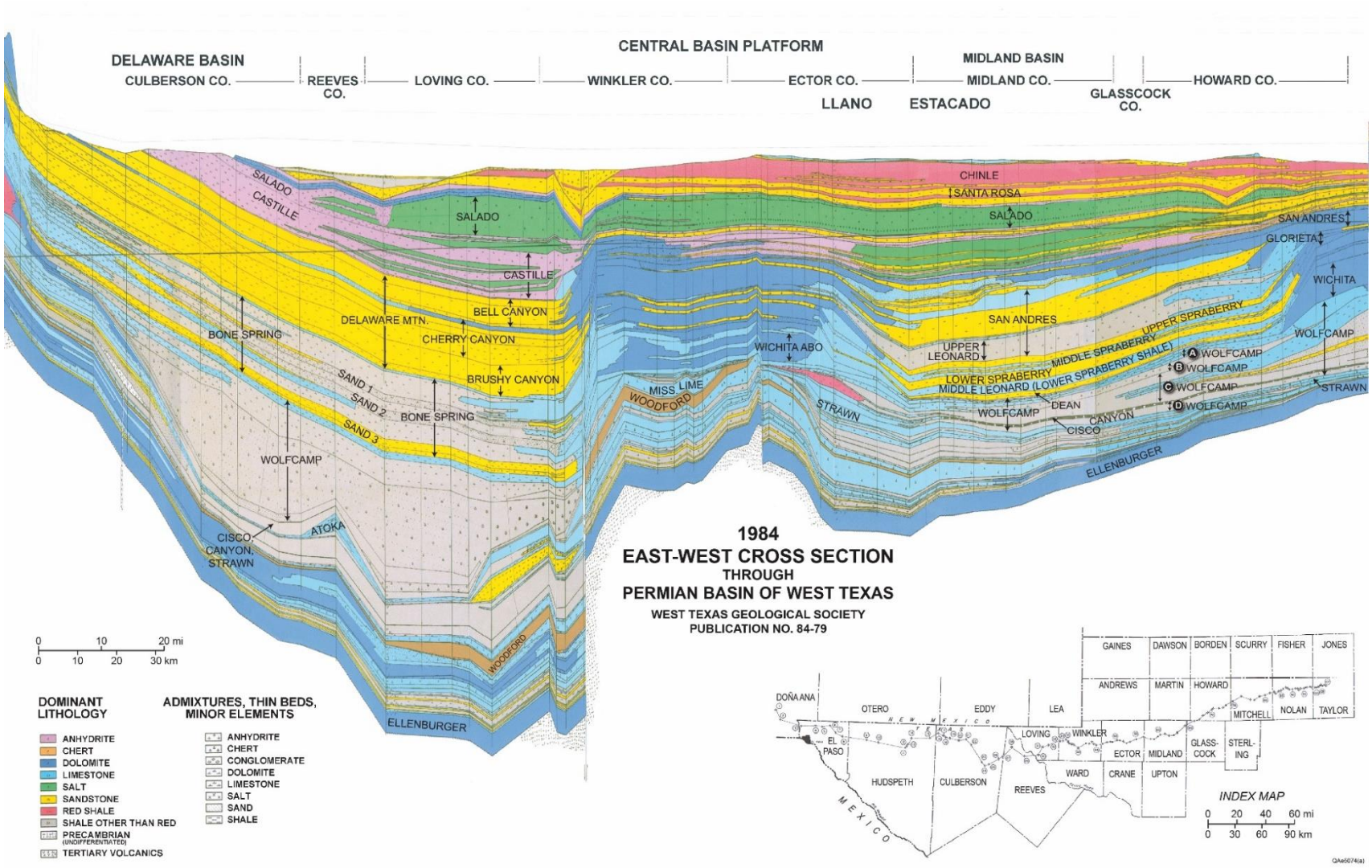

Fig. S3 Cross section of geologic units from the Delaware to the Midland Basinn. The location of the cross section relative to the counties in the basin is shown in the inset. The corresponding stratigraphic column can be found in Fig. S4. Reprinted from Matchus, E. J.; Jones, T. S., East-West Cross Section through Permian Basin of West Texas. *West Texas Geological Society Publication No. 84-79.* **1984**. *Copyright (1984), Publisher: West Texas Geological Society.*

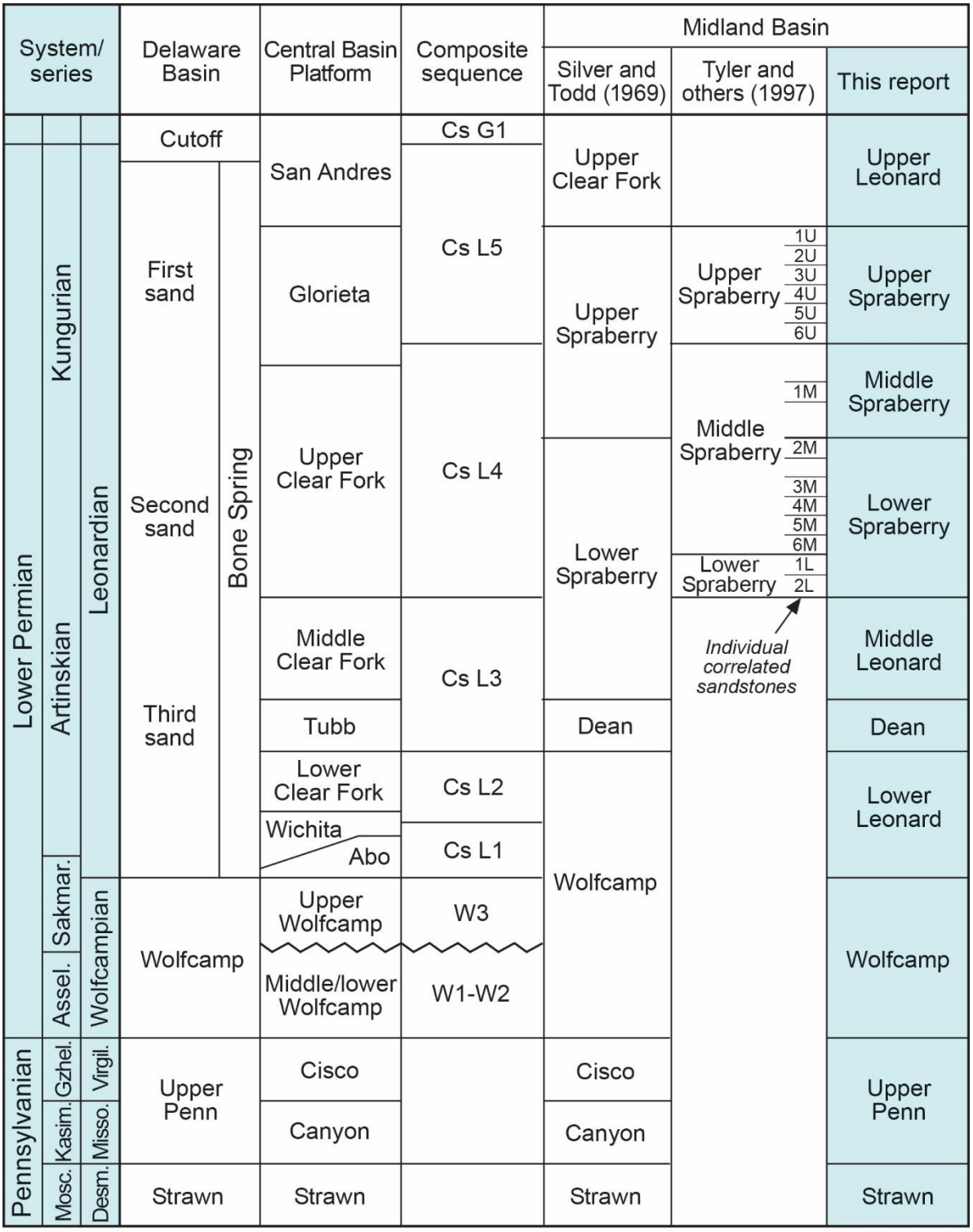

Fig. S4. Stratigraphic column of the geologic units in the Permian Basin[8].

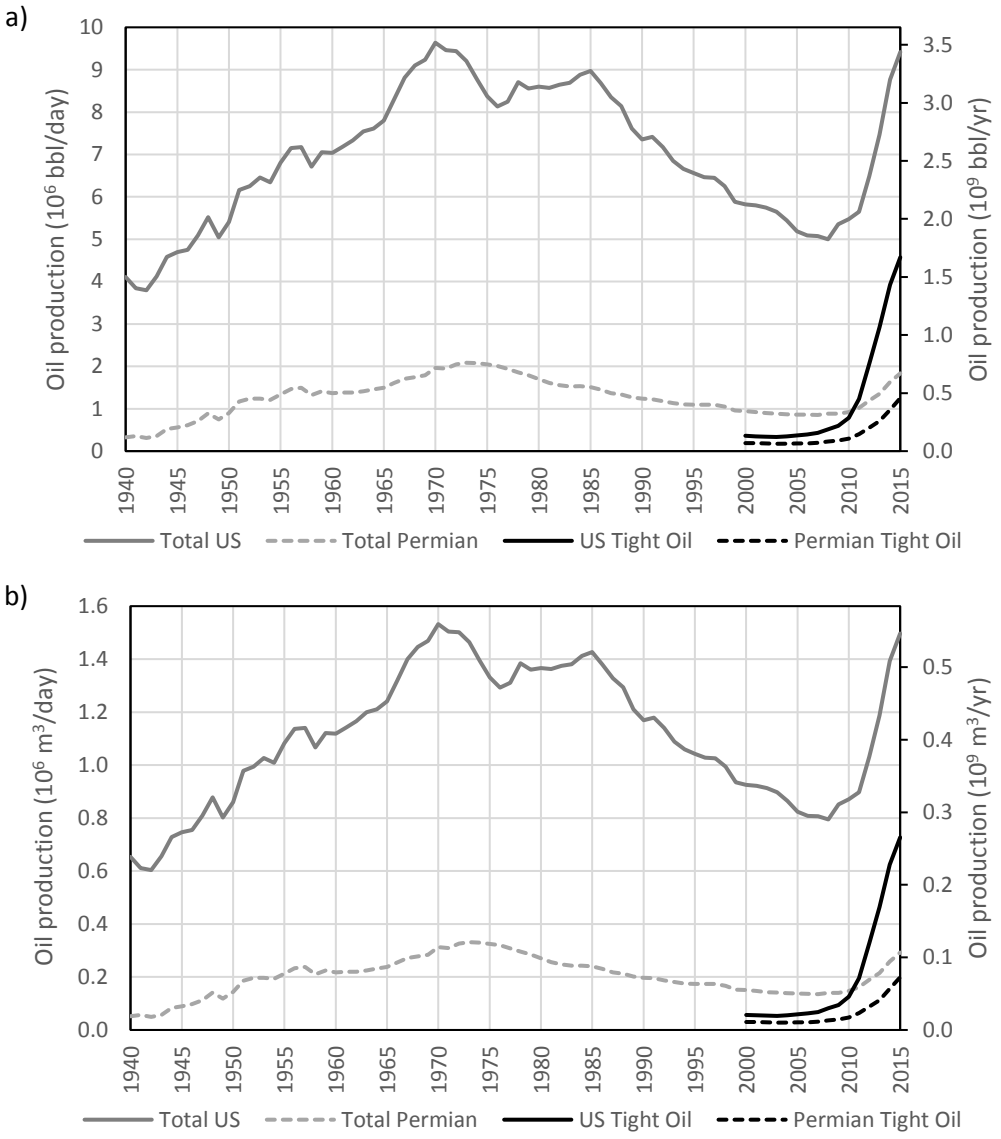

Fig. S5. Historical oil production in the US, Permian Basin and Texas in a) English and b) metric units. Recent total US and Permian tight oil production are also shown. (Public data provided by US Energy Information Agency, EIA, available at https://www.eia.gov/dnav/pet/pet_crd_crpdn_adc_mbbl_m.htm).

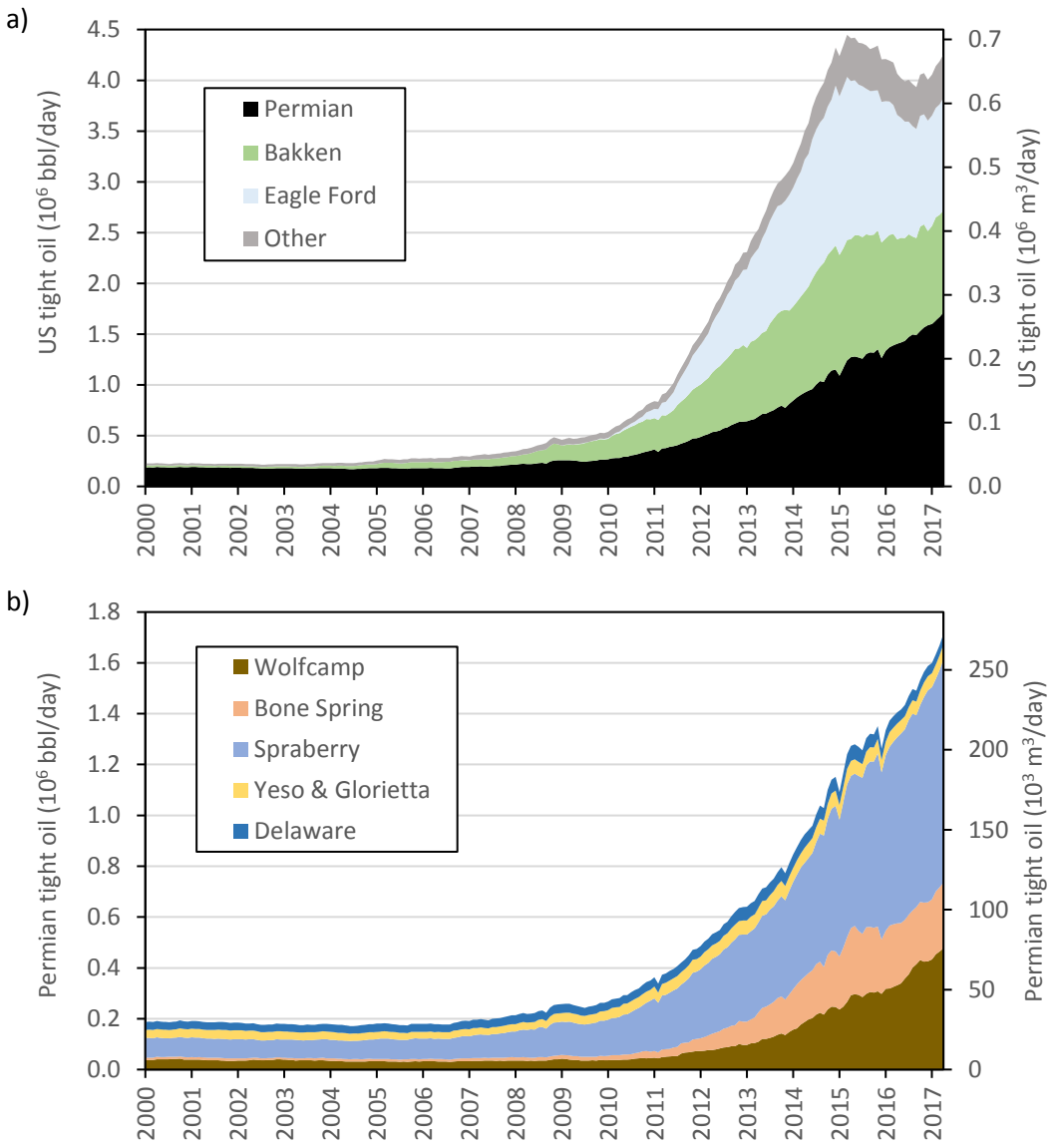

Fig. S6. Tight oil production in a) the US and b) different producing units of the Permian Basin (Public data provided by US Energy Information Agency, EIA, available at http://www.eia.gov/petroleum/drilling).

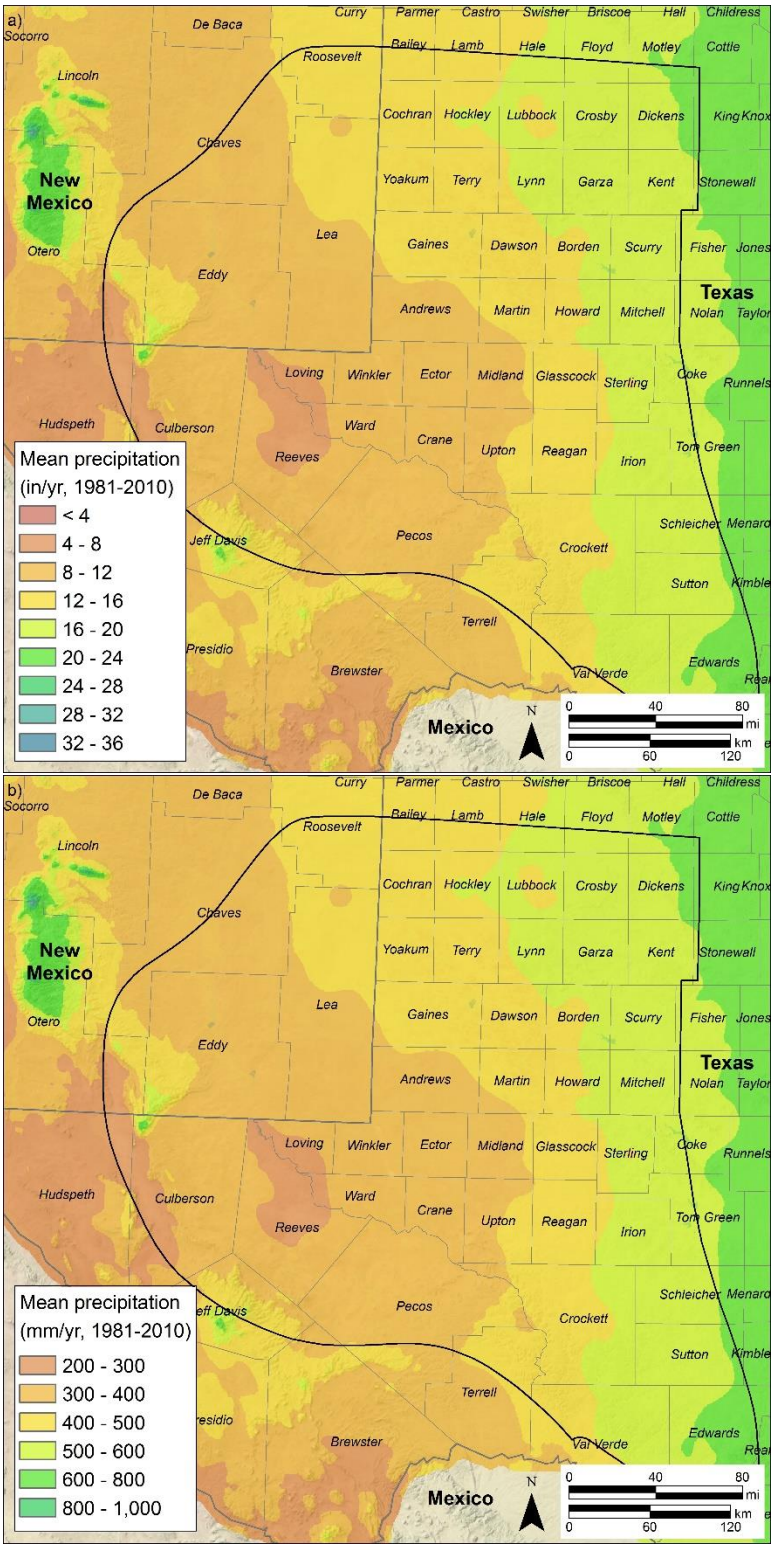

Fig. S7. Regional 30-yr mean annual precipitation in the Permian Basin region in a) English and b) metric units. (Prism Climate Group, http://prism.oregonstate.edu/). Precipitation ranges from 8.9 inches (226 mm) in the west to 28.3 inches (719 mm) in the east. Original map images created in ESRI ArcGIS version 10.3.1.

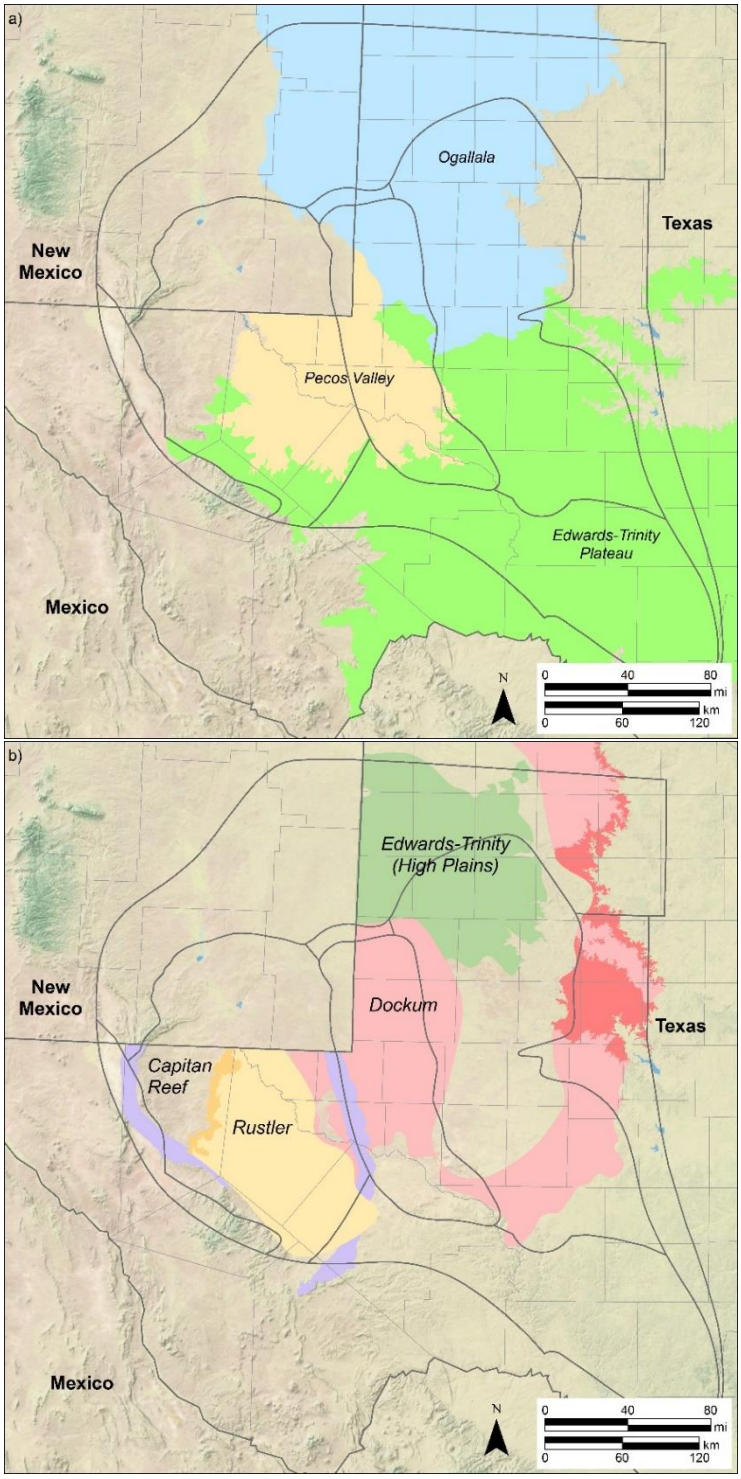

Fig. S8. Lateral extents of a) major and b) minor aquifers in the Permian Basin region. (Texas Water Development Board, http://www.twdb.texas.gov/). The major aquifers include the Ogallala Aquifer (late Miocene to early Pliocene age), Edwards Trinity Plateau Aquifer (Cretaceous age), Pecos Valley Aquifer (Cenozoic age) and the minor aquifers include the Edwards-Trinity (High Plains) Aquifer (Cretaceous age), Dockum Aquifer (Triassic age), Rustler Aquifer (Late Permian) and Capitan Reef Complex Aquifer (Middle Permian). Original map images created in ESRI ArcGIS version 10.3.1.

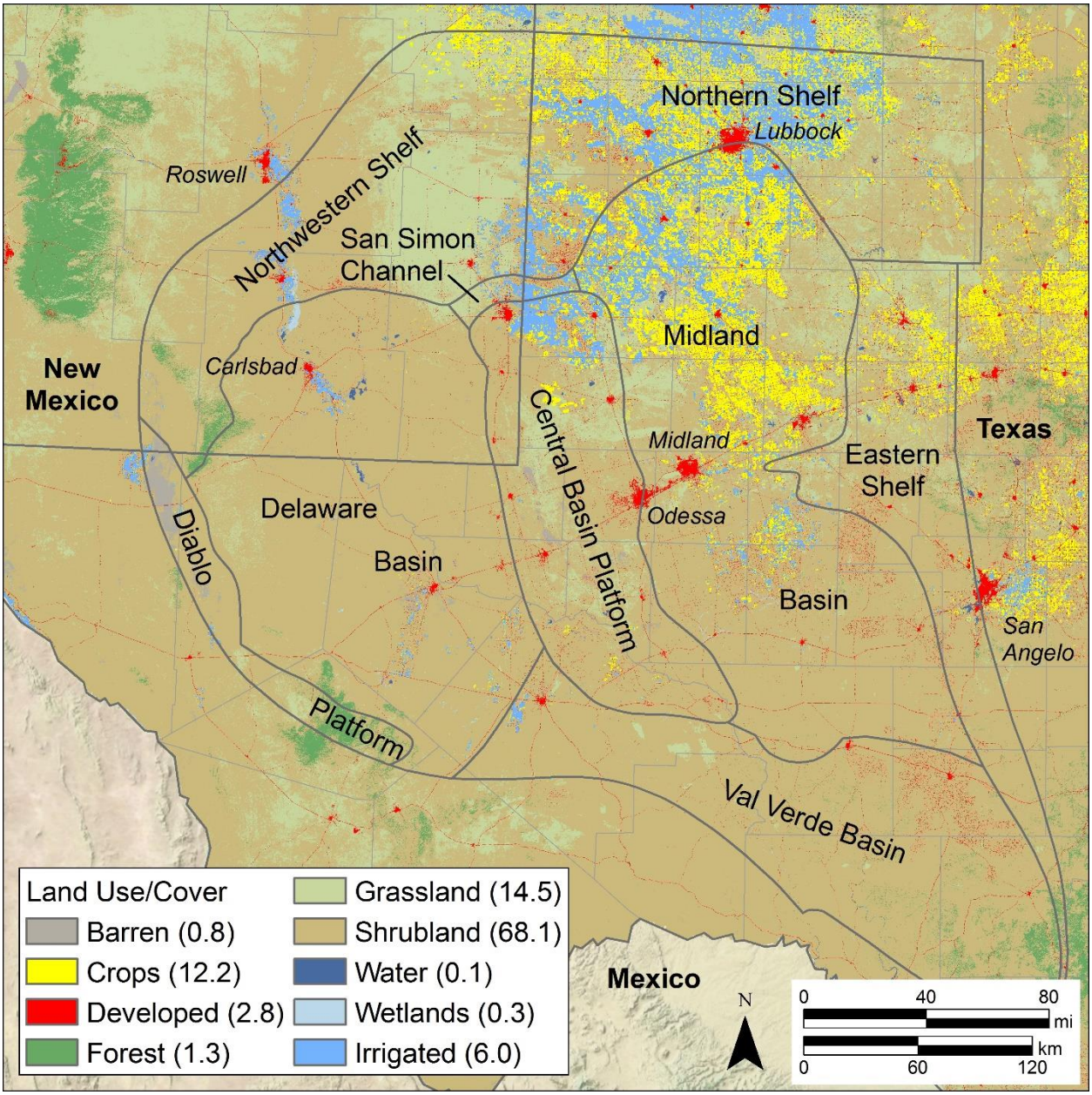

Fig. S9. Land use/land cover in the Permian Basin and subregions within the Permian Basin. Major cities in the area are also labeled. Land use/cover is based on the National Land Cover Database imagery for 2011 (NLCD, http://www.mrlc.gov/nlcd2011.php). Irrigated area represents the composite of 2002, 2007, and 2012 MODIS imagery from the Irrigated Agricultural Dataset for the United States (http://earlywarning.usgs.gov/USirrigation). Original map image created in ESRI ArcGIS version 10.3.1.

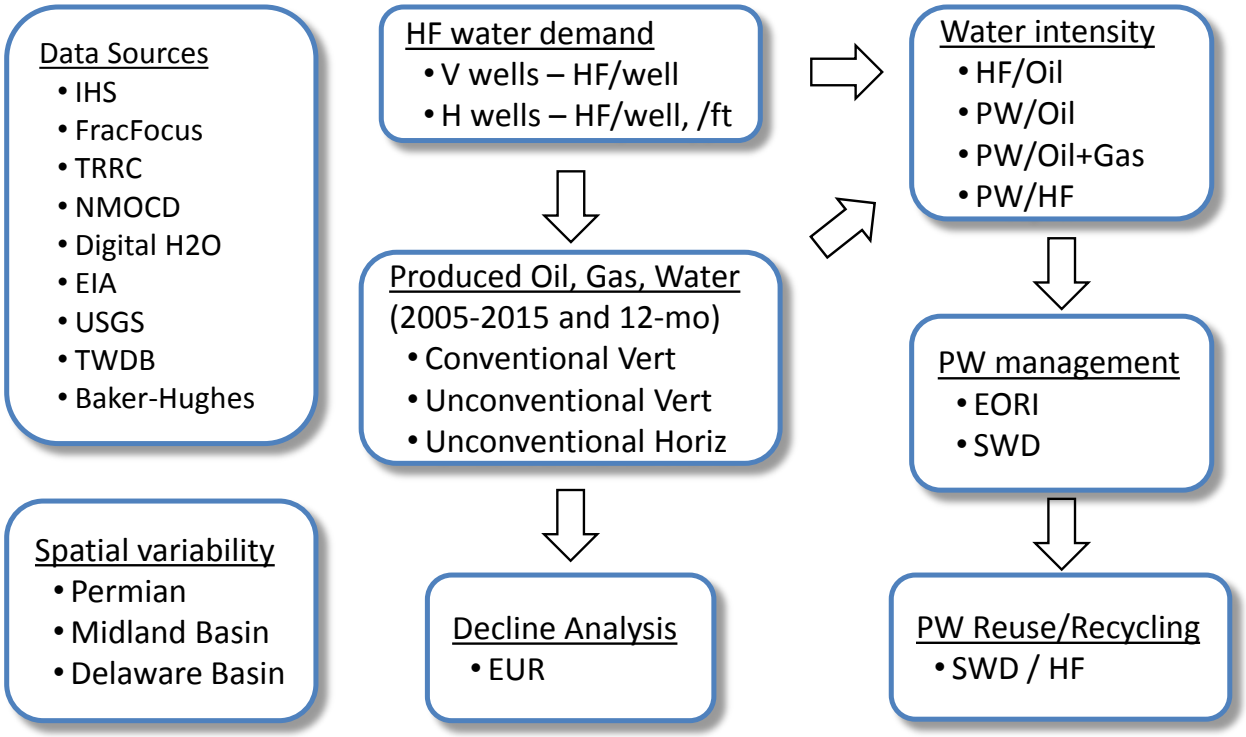

Fig. S10. Methods flow chart. Data sources include IHS Enerdeq (oil, gas, and water production, water injection, hydraulic fracturing [HF] water and proppant use, well information), FracFocus (HF water use) , the Texas Railroad Commission (TRRC, oil, gas, and water production, water injection, well information), the New Mexico Oil Conservation Division (NMOCD, water injection, well information), Digital H2O (well information), Energy Information Agency (EIA, oil and gas production), United States Geological Survey (USGS, PW quality), Texas Water Development Board (TWDB, regional water use), and Baker-Hughes (drill rig counts). Water demand for well completion using hydraulic fracturing (HF) was characterized for unconventional vertical (V) and unconventional horizontal (H) oil and gas wells. The resulting oil, gas, and produced water (PW) from these wells was characterized and compared with that produced from conventionally completed wells. Analyses were summarized for the entire Permian and for the two main subbasins, including the Midland and Delaware basins. Analyses summarized annually for the period 2005-2015 and also on a well-by-well basis using both the initial 12-mo of production and individual decline curves were developed to obtain Estimated Ultimate Recovery (EUR). Relationships between the different variables were examined as ratios between hydrocarbon production, PW, and HF. Traditional management of PW in the Permian is by injection which was characterized spatially and temporally as both Enhanced Oil Recovery Injection (EORI) and Saltwater Disposal (SWD) and the potential for reuse and recycling of SWD water for HF water was examined.

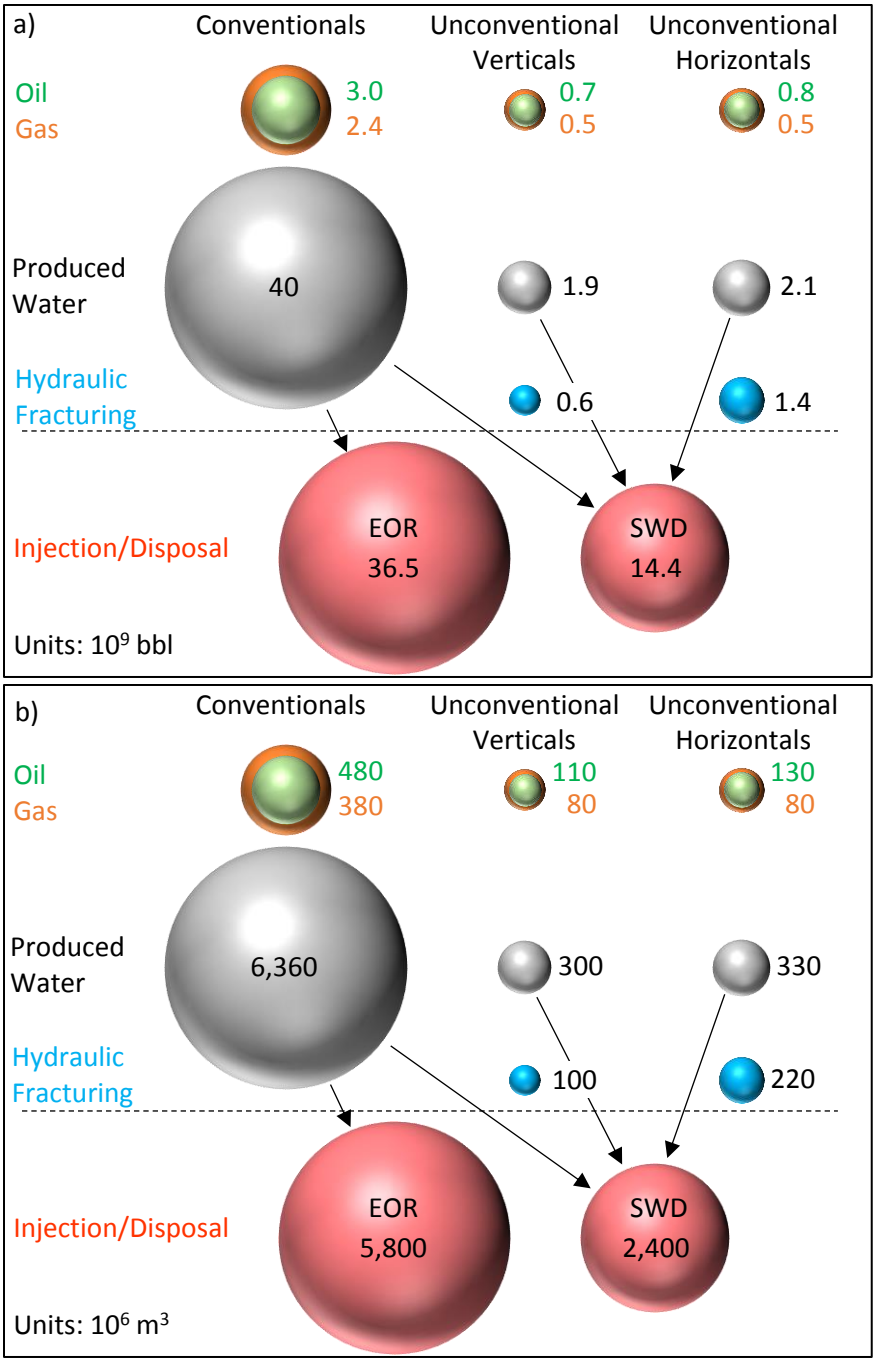

Fig. S11. Permian Basin total production of oil and water from 2005 – 2015 from conventional wells, and unconventional vertical and horizontal wells in a) English and b) metric units (Table S5a). Water use for hydraulic fracturing is also included (Table S6). Total injection/disposal of produced water is shown below production, including injection for enhanced oil recovery (EOR) and salt water disposal (SWD) (Table S18).

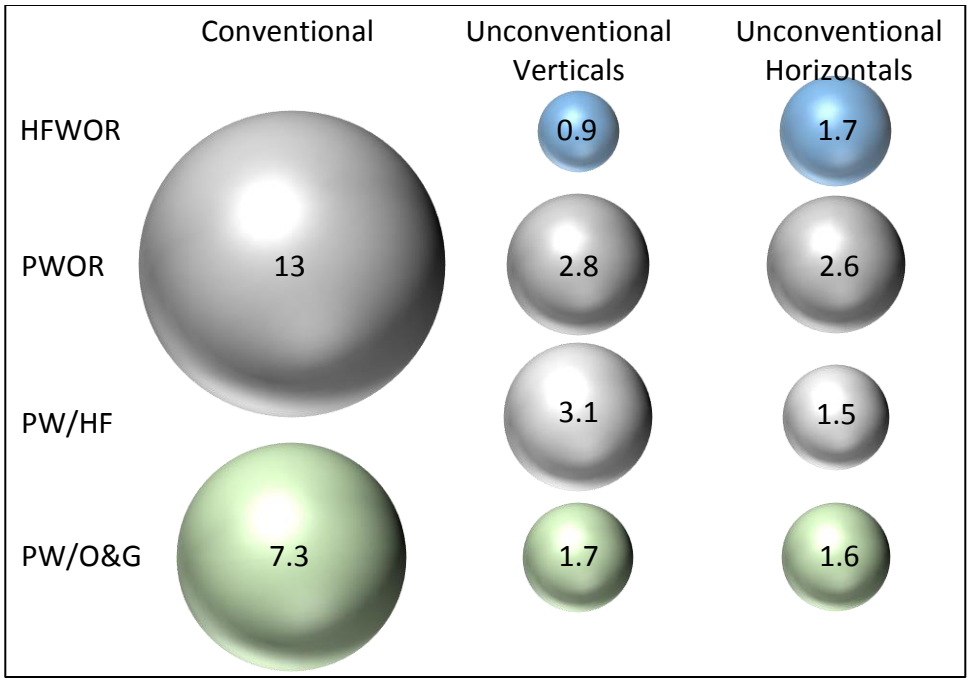

Fig. S11c. Permian Basin water intensities for conventional, unconventional vertical, and unconventional horizontal wells for the period 2005-2015, including the hydraulic fracturing water to oil ratios (HFWOR, Table S16a), produced water to oil ratios (PWOR, Table S17a), produced water (PW) to hydraulic fracturing (HF) ratios (Table S19a), and PW to oil and gas (O&G) ratios (Table S16b). Gas volumes represent equivalent oil volumes.

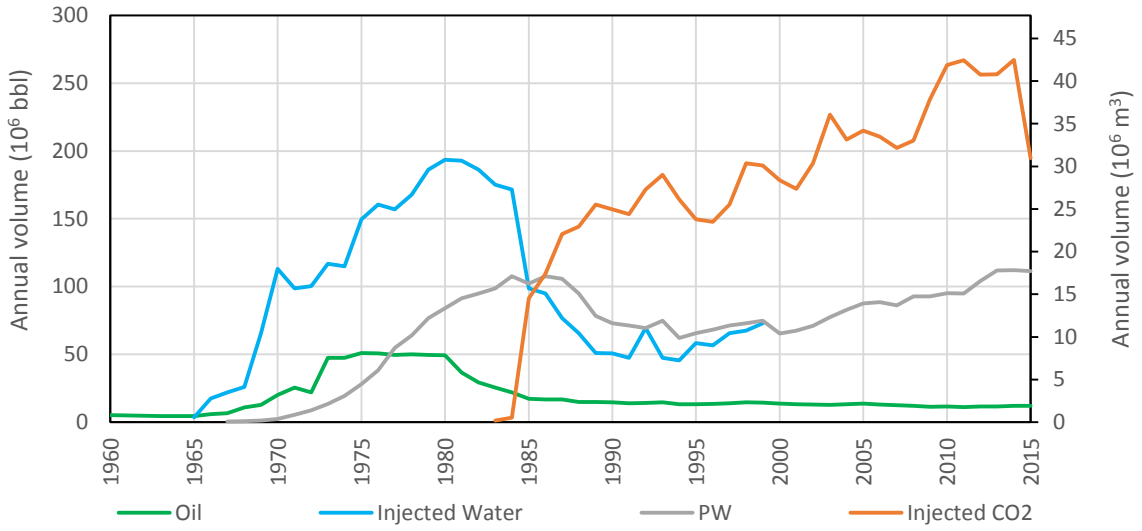

Fig. S12a. Historical annual total oil and produced water volumes along with volumes of injected water and CO_2 for the Wasson Field in the Permian Basin. During the early phase of water flooding, PW was insufficient to support water flooding; therefore, fresh groundwater was used, mostly from the Ogallala Aquifer. A statewide survey indicated that ~180×10^6 bbl (29×10^6 m^3) of freshwater (≤3,000 mg/L TDS) was used in 1995 in the Permian Basin[9].

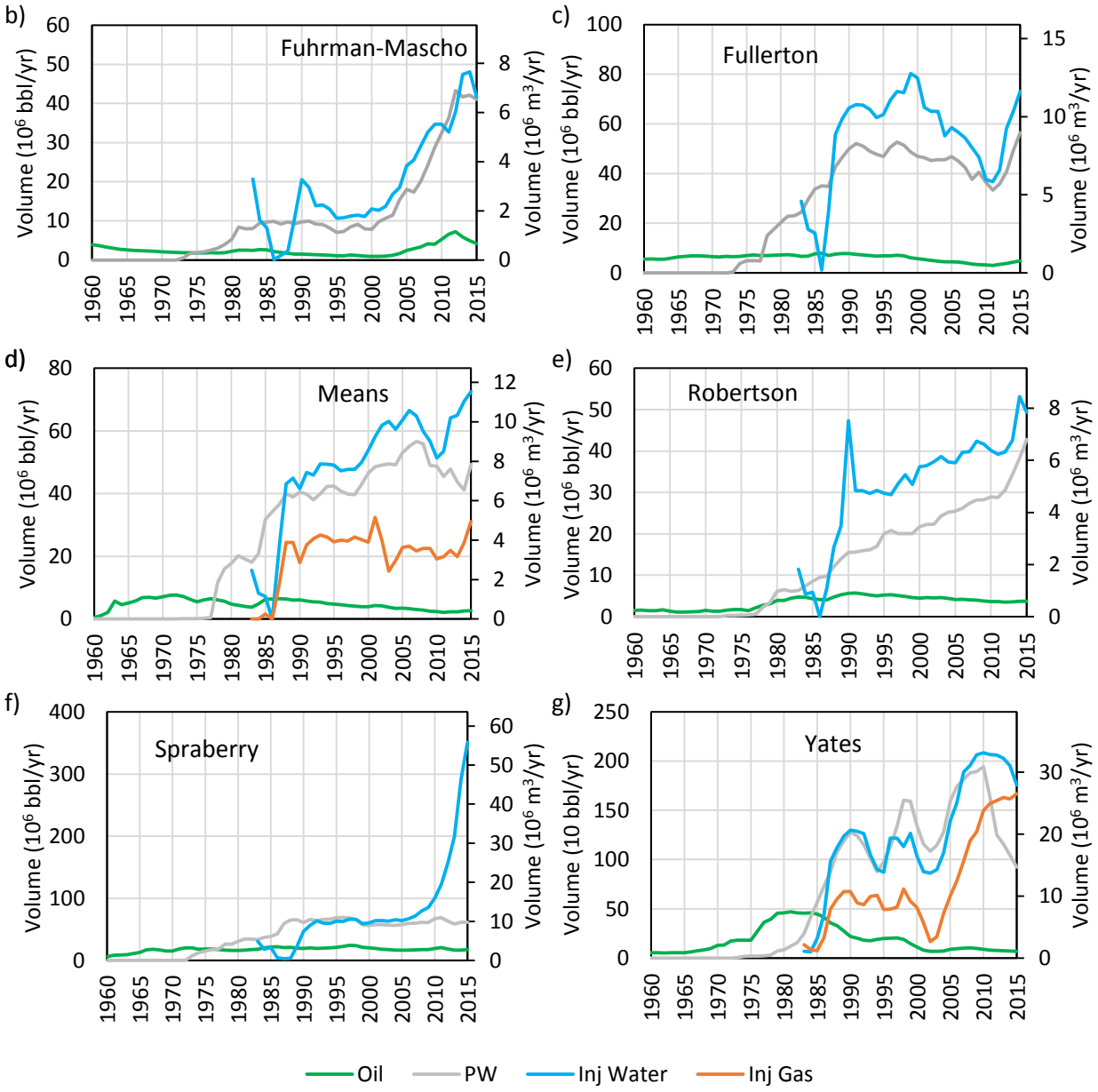

Fig. S12b-g. Historical annual total oil and produced water volumes along with volumes of injected water and gas (CO_2) for the Fuhrman-Mascho, Fullerton, Means, Robertson, Spraberry, and Yates conventional oil fields in the Permian Basin.

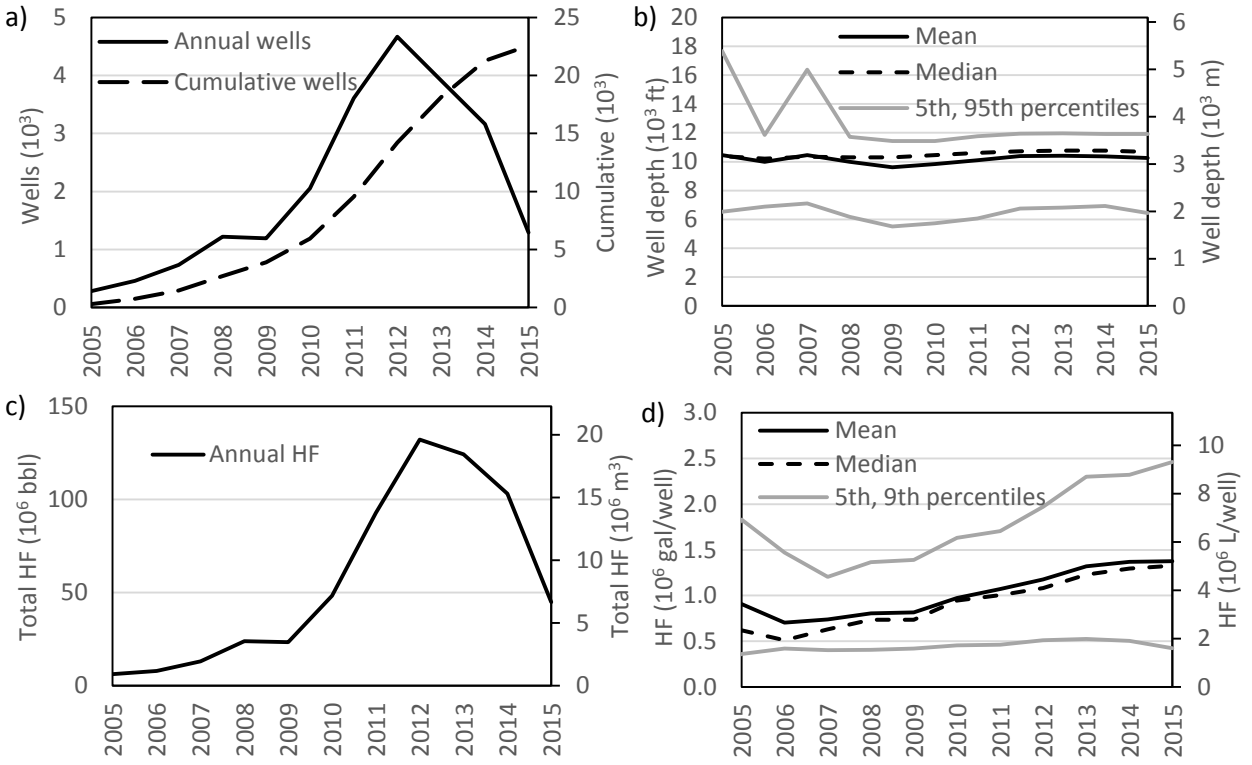

Fig. S13. Permian Basin a) numbers of well completions, b) well depth, c) total HF water use, and d) HF water use per well for unconventional vertical wells completed during the period 2005-2015 (Table S6).

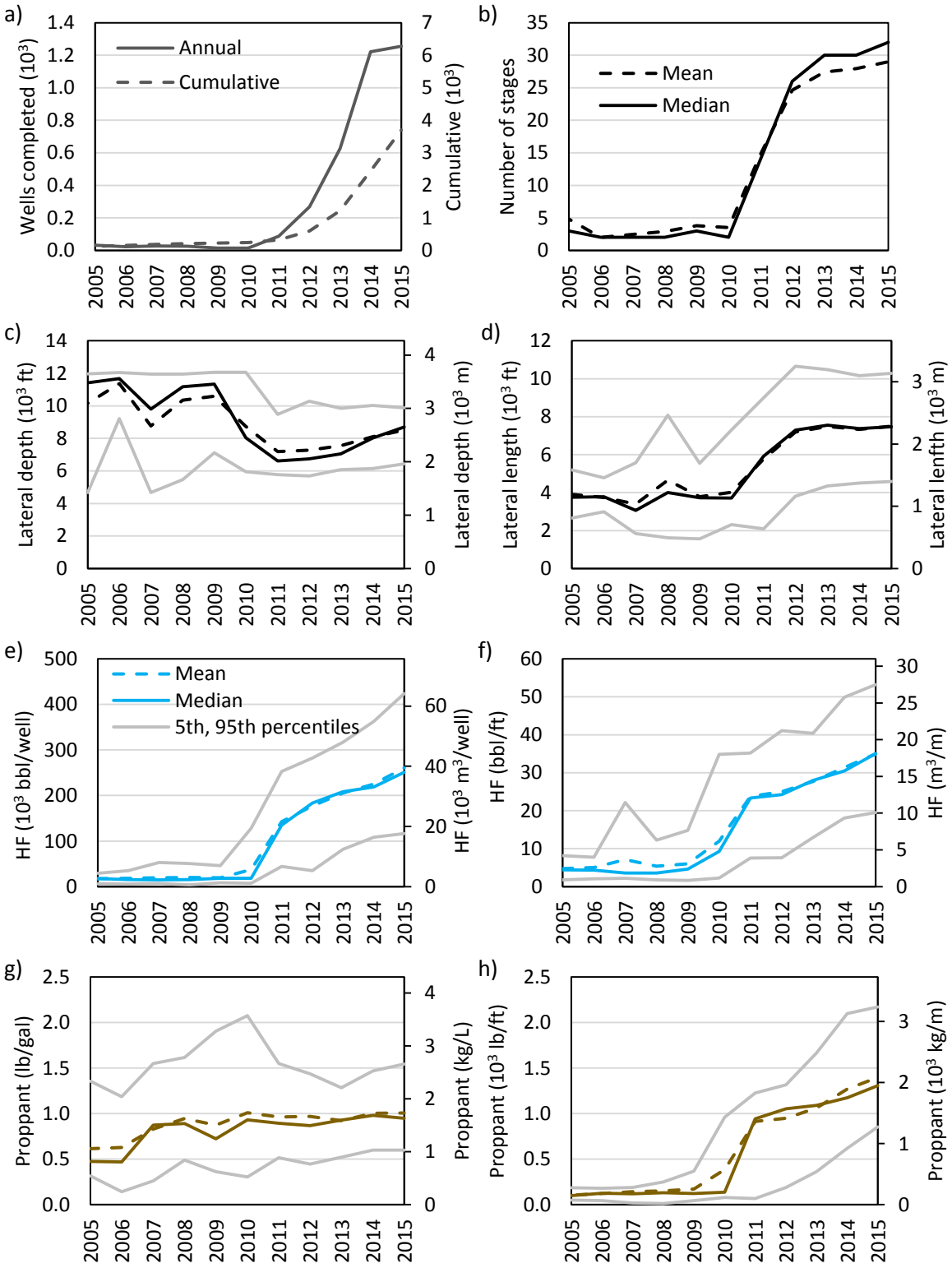

Fig. S14. **Midland Basin** a) numbers of well completions, b) HF stages, c) lateral depth, d) lateral length, e) & f) HF water use, and g) & h) proppant use for unconventional horizontal wells completed during the period 2000-2015 (Table S8Table S8c, Table S9c, Table S10b). Data on stages are very limited prior to 2010.

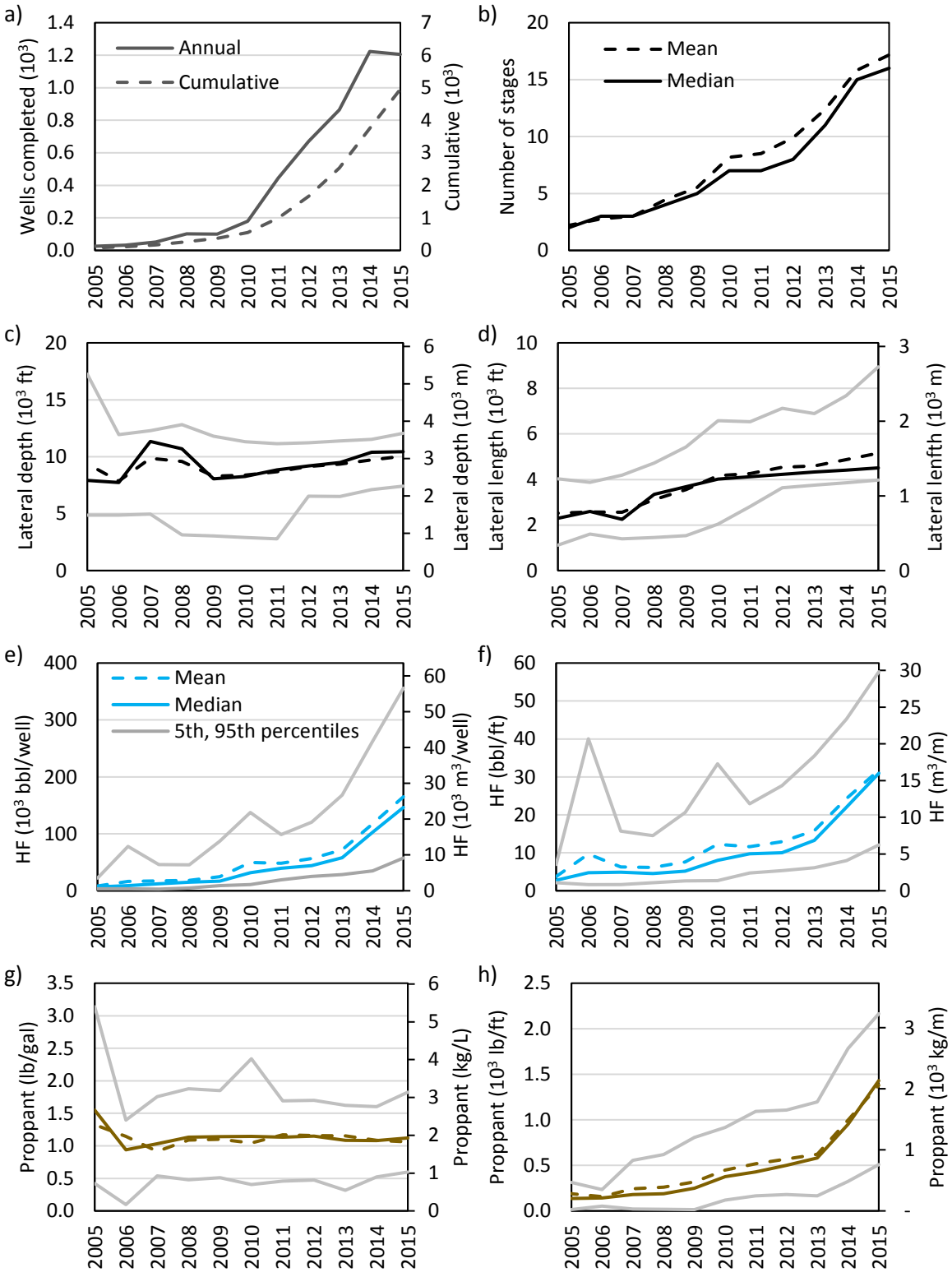

Fig. S15. **Delaware Basin** a) numbers of well completions, b) HF stages, c) lateral depth, d) lateral length, e) & f) HF water use, and g) & h) proppant use for unconventional horizontal wells completed during the period 2000-2015 (Table S8e, Table S9e, Table S10c). Data on stages are very limited prior to 2010.

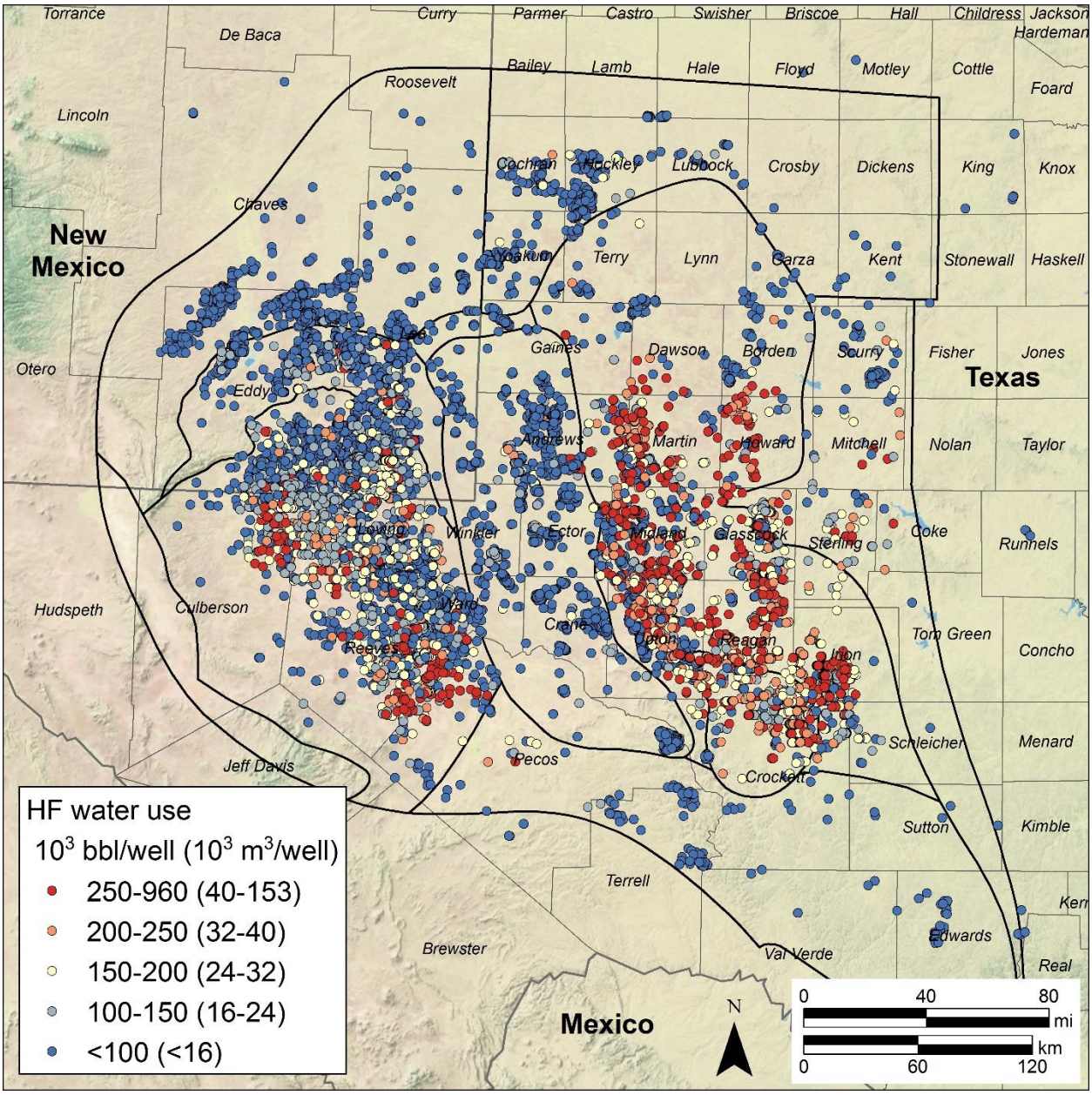

Fig. S16. Distribution of hydraulic fracturing (HF) water use per well for unconventional horizontal wells completed in the Permian Basin during the period 2005-2015. Original map image created in ESRI ArcGIS version 10.3.1.

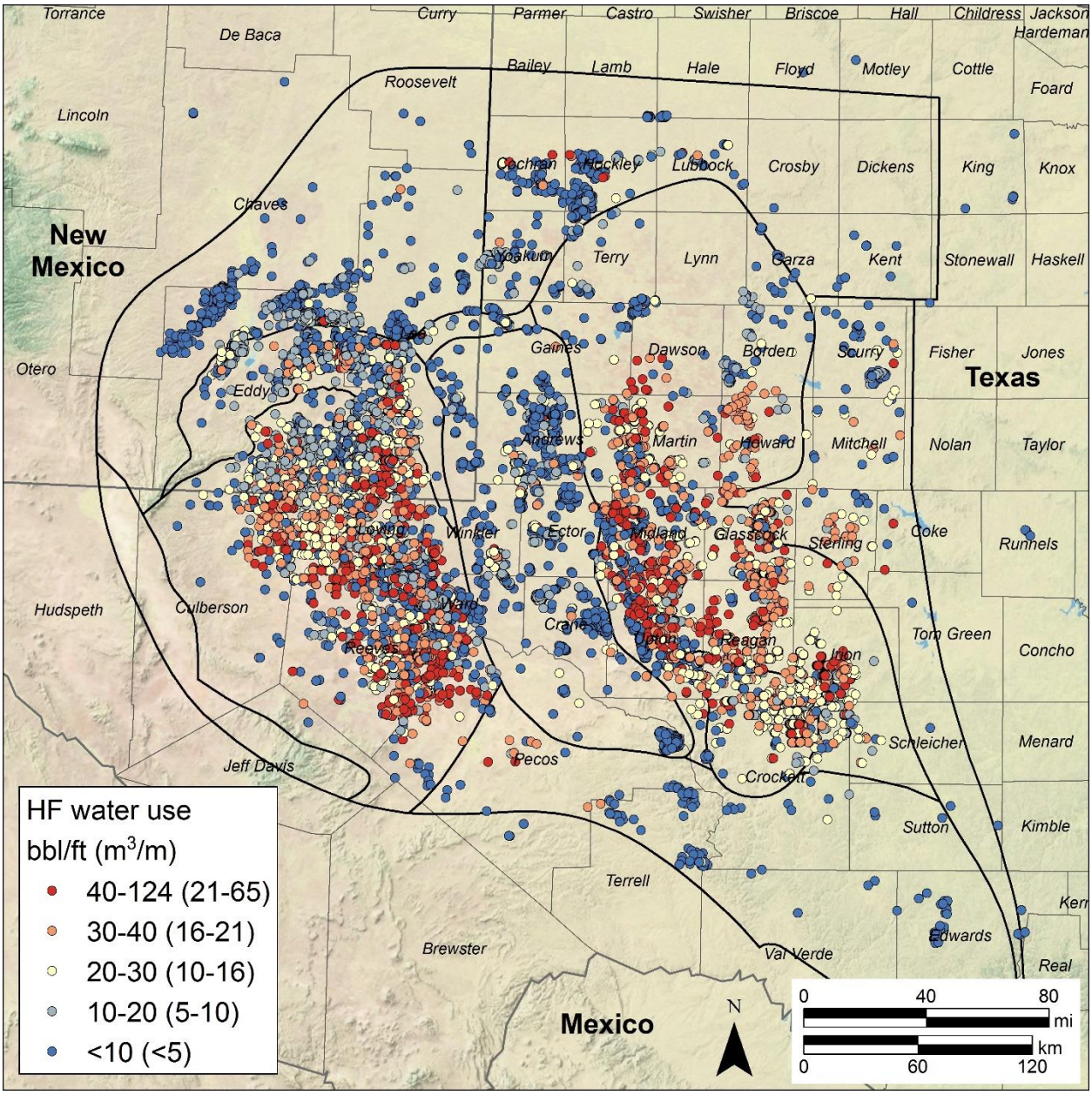

Fig. S17. Distribution of hydraulic fracturing (HF) water use unit lateral length for unconventional horizontal wells completed in the Permian Basin during the period 2005-2015. Original map image created in ESRI ArcGIS version 10.3.1.

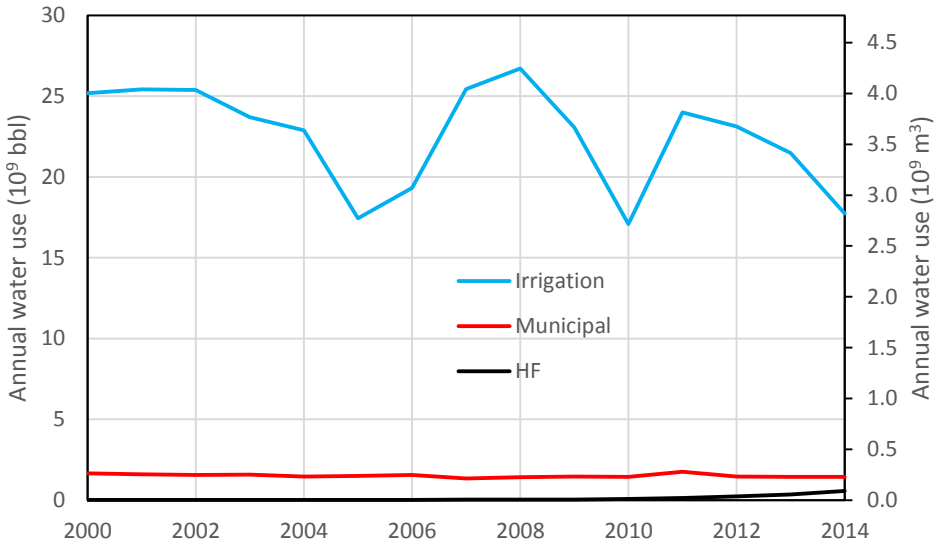

Fig. S18. Total annual irrigation and municipal water use in the Texas portion of the Permian Basin based on Texas Water Development Board (TWDB) county-level historical water use reports compared hydraulic fracturing (HF) water use (Table S11).

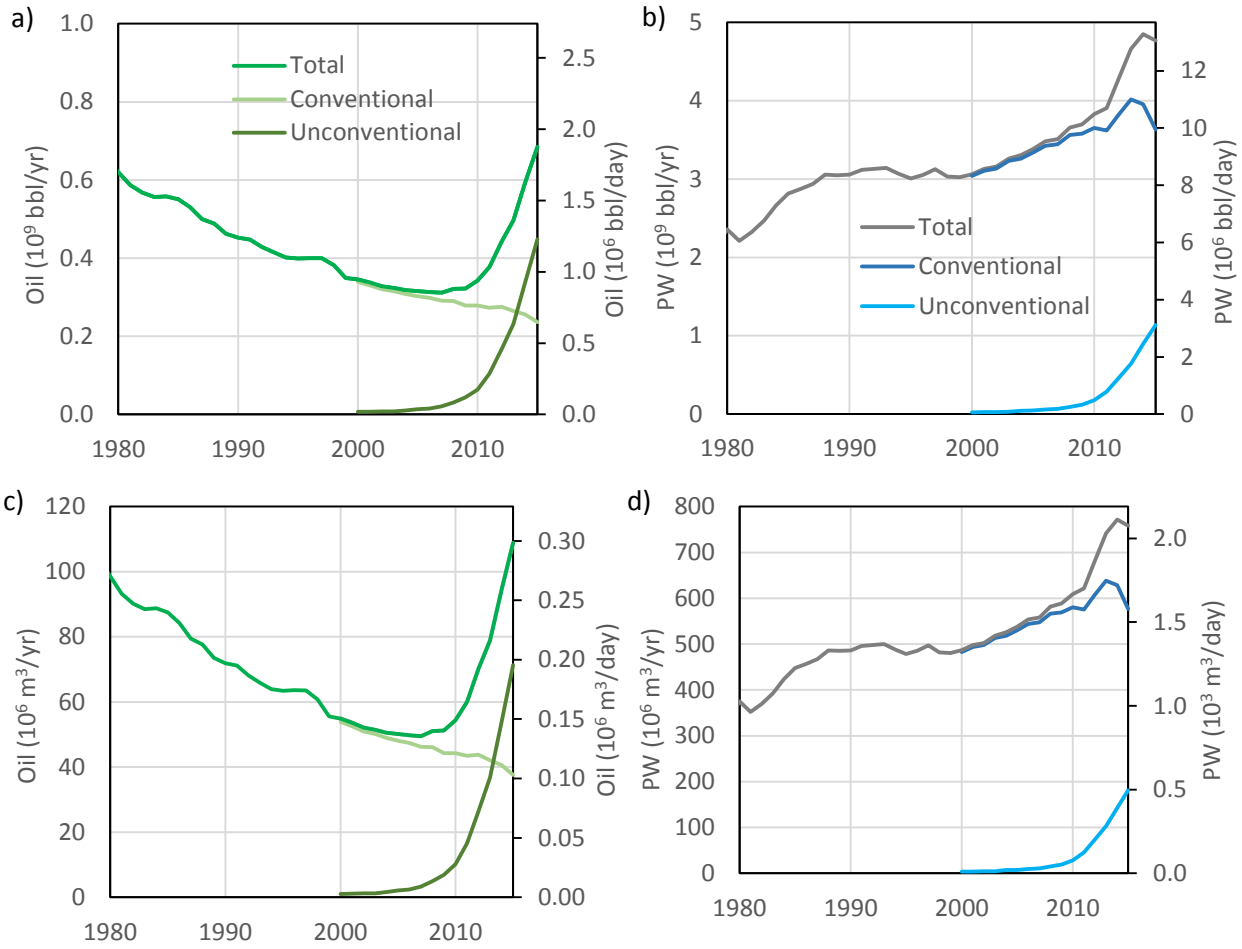

Fig. S19. Permian Basin a) oil and b) water (PW) production during the period 1980-2015 (Table S5). Total values for conventional and unconventional formations are shown for the period 2000-2015. Respective metric unit versions are shown in c) and d).

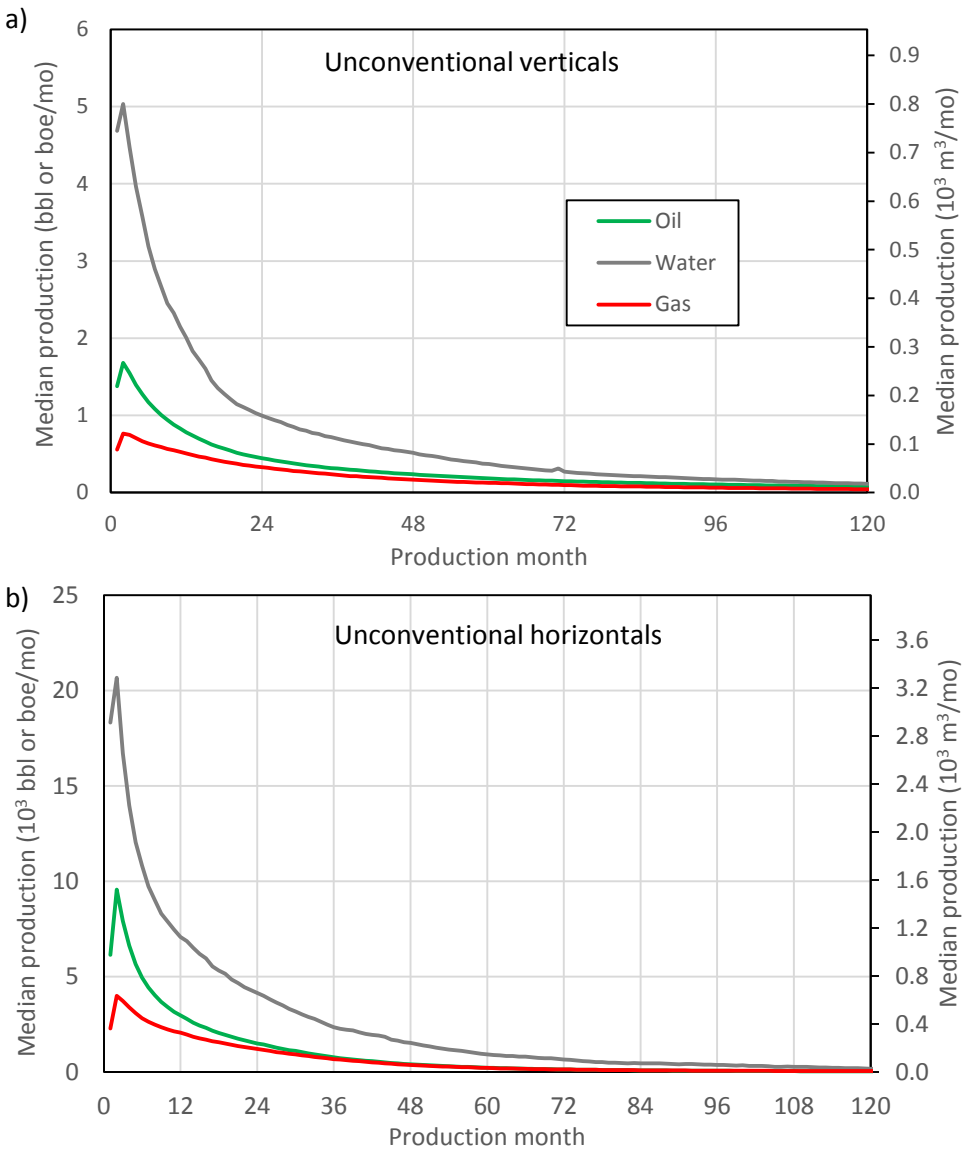

Fig. S20. Decline curves for produced oil, water, and gas based on mean monthly values from a) ~22,500 unconventional vertical and b) ~9,800 unconventional horizontal oil wells completed in the Permian Basin during 2005 – 2015. Gas values are shown in barrels of oil equivalent (boe). Mean EUR for 20 years of production for vertical wells is 43,000 bbl (6,840 m^3) oil, 96,000 bbl (15,300 m^3) water, and 154x10^6 ft^3 (26,500 boe, 4,200 m^3oe) gas. Mean EUR for 20 years of production for horizontal wells is 118,000 bbl (18,800 m3) oil, 316,000 bbl (50,200 m3) water, and 443 x10^6 ft^3 (76,400 boe, 12,300 m^3oe) gas.

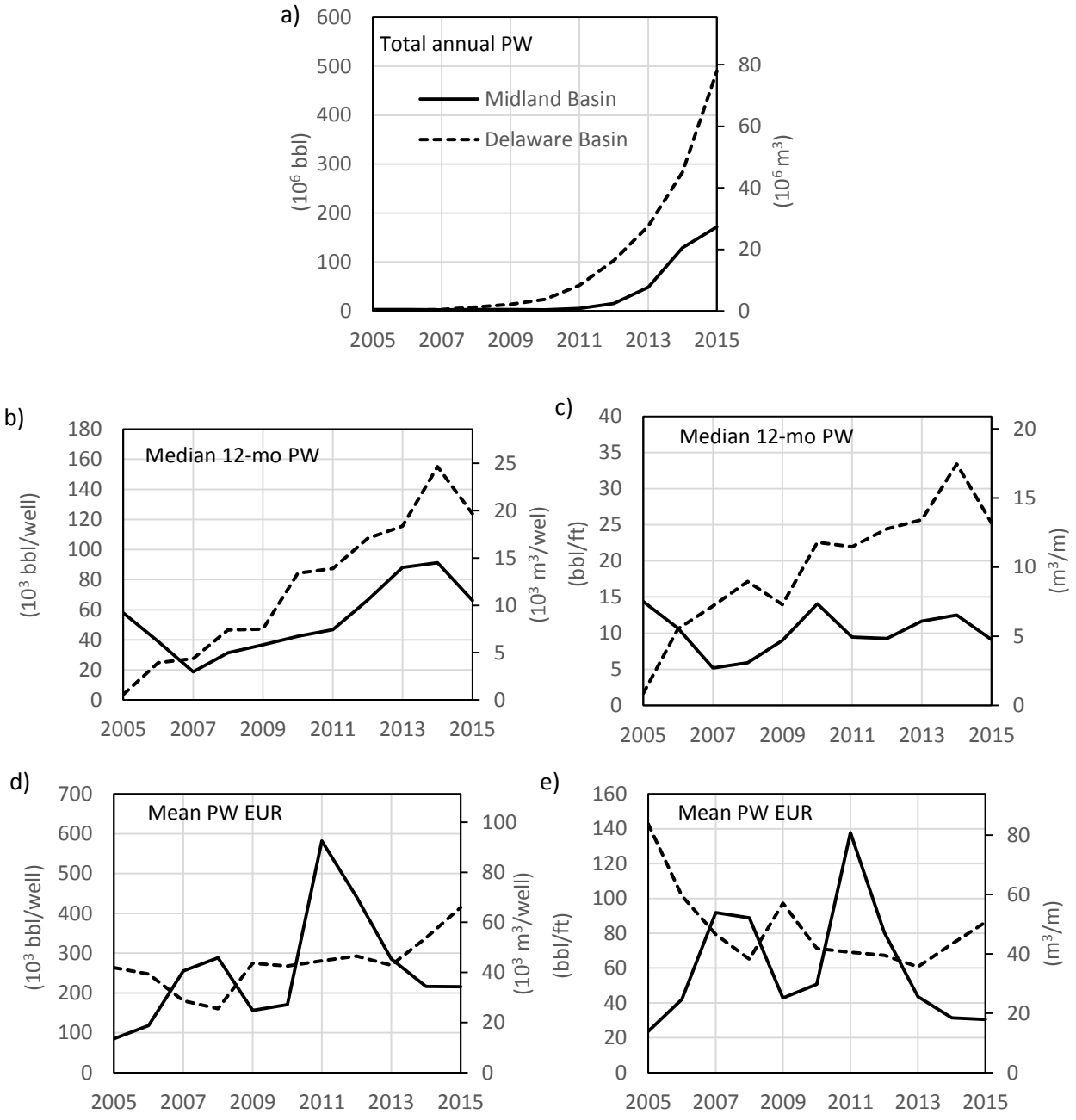

Fig. S21. Midland Basin and Delaware Basin water (PW) production from unconventional horizontal wells shown as a) total annual production (Table S14c, Table S15c), b) & c) median initial (first 12-month) production (Table S12a, Table S12c), and d) & e) mean estimated ultimate recovery (EUR) after 20 years of production (Table S13a, Table S13c). Values shown in (b) through (e) are for wells completed that year.

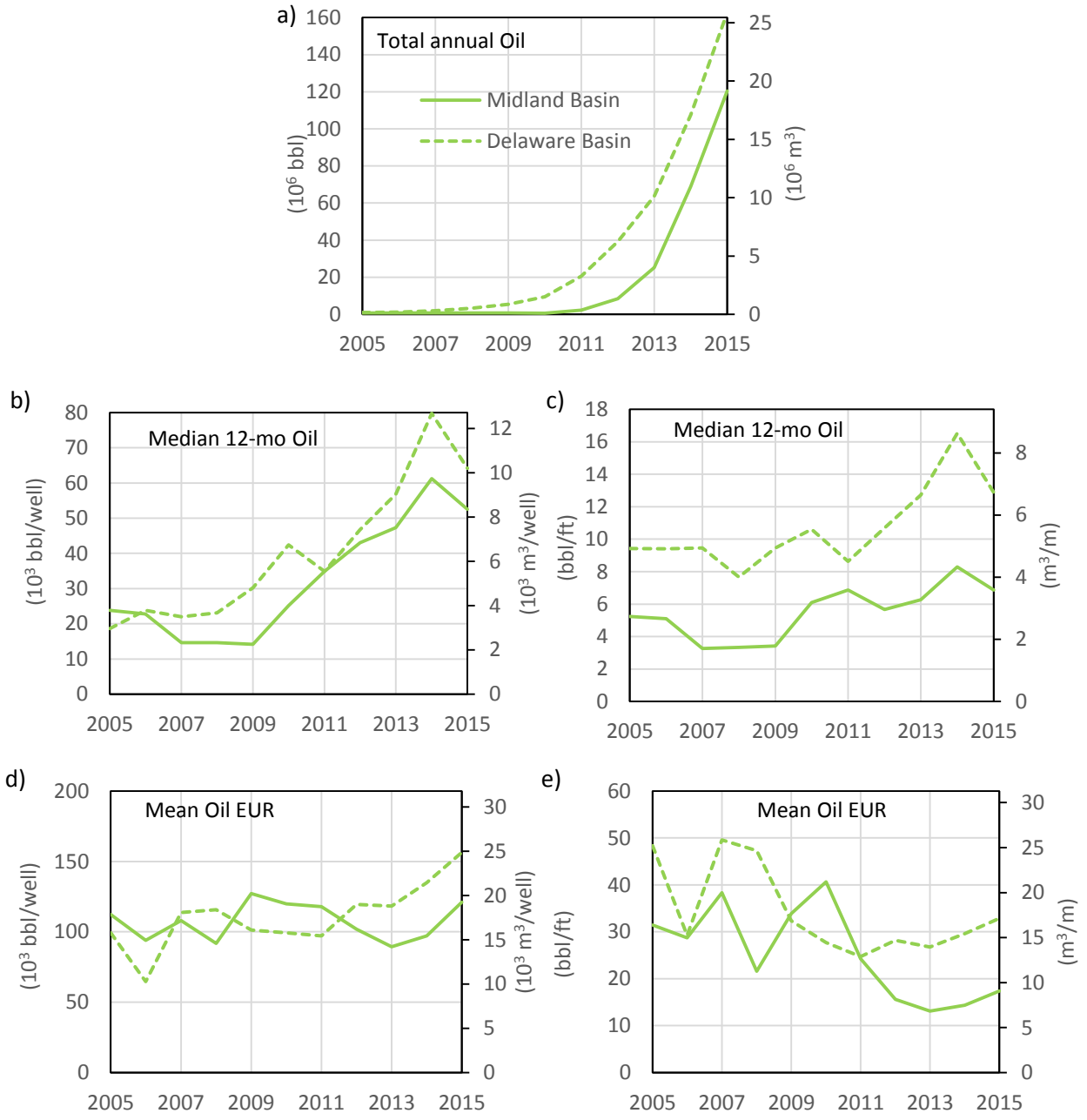

Fig. S22. Midland Basin and Delaware Basin oil production from unconventional horizontal wells shown as a) total annual production (Table S14c, Table S15Table S15c), b) & c) median initital (first 12-month) production (Table S12a, Table S12c), and d) & e) mean estimated ultimate recovery (EUR) after 20 years of production (Table S13a, Table S13c). Values shown in (b) through (e) are for wells completed that year.

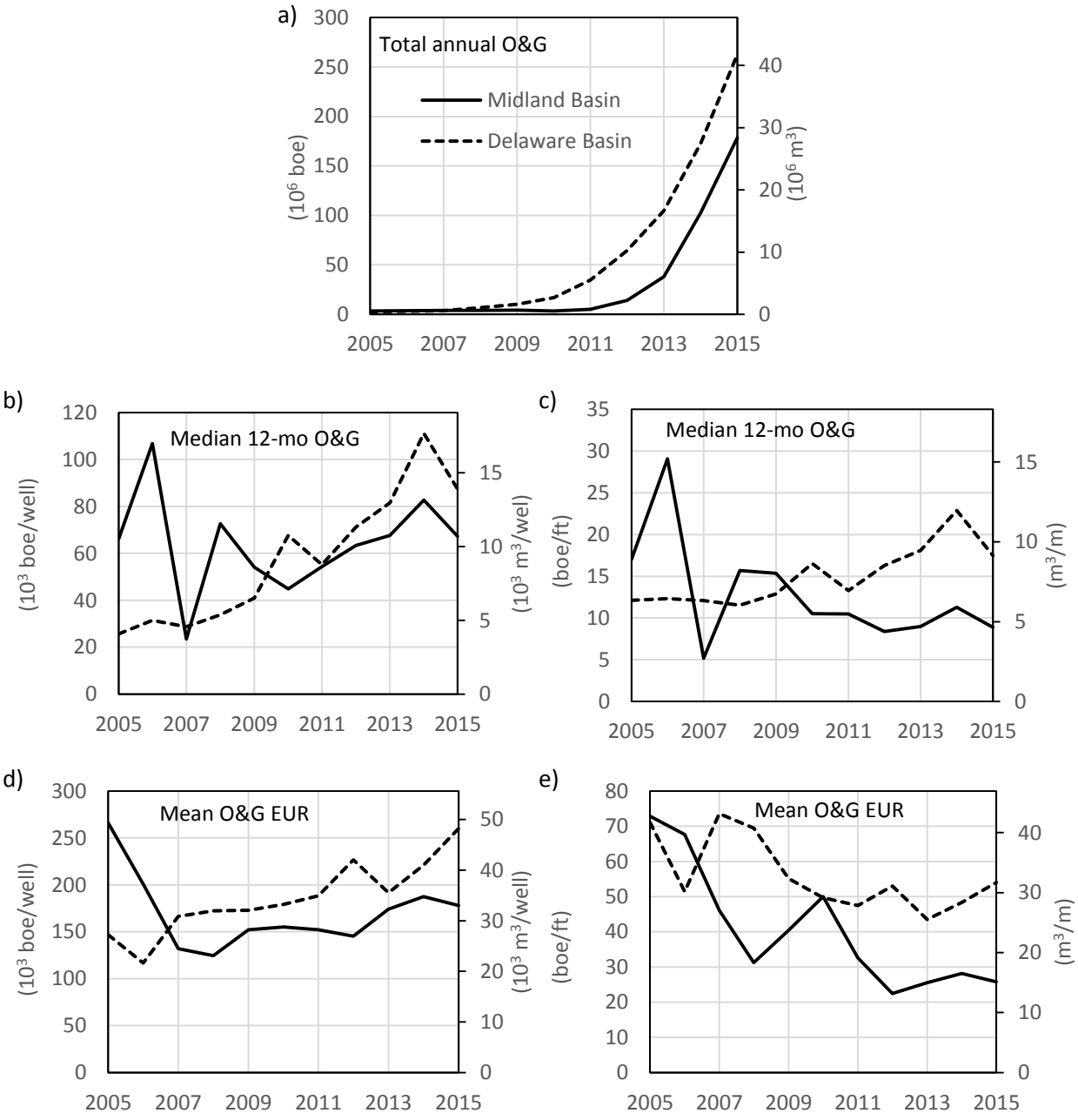

Fig. S23. Midland Basin and Delaware Basin oil+gas production from unconventional horizontal wells shown as a) total annual production (Table S14c,Table S15c), b) & c) median initital (first 12-month) production (Table S12a,Table S12c), and d) & e) mean estimated ultimate recovery (EUR) after 20 years of production (Table S13a,Table S13c). Values shown in (b) through (e) are for wells completed that year.

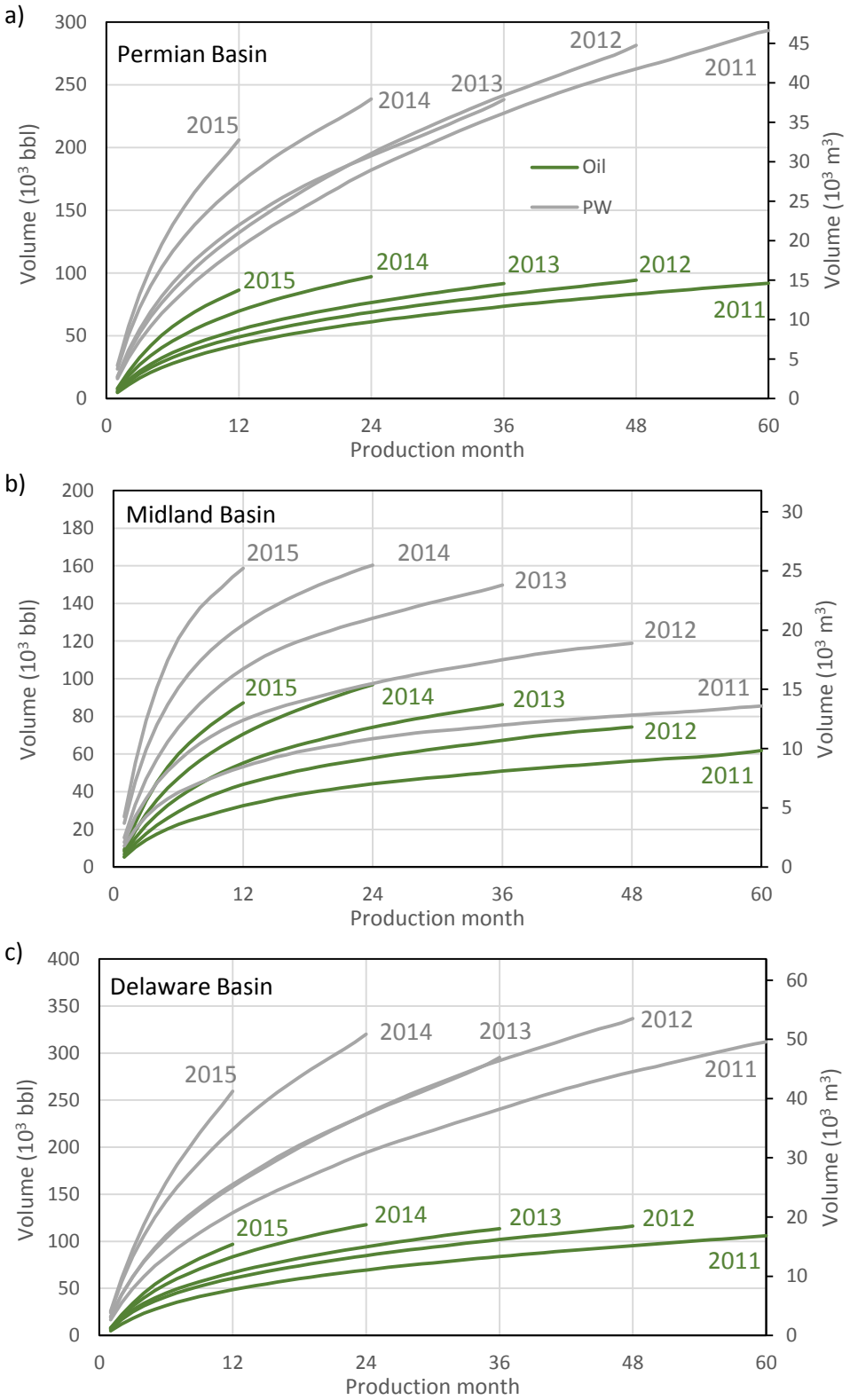

Fig. S24. Comparison of per well mean cumulative oil (green) and mean cumulative PW (gray) for unconventional horizontal wells completed in different years in the a) Permian Basin, b) Midland Basin, and c) Delaware Basin. Mean oil production and PW have increased.

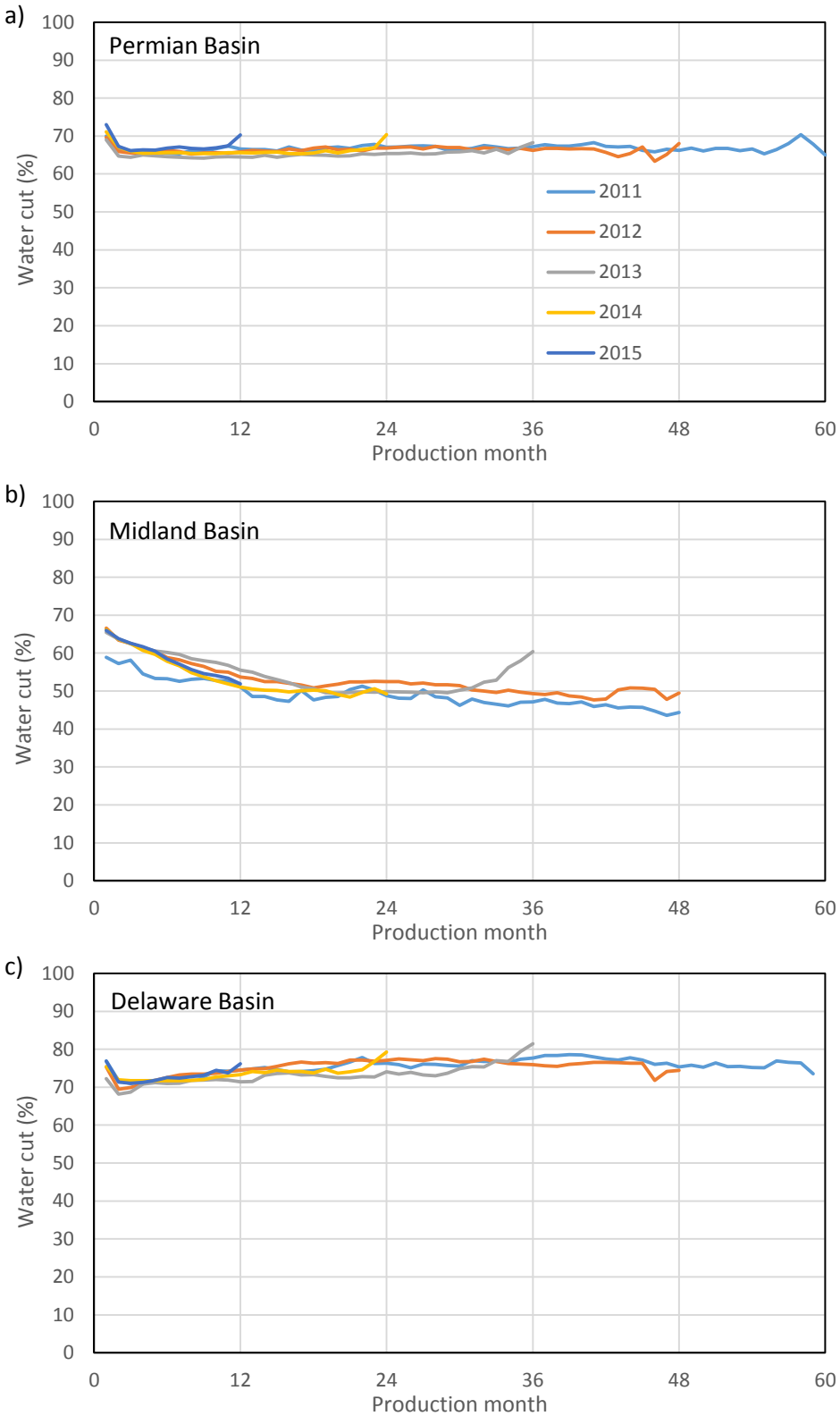

Fig. S25. Evolution of water cut for wells completed from 2011-2015 in the a) Permian Basin, b) Midland Basin, and c) Delaware Basin (Table S17, aggregated). The water cut is PW/(PW+Oil) ratio.

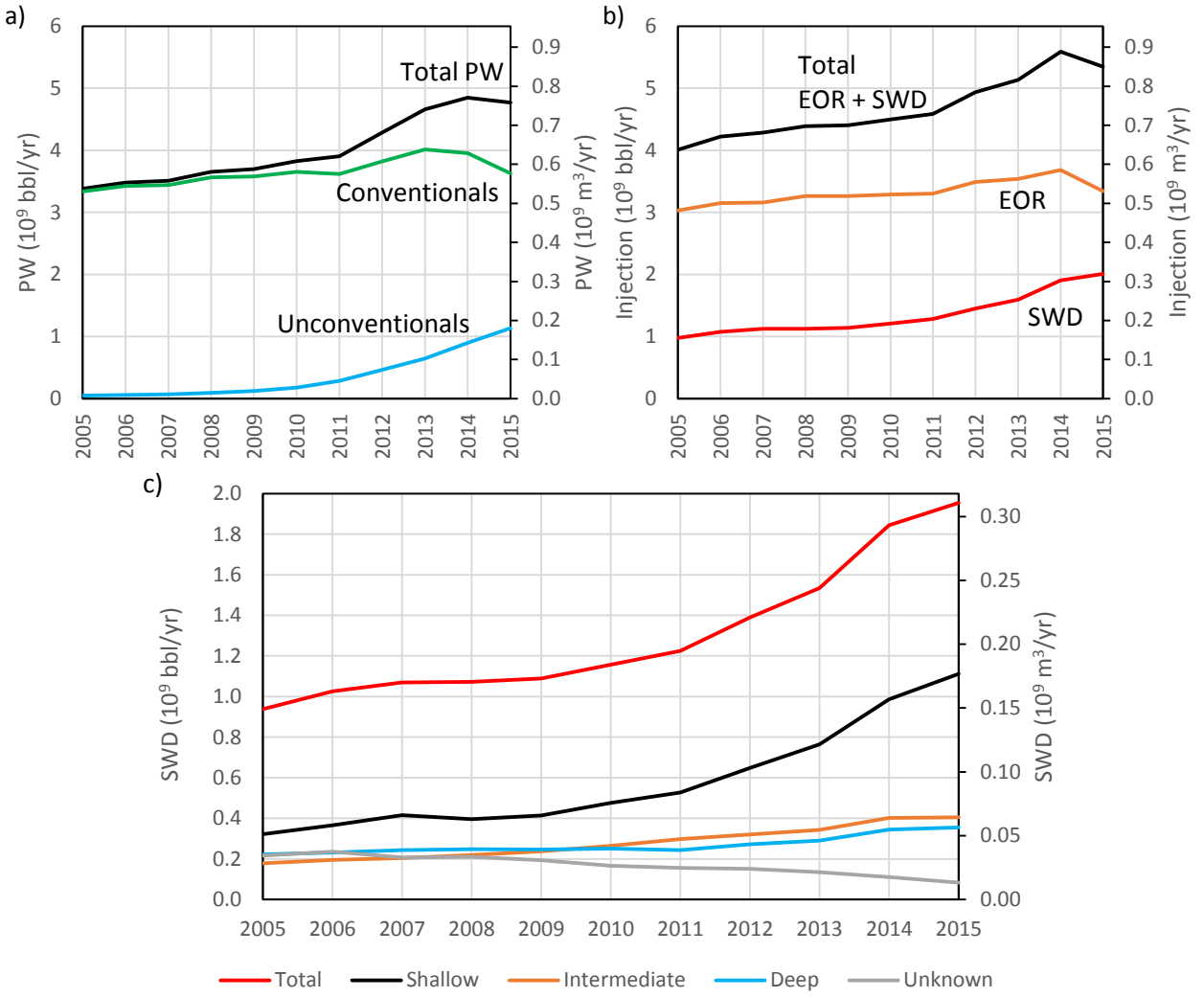

Fig. S26. Comparison between a) produced water (PW) volumes (Table S5a, 5c), b) injected water volumes in the Permian Basin (Table S18a), and c) SWD by generalized relative formation depths in the Permian Basin (shown spatially in Fig. S28). Produced water from both conventional and unconventional wells is shown in (a) and (b). Injected water volume consist of both enhanced oil recovery (EOR) salt water disposal (SWD) (b). Actual formation depths of a given geologic age depend on location within the basin and can vary widely. The terms shallow, intermediate, and deep refer to depths relative to producing intervals. Shallow includes Guadalupian age formations (San Andres, Delaware Mountain Group, etc.) and deep includes Lower Paleozoic formations (Ellenburger, Fusselman, Devonian, etc). Intermediate includes all formations in between these two. The volume associated with unknown injection formations is decreasing as reporting improves.

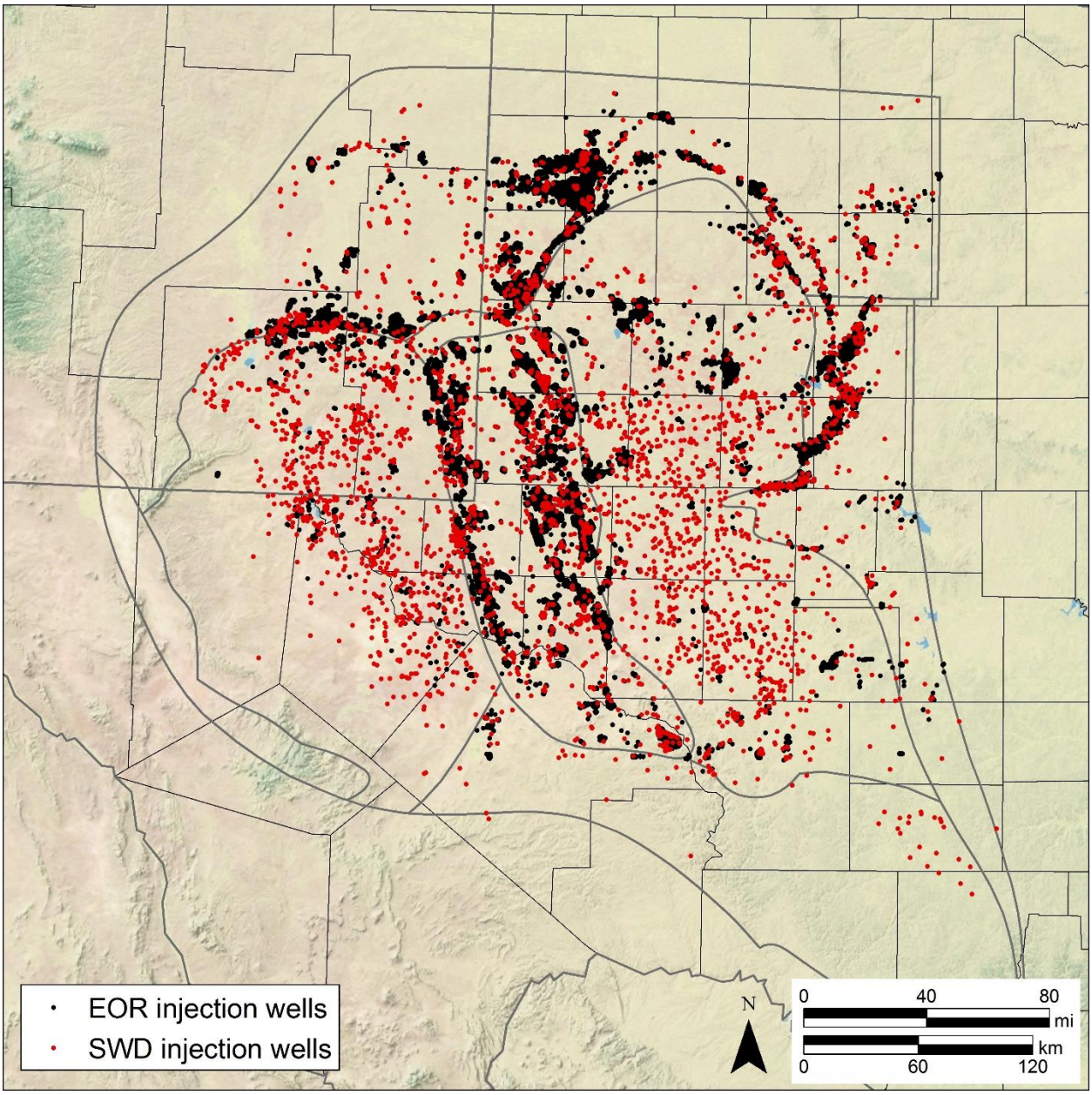

Fig. S27. Locations of active injection/disposal wells categorized by type of injection, including injection for secondary recovery (Enhanced Oil Recovery, EOR) and salt water disposal (SWD). EOR injection is for pressure maintenance of depleted fields and/or water flooding while disposal can be into either producing or nonproducing zones. Most EOR activity occurs in the marginal and platform locations while most SWD activity occurs in the basin areas. Original map image created in ESRI ArcGIS version 10.3.1.

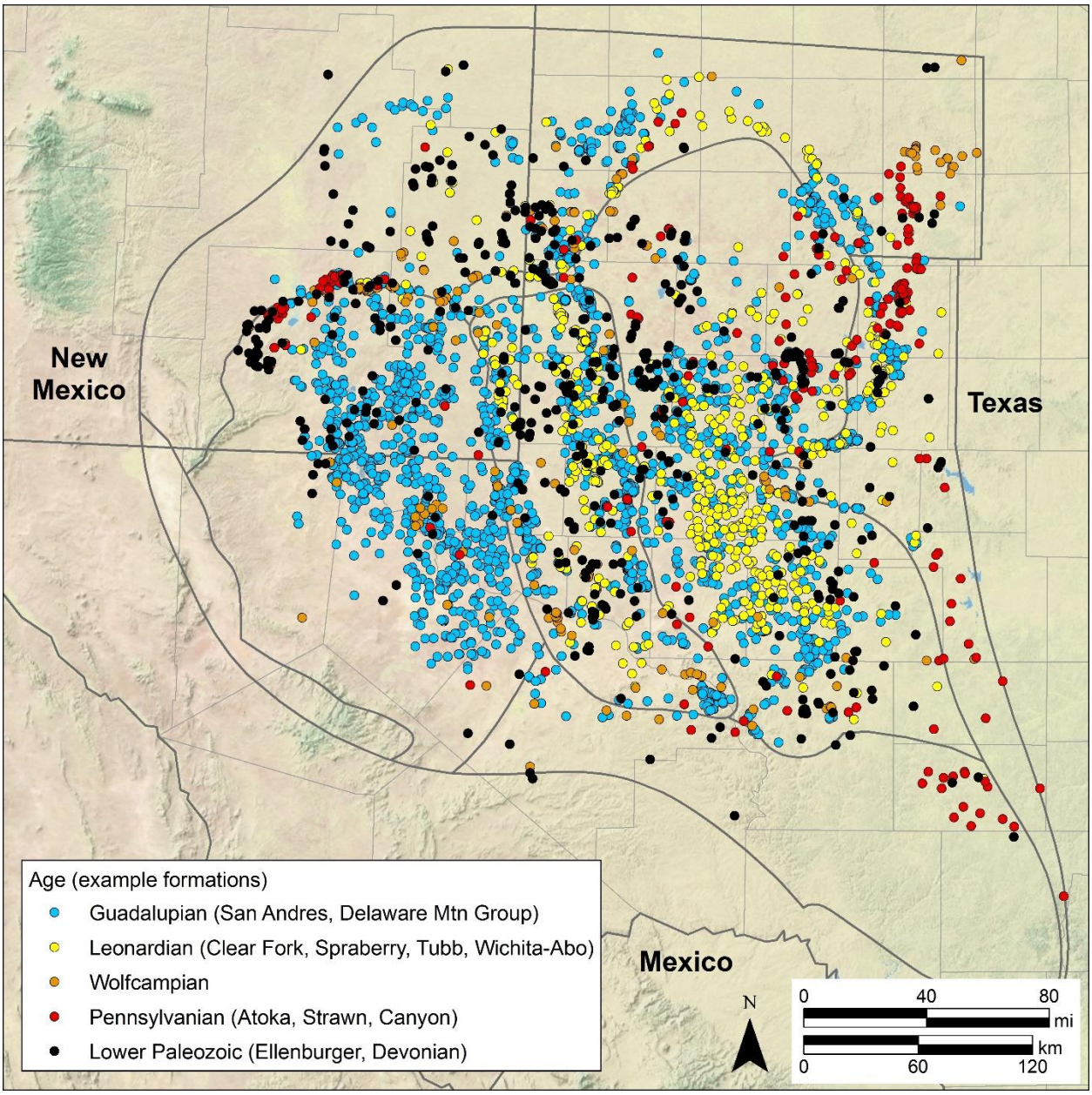

Fig. S28a. Active salt water disposal (SWD) wells in the Permian Basin. Symbols indicate the geologic formation names present at the deepest well perforation depths. With reference to the annual SWD trends shown in Fig. S26c, shallow refers to the Guadalupian age wells (blue), deep refers to the Pennsylvanian (red) and Lower Paleozoic (black) wells, and intermediate refers to the remaining Leonardian (yellow) and Wolfcampian (orange) age wells. Original map image created in ESRI ArcGIS version 10.3.1.

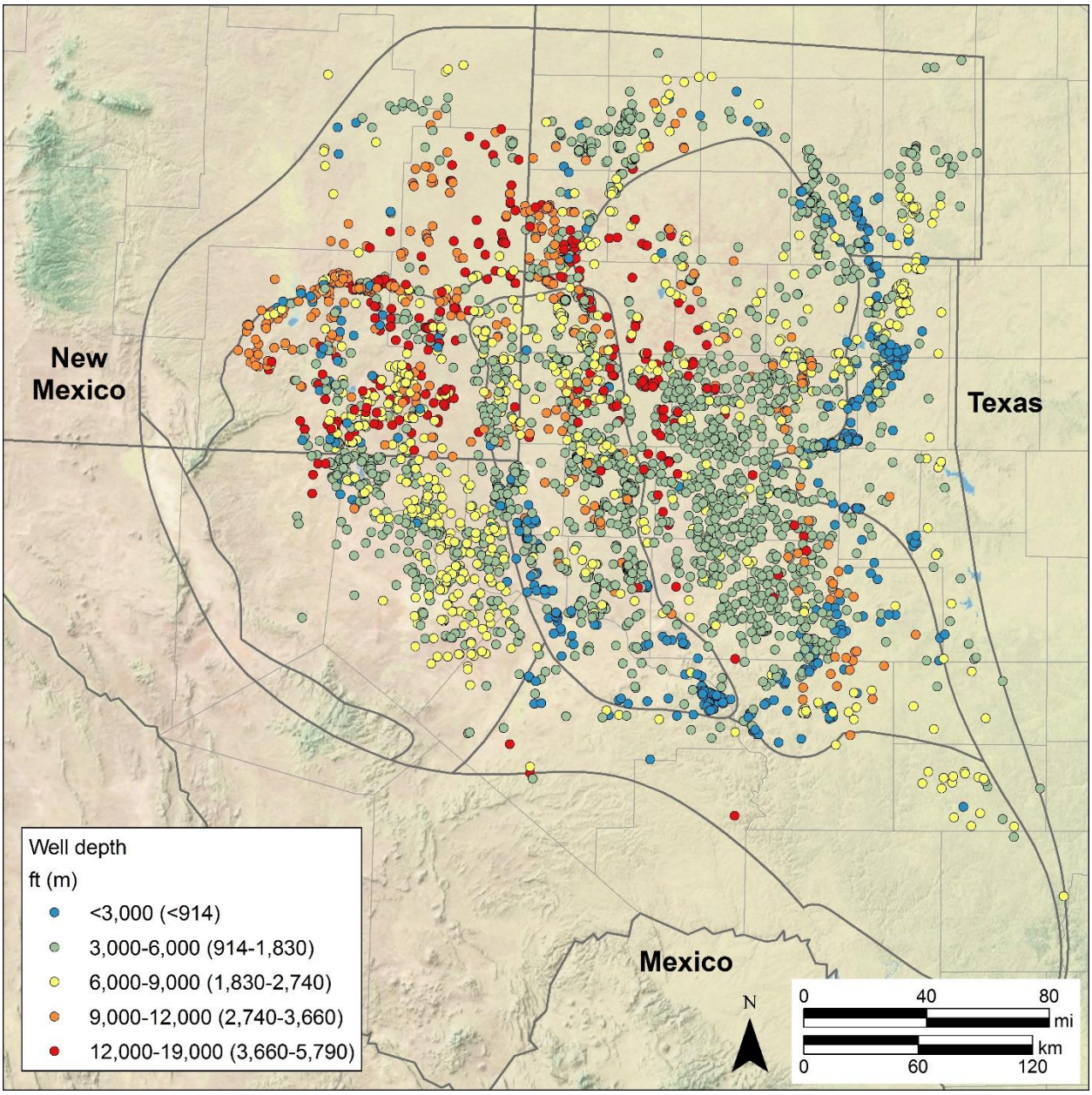

Fig. S28b. Active salt water disposal (SWD) wells in the Permian Basin. Values shown in Texas represent the bottom-most well perforation depth and those in New Mexico represent well total depths. Original map image created in ESRI ArcGIS version 10.3.1.

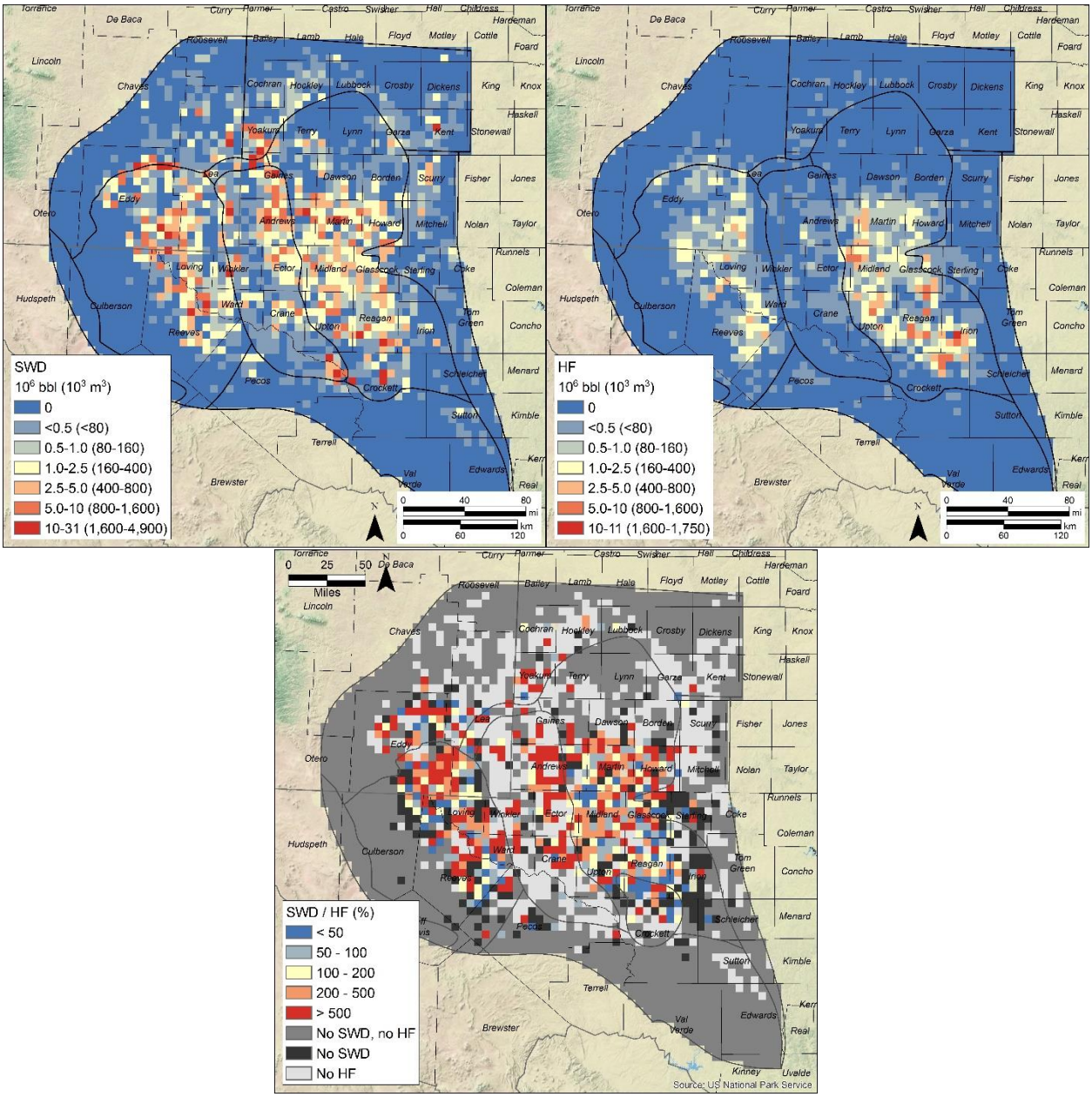

Fig. S29. Salt water disposal (SWD) volumes, water demand for hydraulic fracturing (HF), and the ratio of SWD to HF in 5-mile grid cells based on 2014 data. The ratio of SWD to HF provides information on the potential for SWD volumes meeting HF water requirements. Red color areas show regions where SWD volumes can meet HF water requirements whereas blue areas show regions where there is an SWD deficit to meet HF water demands. Original map images created in ESRI ArcGIS version 10.3.1.

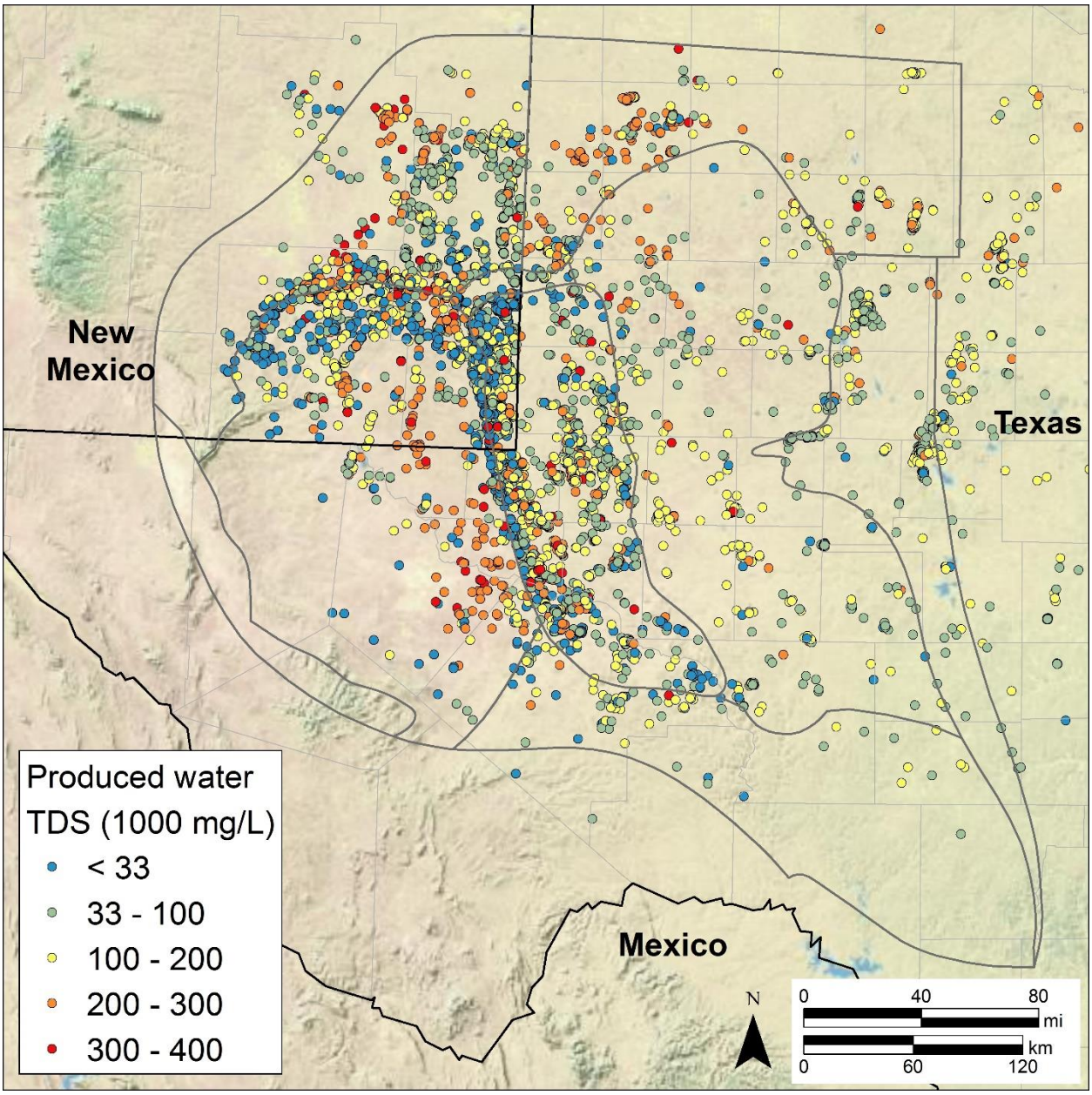

Fig. S30. Distribution of produced water total dissolved solids (TDS) obtained from the USGS produced water database (version 2.2). Original map image created in ESRI ArcGIS version 10.3.1. (Public data available at https://energy.usgs.gov/EnvironmentalAspects/EnvironmentalAspectsofEnergyProductionandUse/ProducedWaters.aspx)

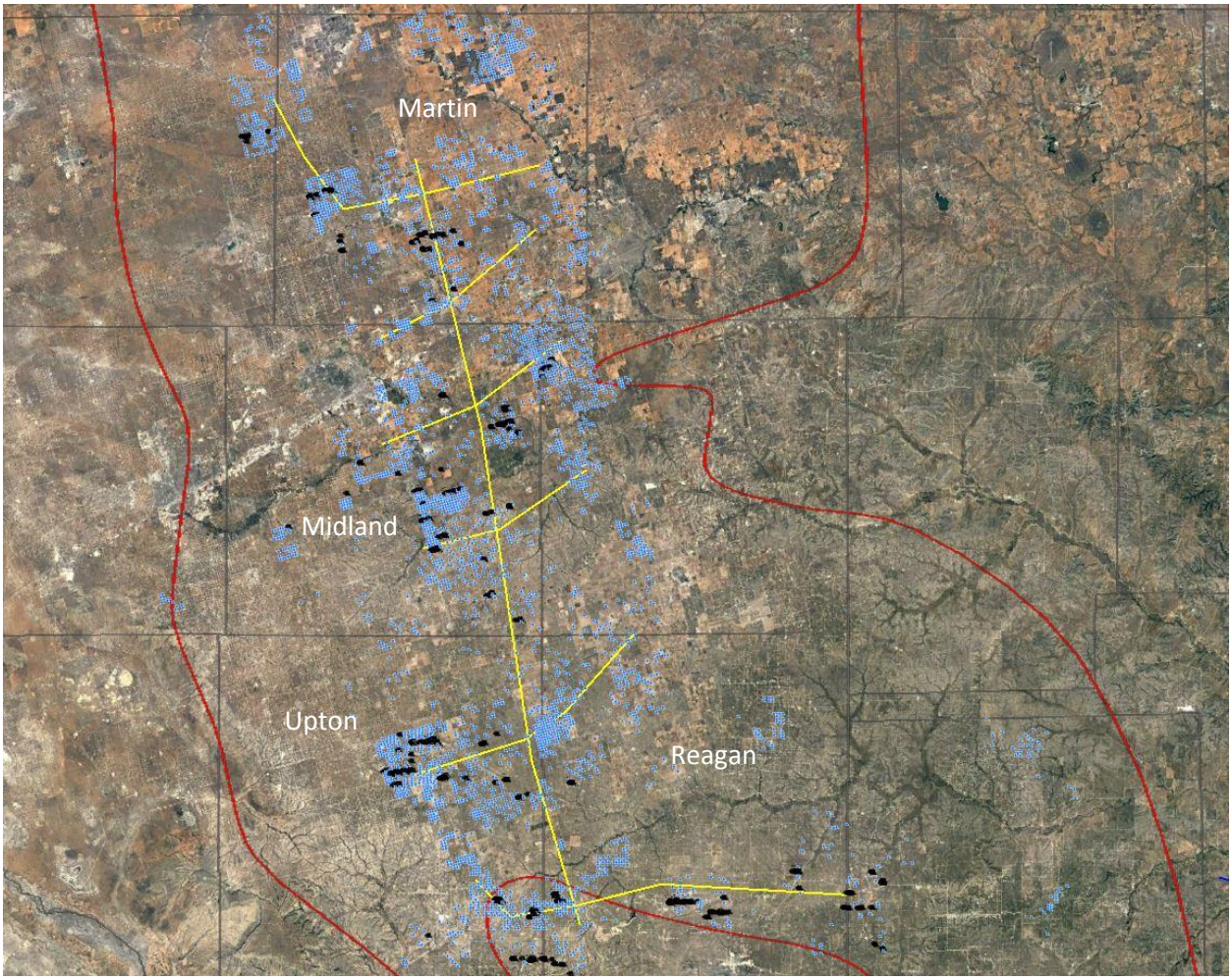

Fig. S31. Schematic of pipeline system being installed by Pioneer Water Management Company. The red outline indicates the boundary for the Midland Basin. Selected county names are shown. Map data provided by Google Earth, Landsat / Copernicus.

Table S1. Selected values for the entire Permian Basin (including Midland, Delaware, Northwestern, Northern, and Eastern regions) whereas Midland and Delaware only refer to these sub-basins (Fig. 1). Values represent medians for the periods indicated unless otherwise noted except for EUR values, which represent means. (/w represents per well values).

Parameter	*Period*	*English units*				*Metric units*			
		Units	*Permian*	*Midland*	*Delaware*	*Units*	*Permian*	*Midland*	*Delaware*
Produced Water									
Total PW	2005-15	10^6 bbl	2,112	386	1,153	10^6 m^3	336	61	183
PW 12-mo	2008	bbl/well		31,392	46,570	m^3/well		4,990	7,403
	2015			66,054	123,831			10,501	19,685
	2008	bbl/ft		5.9	17.1	m^3/m		3.1	8.9
	2015			9.1	25.3			4.7	13.2
PW EUR	2008	bbl/well		280,240	160,515	m^3/well		44,550	25,517
	2015			215,710	412,867			34,291	65,634
	2008	bbl/ft		88.1	65.2	m^3/m		46.0	34.0
	2015			30.5	86.0			15.9	44.9
Oil Production									
Total Oil	2005-15	10^6 bbl	805	230	416	10^6 m^3	128	37	66
Oil 12-mo	2008	bbl/well		14,624	23,127	m^3/well		2,325	3,676
	2015			52,552	64,164			8,354	10,200
	2008	bbl/ft		3.3	7.7	m^3/m		1.7	4.0
	2015			6.9	12.9			3.6	6.7
Oil EUR	2008	bbl/well		84,221	115,724	m^3/well		13,389	18,397
	2015			121,123	155,950			19,255	24,791
	2008	bbl/ft		21.1	47.3	m^3/m		11.0	24.7
	2015			17.4	32.8			9.1	17.1
Completion									
Total HF	2005-15	10^6 bbl	1,371	785	484	10^6 m^3	218	125	77
HF	2008	bbl/well	15,489	15,285	15,187	m^3/well	2,462	2,430	2,414
	2015		184,383	251,091	146,277		29,311	39,916	23,254
	2008	bbl/ft	4.6	3.6	4.6	m^3/m	2.4	1.9	2.4
	2015		32	35	31		16.9	18.4	16.2
Lateral	2008	ft	3,414	3,964	3,295	m	1,041	1,208	1,004
	2015		5,497	7,442	4,490		1,675	2,268	1,368
Gas Production									
Total Gas	2005-15	10^6 boe	516	131	267	10^6 m^3oe	82	21	42
Gas 12-mo	2008	boe/well		58,032	23,127	m^3oe/well		9,225	3,676
	2015			14,712	64,164			2,339	10,200
	2008	boe/ft		12.4	3.9	m^3oe/m		6.4	2.0
	2015			2.0	4.6			1.1	2.4
Gas EUR	2015	boe/well		56,944	103,408	m^3oe/well		9,052	16,439
	2015	boe/ft		25.8	21.1	m^3oe/m		13.4	11.0
Oil & Gas Production									
Total O&G	2005-15	10^6 boe	1,321	361	683	10^6 m^3oe	210	57	109
O&G 12-mo	2008	boe/well		72,656	46,254	m^3oe/well		11,550	7,353
	2015			67,264	128,328			10,693	20,400
	2008	boe/ft		15.7	11.5	m^3oe/m		8.2	6.0
	2015			8.9	17.5			4.6	9.1
O&G EUR	2015	boe/well		178,067	259,359	m^3oe/well		28,307	41,230
	2015	boe/ft		43.1	53.9	m^3oe/m		22.5	28.1

Table S2. Selected ratios between hydraulic fracturing (HF) water use, produced water (PW), produced oil, produced oil and gas (O&G), and estimated ulitmate recovery (EUR) volumes. 12-mo represents the first full 12 month total production. EUR represents estimated 20-yr total production. The Permian Basin column represents the entire Permian Basin and Midland and Delaware basins represent subbasins within the Permian Basin. (mo. is month; EUR is estimated ultimate recovery; O&G is oil and gas, HF is water volume for hydraulic fracturing.

Ratio	*Period*	*Permian Basin*	*Midland Basin*	*Delaware Basin*
HF to Oil Ratio or HF to O&G Ratio				
HF / Oil 12-mo	2005-15	2.5	4.1	1.4
	2008	0.7	1.0	0.4
	2015	3.5	4.7	2.4
HF / Oil EUR	2008	0.2	0.5	0.1
	2015	1.5	2.2	1.0
HF / O&G EUR	2008	0.1	0.4	0.4
	2015	1.0	1.6	0.7
PW to Oil Ratio or PW to O&G				
PW 12-mo / Oil 12-mo	2005-15	1.3	1.6	2.1
	2008	0.5	2.0	1.8
	2015	1.3	1.3	2.2
PW 12-mo / Oil EUR	2008	1.4	3.5	0.9
	2015	1.7	1.3	2.0
PW 12-mo / O&G EUR	2008	0.8	3.0	0.6
	2015	1.2	0.9	1.2
PW to HF Ratio				
PW 12-mo / HF	2005-15	0.8	0.4	1.5
	2008	1.5	1.8	2.7
	2015	0.5	0.3	0.9
PW EUR / HF	2008	7.1	13.0	7.4
	2015	1.1	0.6	1.9

Table S3a. Numbers and types of wells completed in the entire Permian Basin, and enclosed Midland and Delaware basins during the period 2005 – 2015.

Period	*Permian Basin*				*Midland Basin*				*Delaware Basin*			
	All	*Conv.*	*Unconv Vert*	*Unconv Horiz*	*All*	*Conv.*	*Unconv Vert*	*Unconv Horiz*	*All*	*Conv.*	*Unconv Vert*	*Unconv Horiz*
2005	4,815	4,443	293	79	891	623	238	30	586	531	33	22
2006	5,774	5,150	473	151	1,107	687	396	24	600	536	33	31
2007	5,634	4,683	751	200	1,322	682	612	28	526	404	71	51
2008	6,643	5,153	1,241	249	1,950	933	991	26	556	380	74	102
2009	4,258	2,869	1,211	178	1,360	463	881	16	362	202	59	101
2010	6,533	4,152	2,086	295	2,489	878	1,598	13	512	243	89	180
2011	8,530	4,244	3,626	660	3,852	824	2,940	88	797	217	135	445
2012	10,287	4,404	**4,715**	1,168	4,806	637	3,906	263	1,324	310	339	675
2013	9,602	3,885	3,943	1,774	4,372	515	3,234	623	1,400	289	249	862
2014	9,715	3,769	3,183	2,763	4,407	586	2,599	1,222	1,577	216	130	1,231
2015	5,999	1,989	**1,314**	2,696	2,587	281	1,050	1,256	1,404	161	32	1,211
2005-2015	77,790	**44,741**	**22,836**	**10,213**	29,143	7,109	18,445	3,589	9,644	3,489	1,244	4,911

Table S3b. Numbers of unconventional horizontal wells completed in the Permian Basin and in selected sub-regions.

Period	Permian Basin	Midland Basin	Delaware Basin	Central Platform	Northwest Shelf
2005	79	30	22	6	13
2006	151	24	31	18	65
2007	200	28	51	12	92
2008	249	26	102	8	88
2009	178	16	101	2	40
2010	295	13	180	18	70
2011	660	88	445	44	50
2012	1,168	263	675	124	73
2013	1,774	623	862	152	55
2014	2,763	1,222	1,231	152	74
2015	2,696	1,256	1,211	96	101
2005-15	10,213	3,589	4,911	632	721

Table S4a. Permian Basin numbers of conventional and unconventional producing wells during 2005 – 2015.

Period	*All producing wells*	*Conventional wells*			*Unconventional wells*		
		All	*Completed <2005*	*Completed ≥2005*	*All*	*Vertical*	*Horizontal*
2005	**117,655**	115,162	112,058	3,104	2,493	1,969	524
2006	121,655	118,524	112,050	6,474	3,131	2,470	661
2007	124,933	120,749	111,403	9,346	4,184	3,357	827
2008	129,234	123,554	111,045	12,509	5,680	4,624	1,056
2009	130,851	123,995	109,663	14,332	6,856	5,688	1,168
2010	134,357	125,083	108,150	16,933	9,274	7,808	1,466
2011	140,516	126,856	107,392	19,464	13,660	11,537	2,123
2012	147,008	127,380	105,546	21,834	19,628	16,334	3,294
2013	152,650	127,411	103,788	23,623	25,239	20,132	5,107
2014	159,543	128,491	102,982	25,509	31,052	23,183	7,869
2015	**162,029**	**127,581**	**100,948**	26,633	**34,448**	23,869	10,579
% of 2015	100.0	78.7	62.3	16.4	21.3	14.7	6.5
% of category	100.0	100.0	79.1	20.9	100.0	69.3	30.7

Table S4b. Midland Basin numbers of conventional and unconventional producing wells during 2005 – 2015.

Period	*All producing wells*	*Conventional wells*			*Unconventional wells*		
		All	*Completed ≤2004*	*Completed ≥2005*	*All*	*Vertical*	*Horizontal*
2005	24,443	23,164	22,440	724	1,279	1,169	110
2006	25,238	23,544	22,129	1,415	1,694	1,568	126
2007	26,172	23,745	21,674	2,071	2,427	2,281	146
2008	27,633	24,202	21,259	2,943	3,431	3,262	169
2009	28,366	24,204	20,872	3,332	4,162	3,991	171
2010	30,342	24,603	20,499	4,104	5,739	5,563	176
2011	33,556	24,807	20,107	4,700	8,749	8,496	253
2012	37,449	24,588	19,570	5,018	12,861	12,362	499
2013	41,254	24,550	19,274	5,276	16,704	15,582	1,122
2014	44,689	24,425	18,914	5,511	20,264	17,963	2,301
2015	45,545	23,823	18,235	5,588	21,722	18,386	3,336
% of 2015	100.0	52.3	40.0	12.3	47.7	40.4	7.3
% of category	100.0	100.0	76.5	23.5	100.0	84.6	15.4

Table S4c. Delaware Basin numbers of conventional and unconventional producing wells during 2005 – 2015.

Period	*All producing wells*	*Conventional wells*			*Unconventional wells*		
		All	*Completed ≤2004*	*Completed ≥2005*	*All*	*Vertical*	*Horizontal*
2005	10,545	10,336	9,939	397	209	122	87
2006	10,916	10,646	9,849	797	270	155	115
2007	11,328	10,955	9,857	1,098	373	225	148
2008	11,566	11,040	9,706	1,334	526	282	244
2009	11,633	10,987	9,572	1,415	646	319	327
2010	11,844	10,926	9,377	1,549	918	402	516
2011	12,272	10,831	9,201	1,630	1,441	518	923
2012	13,194	10,842	9,034	1,808	2,352	814	1,538
2013	13,922	10,596	8,646	1,950	3,326	981	2,345
2014	15,106	10,606	8,597	2,009	4,500	1,069	3,431
2015	15,915	10,368	8,321	2,047	5,547	1,068	4,479
% of 2015	100.0	65.1	52.3	12.9	34.9	6.7	28.1
% of category	100.0	100.0	80.3	19.7	100.0	19.3	80.7

Table S5a. Permian Basin annual total and conventional annual total oil, gas, and PW volumes for the period 2005 – 2015. Gas values are shown as both produced volumes and as barrels of oil equivalent (boe).

Period	Total					All Conventional				
	Oil	Gas		PW		Oil	Gas		PW	
	10^6 bbl	10^9 ft^3	10^6 boe	10^6 bbl	10^9 gal	10^6 bbl	10^9 ft^3	10^6 boe	10^6 bbl	10^9 gal
2005	316	1,714	296	3,382	142	303	1,589	274	3,335	140
2006	313	1,736	299	3,481	146	298	1,598	275	3,424	144
2007	311	1,752	302	3,508	147	291	1,568	270	3,443	145
2008	321	1,758	303	3,655	153	290	1,513	261	3,562	150
2009	322	1,697	293	3,699	155	279	1,413	244	3,578	150
2010	342	1,307	225	3,827	161	279	1,003	173	3,652	153
2011	377	1,465	253	3,905	164	273	1,091	188	3,619	152
2012	442	1,714	296	4,283	180	275	1,164	201	3,821	160
2013	496	1,871	323	4,659	196	265	1,089	188	4,015	169
2014	594	2,197	379	4,850	204	256	1,046	180	3,955	166
2015	685	2,495	430	4,766	200	236	975	168	3,630	152
2005-2015	**4,520**	19,706	**3,398**	44,014	1,849	**3,045**	14,047	**2,422**	**40,034**	1,681

Table S5b. Metric equivalent to Table S5a. Gas values are shown as both produced volumes and as m^3 of oil equivalent (m^{3}oe).

Period	Total				All Conventional			
	Oil	Gas		PW	Oil	Gas		PW
	10^6 m^3	10^9 m^3	10^6 m^{3}oe	10^6 m^3	10^6 m^3	10^9 m^3	10^6 m^{3}oe	10^6 m^3
2005	50.2	48.5	47.0	537.6	48.1	45.0	43.5	530.2
2006	49.8	49.2	47.6	553.3	47.4	45.2	43.8	544.3
2007	49.5	49.6	48.0	557.7	46.3	44.4	43.0	547.3
2008	51.1	49.8	48.2	581.0	46.2	42.8	41.5	566.3
2009	51.2	48.1	46.5	588.0	44.3	40.0	38.7	568.9
2010	54.4	37.0	35.8	608.4	44.3	28.4	27.5	580.5
2011	60.0	41.5	40.1	620.8	43.5	30.9	29.9	575.4
2012	70.2	48.5	47.0	680.9	43.7	33.0	31.9	607.4
2013	78.9	53.0	51.3	740.7	42.1	30.8	29.9	638.2
2014	94.4	62.2	60.2	770.9	40.7	29.6	28.7	628.7
2015	108.8	70.7	68.4	757.7	37.6	27.6	26.7	577.1
2005-2015	718.6	558.0	540.1	6,997.0	484.1	397.8	385.0	6,364.3

Table S5c. Permian Basin unconventional annual total oil, gas, and PW production for the period 2000 – 2015. Gas values are shown as both produced volumes and as barrels of oil equivalent (boe).

Period	*All Unconventional*				*Unconventional Vertical*				*Unconventional Horizontal*			
	Oil	*Gas*		*PW*	*Oil*	*Gas*		*PW*	*Oil*	*Gas*		*PW*
	10^6 bbl	*10^9 ft^3*	*10^6 boe*	*10^6 bbl*	*10^6 bbl*	*10^9 ft^3*	*10^6 boe*	*10^6 bbl*	*10^6 bbl*	*10^9 ft^3*	*10^6 boe*	*10^6 bbl*
2000	6	41	7	21	5	19	3	15	2	22	4	6
2001	7	66	11	25	5	29	5	16	2	37	6	8
2002	7	83	14	25	5	37	6	16	3	45	8	10
2003	8	92	16	29	5	47	8	17	3	46	8	11
2004	10	99	17	44	6	57	10	32	3	43	7	13
2005	13	125	22	46	9	76	13	32	4	50	9	14
2006	15	138	24	57	10	79	14	40	5	59	10	17
2007	20	184	32	66	15	114	20	48	6	70	12	18
2008	31	245	42	92	23	164	28	68	8	81	14	24
2009	44	285	49	120	33	192	33	90	11	92	16	30
2010	64	304	52	175	48	207	36	130	16	97	17	45
2011	104	374	65	286	73	236	41	198	31	138	24	88
2012	167	550	95	462	105	317	55	295	62	233	40	167
2013	231	781	135	644	120	390	67	329	111	392	68	315
2014	338	1,151	198	895	126	455	78	339	212	695	120	556
2015	448	1,521	262	1,136	108	435	75	299	340	1,085	187	837
2005-2015	**1,475**	5,659	**976**	3,980	**670**	2,665	**459**	**1,868**	805	2,993	516	2,112

Table S5d. Metric equivalent to Table S5c. Gas values are shown as both produced volumes and as m^3 of oil equivalent (m^{3}oe).

Period	*All Unconventional*				*Unconventional Vertical*				*Unconventional Horizontal*			
	Oil	*Gas*		*PW*	*Oil*	*Gas*		*PW*	*Oil*	*Gas*		*PW*
	10^6 m^3	*10^9 m^3*	*10^6 m^{3}oe*	*10^6 m^3*	*10^6 m^3*	*10^9 m^3*	*10^6 m^{3}oe*	*10^6 m^3*	*10^6 m^3*	*10^9 m^3*	*10^6 m^{3}oe*	*10^6 m^3*
2000	1.0	1.2	1.1	3.4	0.7	0.5	0.5	2.5	0.3	0.6	0.6	0.9
2001	1.1	1.9	1.8	3.9	0.7	0.8	0.8	2.6	0.4	1.0	1.0	1.3
2002	1.2	2.3	2.3	4.0	0.8	1.1	1.0	2.5	0.4	1.3	1.2	1.5
2003	1.2	2.6	2.5	4.6	0.8	1.3	1.3	2.8	0.5	1.3	1.3	1.8
2004	1.6	2.8	2.7	7.1	1.0	1.6	1.6	5.1	0.5	1.2	1.2	2.0
2005	2.1	3.5	3.4	7.4	1.4	2.1	2.1	5.1	0.7	1.4	1.4	2.3
2006	2.4	3.9	3.8	9.1	1.6	2.2	2.2	6.4	0.7	1.7	1.6	2.7
2007	3.2	5.2	5.0	10.4	2.3	3.2	3.1	7.6	0.9	2.0	1.9	2.8
2008	4.9	6.9	6.7	14.6	3.7	4.7	4.5	10.8	1.2	2.3	2.2	3.8
2009	6.9	8.1	7.8	19.1	5.2	5.4	5.3	14.3	1.7	2.6	2.5	4.8
2010	10.1	8.6	8.3	27.9	7.6	5.9	5.7	20.6	2.5	2.7	2.7	7.2
2011	16.5	10.6	10.3	45.5	11.6	6.7	6.5	31.4	4.9	3.9	3.8	14.0
2012	26.5	15.6	15.1	73.4	16.7	9.0	8.7	46.8	9.8	6.6	6.4	26.6
2013	36.8	22.1	21.4	102.4	19.1	11.0	10.7	52.4	17.7	11.1	10.7	50.1
2014	53.8	32.6	31.5	142.3	20.1	12.9	12.5	53.9	33.7	19.7	19.1	88.3
2015	71.3	43.1	41.7	180.6	17.2	12.3	11.9	47.6	54.0	30.7	29.8	133.0
2005-2015	234.5	160.2	155.1	632.7	106.6	75.5	73.0	297.0	128.0	84.8	82.0	335.7

Table S6. Permian Basin number of unconventional wells and associated hydraulic fracturing (HF) water use for wells completed during the period 2005 – 2015.

Period	*Unconventional Wells Completed*			*HF water use (10^6 bbl)*			*HF water use (10^6 m^3)*		
	Total	*Vert*	*Horiz*	*Total*	*Vert*	*Horiz*	*Total*	*Vert*	*Horiz*
2005	372	293	79	7	6	1	1.2	1.0	0.2
2006	624	473	151	10	8	3	1.6	1.2	0.4
2007	951	751	200	17	13	4	2.6	2.1	0.6
2008	1,490	1,241	249	29	24	5	4.5	3.8	0.8
2009	1,389	1,211	178	28	23	4	4.4	3.7	0.7
2010	2,381	2,086	295	61	48	13	9.7	7.7	2.0
2011	4,286	3,626	660	131	93	38	20.9	14.7	6.1
2012	5,883	4,715	1,168	231	132	99	36.7	21.0	15.7
2013	5,717	3,943	1,774	338	124	213	53.7	19.7	33.9
2014	5,946	3,183	2,763	550	103	447	87.5	16.4	71.1
2015	**4,010**	1,314	**2,696**	589	45	544	93.6	7.1	86.5
2005-15	33,049	**22,836**	10,213	1,991	619	1,371	316.5	98.5	218.0

Table S7a. Median HF water use (10^3 bbl/well units) for unconventional vertical and horizontal wells in the Permian Basin, Midland Basin, and Delaware Basin.

Period	*Permian Basin*		*Midland Basin*		*Delaware Basin*	
	Vertical	*Horizontal*	*Vertical*	*Horizontal*	*Vertical*	*Horizontal*
2005	15.2	14.3	15.0	20.8	29.2	6.7
2006	12.6	15.0	12.3	15.0	14.9	9.1
2007	15.5	13.4	15.5	14.8	18.0	12.9
2008	17.6	15.5	**18.7**	15.3	16.0	15.2
2009	17.7	18.1	20.7	17.8	15.2	16.6
2010	22.6	30.3	24.1	29.8	23.9	32.1
2011	24.0	41.1	24.9	135.2	24.6	39.3
2012	25.8	55.4	26.1	185.0	28.6	44.2
2013	29.3	90.0	31.0	208.5	21.8	58.2
2014	30.8	154.5	32.6	219.0	17.9	102.3
2015	31.7	184.4	**34.4**	251.1	14.3	146.3
2005-2015	**24.8**	**118.7**	25.8	219.9	22.6	73.5

Table S7b. Metric equivalent to Tables S7a (10^3 m^3/well units)

Period	*Permian Basin*		*Midland Basin*		*Delaware Basin*	
	Vertical	*Horizontal*	*Vertical*	*Horizontal*	*Vertical*	*Horizontal*
2005	2.42	2.27	2.39	3.30	4.63	1.06
2006	2.01	2.38	1.95	2.38	2.38	1.45
2007	2.46	2.14	2.46	2.36	2.86	2.05
2008	2.79	2.46	2.98	2.43	2.55	2.41
2009	2.82	2.88	3.29	2.82	2.42	2.64
2010	3.59	4.82	3.83	4.75	3.80	5.10
2011	3.82	6.54	3.96	21.50	3.91	6.25
2012	4.09	8.81	4.15	29.41	4.55	7.03
2013	4.66	14.31	4.93	33.15	3.46	9.26
2014	4.90	24.57	5.18	34.82	2.85	16.26
2015	5.05	29.31	5.47	39.92	2.28	23.25
2005-2015	**3.93**	**18.87**	4.11	34.95	3.59	11.69

Table S8a. Permian Basin unconventional horizontal well values of mean depth, mean lateral length, and total, mean, and selected percentile values of hydraulic fracturing (HF) water use for wells completed during the period 2005 – 2015.

Period	*Wells*	*Median depth (ft)*	*Median length (ft)*	*Total HF (10^6 bbl)*	*HF (10^3 bbl/well)*				*HF (bbl/ft)*			
					Mean	*5th*	*50th*	*95th*	*Mean*	*5th*	*50th*	*95th*
2005	79	8,003	3,149	1.2	15.8	4.3	14.3	29.1	5.0	1.8	4.5	8.8
2006	151	5,346	3,239	2.5	16.6	3.5	15.0	32.3	5.5	1.9	4.7	9.1
2007	200	4,948	3,273	3.6	17.4	4.5	13.4	43.8	6.0	2.0	4.8	14.2
2008	249	7,814	3,414	4.8	18.7	4.1	15.5	41.7	6.0	1.9	4.6	13.6
2009	178	7,814	3,738	4.3	24.1	7.8	18.1	67.6	7.2	2.5	5.5	20.0
2010	295	8,090	3,975	12.6	43.2	8.5	30.3	108.6	10.6	2.2	7.5	24.1
2011	660	8,304	4,142	38.5	58.7	12.8	41.1	174.8	13.1	3.6	10.2	31.0
2012	1,168	8,114	4,295	98.9	85.7	19.1	55.4	232.5	16.1	4.9	13.3	35.2
2013	1,774	8,172	4,597	213.5	120.8	27.5	90.0	276.2	20.4	6.1	19.4	38.8
2014	2,763	8,766	5,016	447.2	161.8	35.0	154.5	334.0	27.0	8.0	26.7	47.4
2015	2,696	9,279	5,497	544.3	202.6	**50.9**	184.4	**396.8**	32.2	11.5	32.3	54.2
2005-15	10,213	8,603	4,565	1,371.4	138.3	15.2	118.7	334.0	23.4	4.4	22.5	46.0

Table S8b. Metric equivalent to Table S8a.

Period	*Wells*	*Median depth (m)*	*Median length (m)*	*Total HF (10^6 m^3)*	*HF (10^3 m^3/well)*				*HF (m^3/m)*			
					Mean	*5th*	*50th*	*95th*	*Mean*	*5th*	*50th*	*95th*
2005	79	2,439	960	0.19	2.51	0.69	2.27	4.62	2.60	0.96	2.37	4.57
2006	151	1,629	987	0.40	2.64	0.55	2.38	5.13	2.87	1.02	2.44	4.73
2007	200	1,508	998	0.57	2.77	0.71	2.14	6.97	3.15	1.04	2.49	7.42
2008	249	2,382	1,041	0.76	2.97	0.65	2.46	6.63	3.13	1.01	2.39	7.10
2009	178	2,382	1,139	0.69	3.83	1.23	2.88	10.75	3.75	1.29	2.89	10.43
2010	295	2,466	1,212	2.00	6.86	1.35	4.82	17.26	5.51	1.15	3.93	12.54
2011	660	2,531	1,262	6.11	9.33	2.04	6.54	27.79	6.85	1.89	5.35	16.16
2012	1,168	2,473	1,309	15.73	13.62	3.04	8.81	36.97	8.40	2.53	6.92	18.34
2013	1,774	2,491	1,401	33.93	19.21	4.37	14.31	43.91	10.65	3.20	10.10	20.21
2014	2,763	2,672	1,529	71.09	25.73	5.57	24.57	53.10	14.10	4.18	13.95	24.70
2015	2,696	2,828	1,675	86.53	32.21	8.10	29.31	63.08	16.82	6.02	16.87	28.29
2005-15	10,213	2,622	1,391	218.01	21.99	2.41	18.87	53.09	12.20	2.29	11.76	23.98

Table S8c. Midland Basin unconventional horizontal well values of mean depth, mean lateral length, and total, mean, and selected percentile values of hydraulic fracturing (HF) water use for wells completed during the period 2005 – 2015.

Period	*Wells*	*Median depth (ft)*	*Median length (ft)*	*Total HF (10^6 bbl)*	*HF (10^3 bbl/well)*				*HF (bbl/ft)*			
					Mean	*5th*	*50th*	*95th*	*Mean*	*5th*	*50th*	*95th*
2005	30	11,407	3,617	0.5	17.4	5.8	20.8	29.4	5.0	1.8	4.9	8.3
2006	24	11,645	3,818	0.5	18.1	5.8	15.0	33.7	5.0	2.0	4.2	7.5
2007	28	9,795	3,015	0.6	19.2	6.9	14.8	53.2	7.2	2.2	3.6	22.3
2008	26	11,183	3,964	0.6	20.2	3.7	15.3	50.5	5.4	**1.8**	3.6	12.3
2009	16	11,279	3,773	0.3	19.5	8.5	17.8	44.2	5.8	1.7	4.1	14.3
2010	13	7,452	3,654	0.6	37.4	7.0	29.8	131.9	13.0	2.2	9.5	36.1
2011	88	6,618	5,794	11.2	142.7	44.3	135.2	252.7	24.6	8.2	24.1	37.7
2012	263	6,717	7,226	46.4	177.0	39.3	185.0	285.1	26.0	8.5	25.3	41.5
2013	623	7,038	7,480	126.8	205.6	84.2	208.5	316.9	28.2	13.6	28.3	40.7
2014	1,222	8,019	7,335	273.2	225.2	108.5	219.0	362.6	31.8	19.5	30.9	50.2
2015	1,256	8,695	7,442	324.7	260.7	116.7	251.1	423.9	35.2	**19.6**	35.3	53.6
2005-15	3,589	8,041	7,329	785.5	222.9	69.0	219.9	386.4	31.1	12.8	31.0	49.4

Table S8d. Metric equivalent to Table S8c.

Period	*Wells*	*Median depth (m)*	*Median length (m)*	*Total HF (10^6 m)*	*HF (10^3 m^3/well)*				*HF (m^3/m)*			
					Mean	*5th*	*50th*	*95th*	*Mean*	*5th*	*50th*	*95th*
2005	30	3,477	1,102	0.09	2.76	0.92	3.30	4.68	2.60	0.93	2.56	4.34
2006	24	3,549	1,164	0.07	2.88	0.92	2.38	5.36	2.58	1.06	2.17	3.90
2007	28	2,985	919	0.09	3.05	1.10	2.36	8.46	3.74	1.14	1.90	11.61
2008	26	3,408	1,208	0.10	3.20	0.59	2.43	8.03	2.84	0.96	1.88	6.42
2009	16	3,438	1,150	0.05	3.10	1.36	2.82	7.02	3.03	0.87	2.12	7.46
2010	13	2,271	1,114	0.10	5.95	1.11	4.75	20.97	6.79	1.17	4.96	18.80
2011	88	2,017	1,766	1.79	22.68	7.04	21.50	40.17	12.81	4.30	12.56	19.65
2012	263	2,047	2,202	7.37	28.13	6.25	29.41	45.32	13.54	4.42	13.19	21.66
2013	623	2,145	2,280	20.16	32.68	13.39	33.15	50.37	14.71	7.10	14.78	21.21
2014	1,222	2,444	2,236	43.44	35.81	17.26	34.82	57.64	16.58	10.18	16.12	26.20
2015	1,256	2,650	2,268	51.61	41.44	18.56	39.92	67.38	18.38	10.24	18.43	27.95
2005-15	3,589	2,451	2,234	124.87	35.43	10.97	34.95	61.43	16.23	6.68	16.19	25.78

Table S8e. Delaware Basin unconventional horizontal well values of mean depth, mean lateral length, and total, mean, and selected percentile values of hydraulic fracturing (HF) water use for wells completed during the period 2005 – 2015.

Period	*Wells*	*Median depth (ft)*	*Median length (ft)*	*Total HF (10^6 bbl)*	*HF (10^3 bbl/well)*				*HF (bbl/ft)*			
					Mean	*5^{th}*	*50^{th}*	*95^{th}*	*Mean*	*5^{th}*	*50^{th}*	*95^{th}*
2005	22	7,747	2,203	0.2	8.3	4.7	6.7	22.5	4.0	2.3	3.0	7.2
2006	31	7,709	2,555	0.5	16.5	3.5	9.1	77.9	9.8	1.6	5.1	40.5
2007	51	11,304	2,249	0.9	17.5	2.9	12.9	56.6	7.0	1.7	4.9	24.5
2008	102	10,647	3,295	1.8	18.2	5.0	15.2	45.5	6.2	**2.1**	4.6	14.6
2009	101	8,046	3,650	2.5	24.8	8.8	16.6	87.0	7.6	2.6	5.2	20.6
2010	180	8,245	3,984	8.8	49.6	10.8	32.1	136.9	12.4	2.7	8.2	33.4
2011	445	8,841	4,098	21.7	48.4	19.3	39.3	98.8	11.7	4.7	9.7	23.0
2012	675	9,174	4,203	38.7	56.4	25.4	44.2	120.2	13.1	5.8	10.2	28.0
2013	862	9,488	4,303	62.4	71.8	28.4	58.2	167.3	16.0	6.2	13.3	36.1
2014	1,231	10,377	4,386	145.8	117.7	34.7	102.3	262.7	24.5	8.0	22.4	45.6
2015	1,211	10,432	4,490	200.2	165.0	57.1	146.3	355.6	32.0	**12.3**	31.1	58.4
2005-15	4,911	9,877	4,293	483.6	98.9	18.4	73.5	249.9	20.9	4.9	16.8	44.6

Table S8f. Metric equivalent to Table S8e.

Period	*Wells*	*Median depth (m)*	*Median length (m)*	*Total HF (10^6 m)*	*HF (10^3 m^3/well)*				*HF (m^3/m)*			
					Mean	*5^{th}*	*50^{th}*	*95^{th}*	*Mean*	*5^{th}*	*50^{th}*	*95^{th}*
2005	22	2,361	671	0.03	1.32	0.74	1.06	3.57	2.10	1.20	1.57	3.73
2006	31	2,350	779	0.08	2.63	0.56	1.45	12.38	5.14	0.86	2.65	21.13
2007	51	3,445	686	0.14	2.79	0.46	2.05	9.00	3.66	0.88	2.54	12.75
2008	102	3,245	1,004	0.29	2.89	0.80	2.41	7.24	3.24	1.11	2.39	7.63
2009	101	2,452	1,112	0.40	3.95	1.40	2.64	13.83	3.96	1.37	2.72	10.76
2010	180	2,513	1,214	1.39	7.88	1.72	5.10	21.76	6.46	1.41	4.30	17.41
2011	445	2,695	1,249	3.45	7.69	3.07	6.25	15.70	6.11	2.45	5.07	12.02
2012	675	2,796	1,281	6.16	8.97	4.04	7.03	19.11	6.84	3.03	5.33	14.58
2013	862	2,892	1,311	9.93	11.41	4.51	9.26	26.59	8.33	3.22	6.92	18.85
2014	1,231	3,163	1,337	23.18	18.70	5.52	16.26	41.76	12.79	4.18	11.69	23.81
2015	1,211	3,180	1,368	31.82	26.23	9.08	23.25	56.53	16.71	6.44	16.21	30.48
2005-15	4,911	3,011	1,308	76.87	15.72	2.92	11.69	39.72	10.90	2.55	8.74	23.27

Table S9a. **Permian Basin proppant loading** mean and selected percentile values in unconventional wells completed during the period 2005 – 2015.

Period	*Verticals (lb/gal)*				*Horizontals (lb/gal)*				*Horizontals (lb/ft)*			
	Mean	*5th*	*50th*	*95th*	*Mean*	*5th*	*50th*	*95th*	*Mean*	*5th*	*50th*	*95th*
2005	0.66	0.07	0.67	1.43	0.87	0.32	0.62	2.87	141	14	112	321
2006	0.60	0.07	0.58	1.33	0.68	0.08	0.49	1.41	131	13	113	331
2007	0.86	0.13	0.74	1.60	0.74	0.10	0.62	1.75	159	12	136	373
2008	0.79	0.04	0.69	1.93	0.89	0.15	0.72	1.83	186	15	**151**	517
2009	0.70	0.07	0.67	1.61	1.02	0.24	0.96	1.99	268	15	217	784
2010	0.67	0.10	0.65	1.37	1.06	0.30	0.95	2.35	373	63	313	888
2011	0.62	0.09	0.62	1.32	1.05	0.38	1.09	1.66	526	94	414	1,151
2012	0.55	0.08	0.58	1.10	1.05	0.38	1.06	1.64	640	128	548	1,265
2013	0.62	0.08	0.65	1.14	0.98	0.35	0.99	1.56	763	176	717	1,484
2014	0.65	0.06	0.68	1.18	1.03	0.51	1.01	1.58	1,097	272	1,097	1,979
2015	0.77	0.20	0.67	1.54	1.07	0.58	**1.00**	1.92	1,336	388	**1,333**	2,159
2005-15	0.65	0.07	0.65	1.33	1.03	0.40	1.00	1.65	921	101	915	1,936

Table S9b. Metric equivalent to Table S9a.

Period	*Verticals (kg/L)*				*Horizontals (kg/L)*				*Horizontals (kg/m)*			
	Mean	*5th*	*50th*	*95th*	*Mean*	*5th*	*50th*	*95th*	*Mean*	*5th*	*50th*	*95th*
2005	0.08	0.01	0.08	0.17	0.10	0.04	0.07	0.35	211	21	167	478
2006	0.07	0.01	0.07	0.16	0.08	0.01	0.06	0.17	196	20	168	493
2007	0.10	0.02	0.09	0.19	0.09	0.01	0.07	0.21	238	18	203	556
2008	0.09	0.00	0.08	0.23	0.11	0.02	0.09	0.22	278	22	**225**	771
2009	0.08	0.01	0.08	0.19	0.12	0.03	0.12	0.24	400	23	324	1,169
2010	0.08	0.01	0.08	0.16	0.13	0.04	0.11	0.28	556	95	467	1,324
2011	0.07	0.01	0.07	0.16	0.13	0.05	0.13	0.20	785	140	617	1,717
2012	0.07	0.01	0.07	0.13	0.13	0.05	0.13	0.20	955	191	818	1,886
2013	0.07	0.01	0.08	0.14	0.12	0.04	0.12	0.19	1,137	262	1,070	2,213
2014	0.08	0.01	0.08	0.14	0.12	0.06	0.12	0.19	1,637	406	1,636	2,951
2015	0.09	0.02	0.08	0.18	0.13	0.07	**0.12**	0.23	1,992	578	**1,988**	3,220
2005-15	0.08	0.01	0.08	0.16	0.12	0.05	0.12	0.20	1,373	151	1,365	2,887

Table S9c. Midland Basin proppant loading mean and selected percentile values in unconventional wells completed during the period 2005 – 2015.

Period	*Verticals (lb/gal)*				*Horizontals (lb/gal)*				*Horizontals (lb/ft)*			
	Mean	*5th*	*50th*	*95th*	*Mean*	*5th*	*50th*	*95th*	*Mean*	*5th*	*50th*	*95th*
2005	0.70	0.10	0.69	1.42	0.62	0.31	0.46	1.41	110	52	104	190
2006	0.62	0.10	0.61	1.33	0.63	0.14	0.47	1.18	123	44	126	184
2007	0.84	0.13	0.75	1.41	0.83	0.26	0.87	1.55	144	20	121	193
2008	0.67	0.03	0.68	1.22	0.95	0.49	0.89	1.62	153	12	**133**	251
2009	0.62	0.07	0.66	1.08	0.88	0.36	0.78	1.84	171	45	135	371
2010	0.64	0.10	0.66	1.14	1.02	0.30	0.83	2.13	415	80	127	972
2011	0.63	0.09	0.63	1.25	0.96	0.52	0.89	1.55	932	68	954	1,268
2012	0.57	0.09	0.61	1.09	0.98	0.45	0.87	1.44	988	251	1,074	1,325
2013	0.61	0.08	0.66	1.09	0.92	0.52	0.93	1.28	1,080	380	1,098	1,673
2014	0.64	0.05	0.69	1.14	1.01	0.60	0.98	1.47	1,287	654	1,183	2,122
2015	0.75	0.27	0.67	1.27	1.01	0.60	**0.95**	1.54	1,408	882	**1,317**	2,213
2005-15	0.64	0.08	0.66	1.21	0.98	0.54	0.95	1.47	1,237	216	1,166	2,057

Table S9d. Metric equivalent to Table S9c.

Period	*Verticals (kg/L)*				*Horizontals (kg/L)*				*Horizontals (kg/m)*			
	Mean	*5th*	*50th*	*95th*	*Mean*	*5th*	*50th*	*95th*	*Mean*	*5th*	*50th*	*95th*
2005	0.08	0.01	0.08	0.17	0.07	0.04	0.06	0.08	164	77	155	284
2006	0.07	0.01	0.07	0.16	0.08	0.02	0.06	0.07	183	66	188	274
2007	0.10	0.02	0.09	0.17	0.10	0.03	0.10	0.10	214	30	180	288
2008	0.08	0.00	0.08	0.15	0.11	0.06	0.11	0.08	227	17	**198**	374
2009	0.07	0.01	0.08	0.13	0.11	0.04	0.09	0.07	254	67	201	554
2010	0.08	0.01	0.08	0.14	0.12	0.04	0.10	0.08	618	119	190	1,450
2011	0.08	0.01	0.08	0.15	0.12	0.06	0.11	0.08	1,390	102	1,423	1,891
2012	0.07	0.01	0.07	0.13	0.12	0.05	0.10	0.07	1,473	375	1,602	1,976
2013	0.07	0.01	0.08	0.13	0.11	0.06	0.11	0.07	1,611	567	1,637	2,495
2014	0.08	0.01	0.08	0.14	0.12	0.07	0.12	0.08	1,919	975	1,765	3,165
2015	0.09	0.03	0.08	0.15	0.12	0.07	**0.11**	0.09	2,100	1,315	**1,964**	3,300
2005-15	0.08	0.01	0.08	0.15	0.12	0.07	0.11	0.08	1,844	322	1,738	3,068

Table S9e. Delaware Basin proppant loading mean and selected percentile values in unconventional wells completed during the period 2005 – 2015.

Period	*Verticals (lb/gal)*				*Horizontals (lb/gal)*				*Horizontals (lb/ft)*			
	Mean	*5th*	*50th*	*95th*	*Mean*	*5th*	*50th*	*95th*	*Mean*	*5th*	*50th*	*95th*
2005	0.25	0.05	0.16	0.89	1.58	0.37	1.22	3.14	203	14	147	322
2006	0.36	0.02	0.25	1.21	0.94	0.10	1.15	1.40	159	60	153	237
2007	0.55	0.04	0.41	1.91	1.03	0.53	0.92	1.76	261	22	204	650
2008	0.34	0.03	0.15	0.97	1.12	0.48	1.06	1.85	260	19	**188**	620
2009	0.45	0.03	0.06	1.94	1.15	0.51	1.11	2.13	322	15	253	805
2010	0.43	0.05	0.18	1.30	1.14	0.40	1.03	2.33	448	120	380	920
2011	0.56	0.01	0.27	1.53	1.13	0.46	1.17	1.69	523	166	432	1,094
2012	0.43	0.05	0.23	1.05	1.15	0.47	1.16	1.70	576	181	508	1,109
2013	0.68	0.11	0.74	1.47	1.09	0.32	1.16	1.62	628	182	584	1,206
2014	0.95	0.16	0.94	2.23	1.08	0.52	1.09	1.60	1,008	329	969	1,803
2015	0.74	0.31	0.77	1.06	1.12	0.60	**1.06**	1.81	1,391	512	**1,445**	2,170
2005-15	0.55	0.04	0.38	1.49	1.11	0.47	1.10	1.69	873	150	740	1,792

Table S9f. Metric equivalent to Table S9e.

Period	*Verticals (kg/L)*				*Horizontals (kg/L)*				*Horizontals (kg/m)*			
	Mean	*5th*	*50th*	*95th*	*Mean*	*5th*	*50th*	*95th*	*Mean*	*5th*	*50th*	*95th*
2005	0.03	0.01	0.02	0.11	0.19	0.04	0.15	0.03	303	20	220	481
2006	0.04	0.00	0.03	0.15	0.11	0.01	0.14	0.04	238	90	228	353
2007	0.07	0.00	0.05	0.23	0.12	0.06	0.11	0.07	389	33	304	969
2008	0.04	0.00	0.02	0.12	0.13	0.06	0.13	0.04	387	28	**281**	924
2009	0.05	0.00	0.01	0.23	0.14	0.06	0.13	0.05	480	22	377	1,201
2010	0.05	0.01	0.02	0.16	0.14	0.05	0.12	0.05	668	180	567	1,372
2011	0.07	0.00	0.03	0.18	0.14	0.05	0.14	0.07	780	247	644	1,632
2012	0.05	0.01	0.03	0.13	0.14	0.06	0.14	0.05	859	270	757	1,655
2013	0.08	0.01	0.09	0.18	0.13	0.04	0.14	0.08	936	272	872	1,799
2014	0.11	0.02	0.11	0.27	0.13	0.06	0.13	0.11	1,503	491	1,445	2,689
2015	0.09	0.04	0.09	0.13	0.13	0.07	**0.13**	0.09	2,074	764	**2,154**	3,236
2005-15	0.07	0.01	0.05	0.18	0.13	0.06	0.13	0.07	1,302	224	1,104	2,672

Table S10a. Permian Basin numbers of **hydraulic fracturing stages** and stage lengths through time for unconventional horizontal wells completed during the period 2005 – 2015.

Year	*Permian Basin*						
	Data Count	*Number of Stages*		*Stage Length (ft)*		*Stage Length (m)*	
		Mean	*Median*	*Mean*	*Median*	*Mean*	*Median*
2005	39	4	2	851	703	259	214
2006	64	4	3	760	684	232	209
2007	90	3	4	733	671	224	205
2008	143	4	**4**	684	**639**	208	195
2009	118	6	5	531	507	162	154
2010	198	8	7	417	396	127	121
2011	333	10	8	482	404	147	123
2012	447	15	11	373	277	114	84
2013	740	18	16	350	242	107	74
2014	919	21	19	329	242	100	74
2015	774	22	**18**	306	**264**	93	80

Table S10b. Midland Basin numbers of hydraulic fracturing stages and stage lengths through time for unconventional horizontal wells completed during the period 2005 – 2015.

Year	*Midland Basin*						
	Data Count	*Number of Stages*		*Stage Length (ft)*		*Stage Length (m)*	
		Mean	*Median*	*Mean*	*Median*	*Mean*	*Median*
2005	16	5	3	806	696	246	212
2006	6	2	2	1,065	1,127	325	343
2007	13	2	2	856	878	261	267
2008	16	3	**2**	1,113	1,058	339	322
2009	9	4	3	728	507	222	155
2010	5	5	5	502	477	153	145
2011	36	17	15	273	223	83	68
2012	139	26	27	239	187	73	57
2013	280	28	30	298	199	91	61
2014	356	29	30	262	195	80	59
2015	191	35	**33**	301	**184**	92	**56**

Table S10c. Delaware Basin numbers of hydraulic fracturing stages and stage lengths through time for unconventional horizontal wells completed during the period 2005 – 2015.

Year	*Delaware Basin*						
	Data Count	*Number of Stages*		*Stage Length (ft)*		*Stage Length (m)*	
		Mean	*Median*	*Mean*	*Median*	*Mean*	*Median*
2005	11	2	2	1,039	843	317	257
2006	8	3	3	626	403	191	123
2007	13	3	3	996	1,063	304	324
2008	50	5	**4**	605	437	185	133
2009	69	6	5	497	505	152	154
2010	129	8	7	429	419	131	128
2011	245	9	7	526	449	160	137
2012	249	10	8	482	407	147	124
2013	354	13	11	391	322	119	98
2014	423	16	15	352	273	107	83
2015	437	19	**16**	284	**269**	87	**82**

Table S11a. Permian, Midland, and Delaware basin total water use and water use by category (10^9 gal units) based on historical county level water use (TWDB). Categories include Total (Tot), Irrigation (Irr), Municipal (Mun), Other (Oth), and Hydraulic Fracturing (HF). Other consists of combined manufacturing, steam electric, and livestock. HF was substituted for the mining category. Data were obtained from the Texas Water Development Board (http://www.twdb.texas.gov/).

Period	*Permian*					*Midland Basin*					*Delaware Basin*				
	Tot	*Irr*	*Mun*	*Oth*	*HF*	*Tot*	*Irr*	*Mun*	*Oth*	*HF*	*Tot*	*Irr*	*Mun*	*Oth*	*HF*
2000	1,150	1,058	70	22	0.18	209	191	15	2	0	42	37	2	2	0
2001	1,157	1,068	67	22	0.15	193	175	16	2	0	39	34	3	2	0
2002	1,153	1,066	65	22	0.12	193	175	16	2	0	35	29	4	2	0
2003	1,082	995	67	20	0.16	174	157	16	2	0	23	19	2	2	0
2004	1,091	961	61	68	0.18	150	134	14	2	0	41	37	3	1	0
2005	815	733	63	18	0.31	152	134	15	2	0	42	38	2	1	0
2006	899	812	66	21	0.43	175	158	15	2	0	42	37	3	2	0
2007	1,144	1,068	57	18	0.69	143	126	14	2	0	36	32	2	2	0
2008	1,204	1,121	60	22	1.20	191	174	15	2	0	24	21	2	1	0
2009	1,052	968	61	21	1.16	193	177	14	2	0	37	33	2	1	0
2010	800	718	60	19	2.56	150	136	12	2	0	38	34	2	1	0
2011	1,105	1,008	73	18	5.52	224	206	16	2	0	34	31	2	0	1
2012	1,059	971	61	17	9.71	178	164	11	1	2	40	36	2	0	2
2013	995	902	61	18	14.20	197	178	11	1	5	39	34	2	0	3
2014	845	745	61	16	23.21	170	143	14	1	12	37	28	2	0	6
2015					24.79										
’05–‘15					84.57										

Table S11b. Metric equivalent to Table S11a (10^6 m^3 units).

Period	*Permian*					*Midland Basin*					*Delaware Basin*				
	Tot	*Irr*	*Mun*	*Oth*	*HF*	*Tot*	*Irr*	*Mun*	*Oth*	*HF*	*Tot*	*Irr*	*Mun*	*Oth*	*HF*
2000	4,351	4,004	264	82	1.2	791	724	58	8	0.1	158	140	9	9	0.1
2001	4,379	4,042	254	82	1.3	731	663	60	7	0.0	146	128	9	9	0.0
2002	4,364	4,034	247	82	1.0	730	662	60	7	0.0	134	110	15	9	0.1
2003	4,096	3,766	252	77	1.5	660	593	61	6	0.1	86	70	9	7	0.0
2004	4,129	3,638	232	257	1.5	568	508	54	6	0.1	154	139	11	5	0.0
2005	3,085	2,773	239	69	2.3	574	509	57	8	0.1	158	145	9	5	0.0
2006	3,402	3,072	249	79	3.0	661	598	56	6	0.1	157	141	11	6	0.1
2007	4,332	4,044	215	69	3.8	540	479	53	8	0.1	137	122	8	6	0.1
2008	4,557	4,244	225	82	6.1	722	658	56	8	0.1	92	78	9	5	0.3
2009	3,982	3,666	233	79	5.2	731	668	55	7	0.1	140	126	9	5	0.4
2010	3,028	2,716	227	74	10.8	568	514	47	7	0.1	145	130	9	4	1.5
2011	4,184	3,815	278	69	22.1	848	781	59	6	1.8	130	116	9	1	3.6
2012	4,009	3,675	231	66	38.1	676	622	42	5	7.4	152	136	9	1	6.3
2013	3,767	3,415	229	68	54.9	744	675	43	5	20.3	148	128	9	1	10.1
2014	3,200	2,819	230	61	89.0	644	542	53	5	43.6	140	106	9	1	23.4
2015					93.8										
’05–‘15					320.1										

Table S12a. **Midland Basin** first **12 months of produced oil, gas, and water** (PW) for unconventional horizontal wells for the period 2005 – 2015. Values are shown as total volumes per well and total volumes normalized by lateral length. Values for 2005 represent those for wells completed in that year and so forth. Gas values are expressed as either barrels of oil equivalent (boe).

Completion Period	*Wells*	*Median Length (ft)*	*Median Oil (bbl/well)*	*Median Gas (boe/well)*	*Median PW*		*Median Oil (bbl/ft)*	*Median Gas (boe/ft)*	*Median PW (bbl/ft)*
					(bbl/well)	*(10^6 gal/well)*			
2005	35	3,617	23,823	42,460	57,846	2.43	5.2	11.8	14.4
2006	19	3,818	22,759	84,006	38,840	1.63	5.1	24.0	10.7
2007	29	3,015	14,612	8,866	18,657	0.78	3.3	1.9	5.2
2008	28	3,964	14,624	58,032	31,392	1.32	3.3	12.4	5.9
2009	16	3,773	14,164	40,015	36,732	1.54	3.4	11.9	9.0
2010	16	3,654	25,194	19,701	42,392	1.78	6.1	4.4	14.1
2011	94	5,794	34,864	19,460	46,726	1.96	6.9	3.6	9.4
2012	301	7,226	43,028	20,410	66,369	2.79	5.7	2.7	9.2
2013	657	7,480	47,312	20,281	88,182	3.70	6.3	2.7	11.7
2014	1,233	7,335	61,207	21,522	91,216	3.83	8.3	3.0	12.5
2015	1,245	7,442	52,552	14,712	66,054	**2.77**	6.9	2.0	**9.1**
2005-2015	3,673	7,329	50,963	18,403	77,430	3.25	**7.0**	2.6	10.7

Table S12b. Metric equivalent to Table S12a. Gas values are expressed as m^3 of oil equivalent (m^3oe).

Completion Period	*Wells*	*Median Length (m)*	*Median Oil (10^3 m^3/well)*	*Median Gas (10^3 m^3oe/well)*	*Median PW (10^3 m^3/well)*	*Median Oil (m^3/m)*	*Median Gas (m^3oe/m)*	*Median PW (m^3/m)*
2005	35	1,102	3.79	6.75	9.20	2.73	6.15	7.50
2006	19	1,164	3.62	13.35	6.17	2.66	12.50	5.56
2007	29	919	2.32	1.41	2.97	1.70	1.00	2.70
2008	28	1,208	2.32	9.23	4.99	1.74	6.45	3.09
2009	16	1,150	2.25	6.36	5.84	1.78	6.23	4.69
2010	16	1,114	4.01	3.13	6.74	3.18	2.30	7.34
2011	94	1,766	5.54	3.09	7.43	3.58	1.88	4.93
2012	301	2,202	6.84	3.24	10.55	2.95	1.42	4.82
2013	657	2,280	7.52	3.22	14.02	3.26	1.42	6.08
2014	1,233	2,236	9.73	3.42	14.50	4.32	1.56	6.51
2015	1,245	2,268	8.35	2.34	10.50	3.58	1.05	4.74
2005-2015	3,673	2,234	8.10	2.93	12.31	3.65	1.34	5.58

Table S12c. **Delaware Basin** first 12 months of produced oil, gas, and water (PW) for unconventional horizontal wells for the period 2005 – 2015. Values are shown as total volumes per well and total volumes normalized by lateral length. Values for 2005 represent those for wells completed in that year and so forth. Gas values are expressed as either barrels of oil equivalent (boe).

Completion Period	*Wells*	*Median Length (ft)*	*Median Oil (bbl/well)*	*Median Gas (boe/well)*	*Median PW*		*Median Oil (bbl/ft)*	*Median Gas (boe/ft)*	*Median PW (bbl/ft)*
					(bbl/well)	*(10^6 gal/well)*			
2005	25	2,203	18,631	7,045	3,638	0.15	9.4	2.7	1.6
2006	31	2,555	23,832	7,563	24,677	1.04	9.4	2.9	10.6
2007	55	2,249	21,990	6,685	27,518	1.16	9.5	2.6	13.8
2008	102	3,295	23,127	10,734	46,570	1.96	7.7	3.9	17.1
2009	99	3,650	30,217	10,681	47,122	1.98	9.5	3.4	**13.9**
2010	188	3,984	42,401	25,276	84,273	3.54	10.6	5.9	22.6
2011	451	4,098	34,914	20,255	87,307	3.67	8.6	4.7	22.0
2012	689	4,203	46,770	24,395	107,409	4.51	10.7	5.6	24.4
2013	865	4,303	56,794	24,731	115,525	4.85	12.7	5.4	25.7
2014	1,242	4,386	79,768	31,376	155,097	6.51	16.5	6.4	**33.4**
2015	1,189	4,490	64,164	23,144	123,831	**5.20**	12.9	4.6	**25.3**
2005-2015	4,936	4,293	57,150	24,105	115,274	4.84	**12.7**	5.3	25.9

Table S12d. Metric equivalent to Table S12c. Gas values are expressed as m^3 of oil equivalent (m^3oe).

Completion Period	*Wells*	*Median Length (m)*	*Median Oil (10^3 m^3/well)*	*Median Gas (10^3 m^3oe/well)*	*Median PW (10^3 m^3/well)*	*Median Oil (m^3/m)*	*Median Gas (m^3oe/m)*	*Median PW (m^3/m)*
2005	25	671	2.96	1.12	0.58	4.91	1.40	0.86
2006	31	779	3.79	1.20	3.92	4.91	1.52	5.53
2007	55	686	3.50	1.06	4.37	4.93	1.37	7.18
2008	102	1,004	3.68	1.71	7.40	4.00	2.02	8.94
2009	99	1,112	4.80	1.70	7.49	4.93	1.79	7.27
2010	188	1,214	6.74	4.02	13.40	5.53	3.09	11.76
2011	451	1,249	5.55	3.22	13.88	4.50	2.43	11.46
2012	689	1,281	7.44	3.88	17.07	5.58	2.91	12.75
2013	865	1,311	9.03	3.93	18.37	6.63	2.80	13.41
2014	1,242	1,337	12.68	4.99	24.66	8.62	3.32	17.43
2015	1,189	1,368	10.20	3.68	19.69	6.72	2.40	13.17
2005-2015	4,936	1,308	9.09	3.83	18.33	6.63	2.77	13.50

Table S13a. **Midland Basin** estimated ultimate recovery (**EUR**) for oil, gas, and water (PW) from unconventional horizontal wells for the period 2005 – 2015. Values represent 20-year estimates and are shown as total volumes per well and total volumes normalized by lateral length. Values for 2005 represent those for wells completed in that year and so forth. Gas values are expressed as either barrels of oil equivalent (boe).

Period	*Wells*	*Mean Oil (bbl/well)*	*Mean Gas (boe/well)*	*Mean PW (bbl/well)*	*Mean Oil (bbl/ft)*	*Mean Gas (boe/ft)*	*Mean PW (bbl/ft)*
2005	25	112,288	151,256	82,783	31.4	72.1	23.2
2006	20	93,930	106,925	117,858	28.7	67.6	42.1
2007	27	108,062	23,923	255,406	38.3	46.1	91.8
2008	25	84,221	32,281	280,240	21.1	30.6	88.1
2009	13	127,147	24,987	155,824	33.9	40.4	42.9
2010	13	119,922	35,161	170,372	40.6	50.0	50.7
2011	83	117,850	34,198	582,073	24.3	32.6	137.7
2012	255	101,824	43,619	441,598	15.6	22.4	80.4
2013	615	88,690	84,384	284,455	13.0	25.5	43.5
2014	1,200	96,850	90,426	216,186	14.3	28.1	31.3
2015	1,247	121,123	56,944	215,710	17.4	25.8	**30.5**

Table S13b. Metric equivalent to Table S13a. Gas values are expressed as m^3 of oil equivalent (m^3oe)

Completion Period	*Wells*	*Mean Oil (10^3 m^3/well)*	*Mean Gas (10^3 m^3oe/well)*	*Mean PW (10^3 m^3/well)*	*Mean Oil (m^3/m)*	*Mean Gas (m^3oe/m)*	*Mean PW (m^3/m)*
2005	25	17.85	24.05	13.16	16.40	37.62	12.08
2006	20	14.93	17.00	18.74	14.98	35.26	21.95
2007	27	17.18	3.80	40.60	19.99	24.06	47.89
2008	25	13.39	5.13	44.55	11.00	15.98	45.96
2009	13	20.21	3.97	24.77	17.67	21.08	22.35
2010	13	19.06	5.59	27.08	21.20	26.07	26.43
2011	83	18.73	5.44	92.53	12.65	17.01	71.81
2012	255	16.19	6.93	70.20	8.13	11.70	41.94
2013	615	14.10	13.41	45.22	6.79	13.28	22.69
2014	1,200	15.40	14.38	34.37	7.48	14.68	16.35
2015	1,247	19.25	9.05	34.29	9.07	13.43	15.92

Table S13c. **Delaware Basin** estimated ultimate recovery (EUR) for oil, gas, and water (PW) from unconventional horizontal wells for the period 2005 – 2015. Values represent 20-year estimates and are shown as total volumes per well and total volumes normalized by lateral length. Values for 2005 represent those for wells completed in that year and so forth. Gas values are expressed as either barrels of oil equivalent (boe).

Period	*Wells*	*Mean Oil (bbl/well)*	*Mean Gas (boe/well)*	*Mean PW (bbl/well)*	*Mean Oil (bbl/ft)*	*Mean Gas (boe/ft)*	*Mean PW (bbl/ft)*
2005	19	99,292	47,507	263,128	48.4	22.8	142.8
2006	27	64,655	52,121	247,803	29.2	22.2	101.6
2007	48	113,685	52,606	180,673	49.6	24.0	79.4
2008	94	115,724	56,493	160,515	47.3	22.2	65.2
2009	88	101,301	71,536	274,797	32.3	22.8	97.3
2010	176	99,256	79,912	267,311	27.7	21.9	71.3
2011	437	97,137	91,278	280,662	24.7	22.8	69.1
2012	663	119,446	107,280	292,215	28.2	24.8	**67.4**
2013	848	118,190	73,478	269,431	26.7	16.8	60.7
2014	1,218	134,899	86,234	338,464	29.6	18.7	73.9
2015	1,191	155,950	103,408	412,867	32.8	21.1	**86.0**

Table S13d. Metric equivalent to Table S13c. Gas values are expressed as m^3 of oil equivalent (m^3oe)

Period	*Wells*	*Mean Oil (10^3 m^3/well)*	*Mean Gas (10^3 m^3oe/well)*	*Mean PW (10^3 m^3/well)*	*Mean Oil (m^3/m)*	*Mean Gas (m^3oe/m)*	*Mean PW (m^3/m)*
2005	19	15.78	7.55	41.83	25.22	11.88	74.49
2006	27	10.28	8.29	39.39	15.25	11.56	52.97
2007	48	18.07	8.36	28.72	25.86	12.51	41.40
2008	94	18.40	8.98	25.52	24.67	11.56	33.99
2009	88	16.10	11.37	43.68	16.86	11.88	50.75
2010	176	15.78	12.70	42.49	14.46	11.44	37.17
2011	437	15.44	14.51	44.62	12.89	11.88	36.02
2012	663	18.99	17.05	46.45	14.69	12.96	35.15
2013	848	18.79	11.68	42.83	13.94	8.75	31.67
2014	1,218	21.44	13.71	53.81	15.43	9.78	38.55
2015	1,191	24.79	16.44	65.63	17.11	11.03	44.87

Table S14a. **Midland Basin** annual total and conventional annual total oil, gas, and PW for the period 2000 – 2015. Gas values are shown as both produced volumes and as barrels of oil equivalent (boe).

Period	Total					All Conventional				
	Oil	Gas		PW		Oil	Gas		PW	
	10^6 bbl	10^9 ft^3	10^6 boe	10^6 bbl	10^9 gal	10^6 bbl	10^9 ft^3	10^6 boe	10^6 bbl	10^9 gal
2000	67	245	42	454	19	64	232	40	450	19
2001	65	240	41	463	19	62	223	38	457	19
2002	61	234	40	467	20	58	212	37	462	19
2003	59	222	38	466	20	56	199	34	458	19
2004	57	216	37	460	19	52	190	33	447	19
2005	58	214	37	477	20	51	177	31	456	19
2006	58	217	37	494	21	50	176	30	466	20
2007	62	217	37	506	21	49	167	29	473	20
2008	69	225	39	502	21	49	163	28	455	19
2009	73	239	41	504	21	47	157	27	448	19
2010	84	255	44	552	23	47	157	27	478	20
2011	106	304	52	604	25	48	156	27	478	20
2012	135	389	67	697	29	45	143	25	487	20
2013	162	487	84	743	31	42	128	22	482	20
2014	208	654	113	807	34	40	120	21	470	20
2015	242	773	133	769	32	38	112	19	419	18
2005-2015	1,258	3,975	685	6,654	279	507	1,655	285	5,112	215

Table S14b. Metric equivalent to Table S14a. Gas values are shown as both produced volumes and as m^3 of oil equivalent (m^{3}oe)

Period	Total				All Conventional			
	Oil	Gas		PW	Oil	Gas		PW
	10^6 m^3	10^9 m^3	10^6 m^{3}oe	10^6 m^3	10^6 m^3	10^9 m^3	10^6 m^{3}oe	10^6 m^3
2000	10.7	6.9	6.7	72.2	10.2	6.6	6.4	71.5
2001	10.3	6.8	6.6	73.6	9.9	6.3	6.1	72.7
2002	9.7	6.6	6.4	74.3	9.2	6.0	5.8	73.4
2003	9.4	6.3	6.1	74.1	8.9	5.6	5.5	72.8
2004	9.1	6.1	5.9	73.1	8.3	5.4	5.2	71.0
2005	9.3	6.1	5.9	75.8	8.1	5.0	4.9	72.4
2006	9.3	6.1	5.9	78.6	7.9	5.0	4.8	74.1
2007	9.8	6.1	5.9	80.4	7.8	4.7	4.6	75.2
2008	11.0	6.4	6.2	79.8	7.9	4.6	4.5	72.4
2009	11.6	6.8	6.5	80.1	7.5	4.4	4.3	71.2
2010	13.3	7.2	7.0	87.8	7.5	4.4	4.3	76.0
2011	16.8	8.6	8.3	96.0	7.6	4.4	4.3	76.0
2012	21.5	11.0	10.7	110.7	7.2	4.1	3.9	77.5
2013	25.8	13.8	13.4	118.1	6.7	3.6	3.5	76.6
2014	33.1	18.5	17.9	128.3	6.4	3.4	3.3	74.7
2015	38.5	21.9	21.2	122.2	6.0	3.2	3.1	66.6
2005-2015	200.0	112.6	108.9	1,057.8	80.5	46.9	45.4	812.6

Table S14c. **Midland Basin** unconventional **annual total** oil, gas, and PW production for the period 2000 – 2015. Gas values are shown as both produced volumes and as barrels of oil equivalent (boe).

Period	*All Unconventional*				*Unconventional Vertical*				*Unconventional Horizontal*			
	Oil	*Gas*		*PW*	*Oil*	*Gas*		*PW*	*Oil*	*Gas*		*PW*
	10^6 *bbl*	10^9 *ft³*	10^6 *boe*	10^6 *bbl*	10^6 *bbl*	10^9 *ft³*	10^6 *boe*	10^6 *bbl*	10^6 *bbl*	10^9 *ft³*	10^6 *boe*	10^6 *bbl*
2000	3	13	2	4	3	9	2	3	0	4	1	0
2001	3	17	3	6	2	10	2	5	1	7	1	1
2002	3	22	4	6	2	13	2	5	1	9	2	1
2003	3	23	4	8	3	14	2	7	0	9	2	1
2004	5	26	4	13	4	17	3	11	0	9	2	2
2005	7	37	6	22	7	22	4	19	1	15	3	3
2006	9	41	7	28	8	24	4	25	1	17	3	3
2007	13	50	9	33	12	31	5	31	1	19	3	3
2008	20	63	11	47	19	43	7	44	1	19	3	3
2009	26	82	14	56	25	62	11	53	1	20	3	3
2010	37	99	17	75	36	83	14	72	1	16	3	2
2011	58	148	25	125	56	131	23	120	2	17	3	5
2012	90	246	42	209	81	214	37	194	8	32	6	15
2013	120	359	62	261	95	284	49	213	25	75	13	49
2014	168	533	92	337	99	339	59	208	69	194	33	129
2015	204	661	114	350	84	325	56	178	120	336	58	172
2005-2015	752	2,319	400	1,543	522	1,560	269	1,157	230	759	131	386

Table S14d. Metric equivalent to Table S14c. Gas values are shown as both produced volumes and as m^3 of oil equivalent (m^3oe).

Period	*All Unconventional*				*Unconventional Vertical*				*Unconventional Horizontal*			
	Oil	*Gas*		*PW*	*Oil*	*Gas*		*PW*	*Oil*	*Gas*		*PW*
	10^6 m^3	10^9 m^3	10^6 m^3oe	10^6 m^3	10^6 m^3	10^9 m^3	10^6 m^3oe	10^6 m^3	10^6 m^3	10^9 m^3	10^6 m^3oe	10^6 m^3
2000	0.5	0.4	0.4	0.6	0.5	0.3	0.2	0.5	0.1	0.1	0.1	0.1
2001	0.5	0.5	0.5	0.9	0.4	0.3	0.3	0.8	0.1	0.2	0.2	0.1
2002	0.5	0.6	0.6	0.9	0.4	0.4	0.4	0.8	0.1	0.3	0.2	0.2
2003	0.5	0.6	0.6	1.3	0.5	0.4	0.4	1.1	0.1	0.3	0.3	0.2
2004	0.8	0.7	0.7	2.0	0.7	0.5	0.5	1.8	0.1	0.3	0.3	0.2
2005	1.2	1.0	1.0	3.4	1.1	0.6	0.6	3.0	0.1	0.4	0.4	0.5
2006	1.4	1.2	1.1	4.5	1.3	0.7	0.7	4.0	0.1	0.5	0.5	0.4
2007	2.0	1.4	1.4	5.3	1.9	0.9	0.9	4.9	0.1	0.5	0.5	0.4
2008	3.2	1.8	1.7	7.5	3.1	1.2	1.2	7.0	0.1	0.5	0.5	0.4
2009	4.2	2.3	2.3	8.9	4.0	1.8	1.7	8.5	0.1	0.6	0.6	0.4
2010	5.8	2.8	2.7	11.9	5.7	2.4	2.3	11.5	0.1	0.4	0.4	0.4
2011	9.2	4.2	4.0	19.9	8.8	3.7	3.6	19.1	0.4	0.5	0.5	0.8
2012	14.3	7.0	6.7	33.3	12.9	6.1	5.9	30.9	1.4	0.9	0.9	2.4
2013	19.1	10.2	9.8	41.5	15.1	8.1	7.8	33.8	4.0	2.1	2.1	7.7
2014	26.7	15.1	14.6	53.5	15.7	9.6	9.3	33.0	11.0	5.5	5.3	20.5
2015	32.5	18.7	18.1	55.6	13.4	9.2	8.9	28.3	19.2	9.5	9.2	27.3
2005-2015	119.5	65.7	63.6	245.3	83.0	44.2	42.8	184.0	36.5	21.5	20.8	61.3

Table S15a. **Delaware Basin** annual total and conventional annual total oil, gas, and PW volumes for the period 2000 – 2015. Gas values are shown as both produced volumes and as barrels of oil equivalent (boe).

Period	Total					All Conventional				
	Oil	Gas		PW		Oil	Gas		PW	
	10^6 bbl	10^9 ft^3	10^6 boe	10^6 bbl	10^9 gal	10^6 bbl	10^9 ft^3	10^6 boe	10^6 bbl	10^9 gal
2000	24	396	68	199	8	24	392	68	196	8
2001	26	446	77	219	9	25	429	74	215	9
2002	26	432	74	216	9	25	410	71	213	9
2003	26	412	71	223	9	26	387	67	220	9
2004	25	403	70	229	10	24	375	65	216	9
2005	23	405	70	232	10	21	361	62	226	9
2006	22	413	71	243	10	21	369	64	236	10
2007	23	428	74	244	10	20	359	62	234	10
2008	24	409	71	244	10	20	328	57	227	10
2009	25	376	65	234	10	18	302	52	208	9
2010	29	339	58	231	10	17	256	44	192	8
2011	41	318	55	246	10	17	204	35	172	7
2012	64	350	60	331	14	18	171	30	193	8
2013	89	418	72	400	17	17	146	25	186	8
2014	133	546	94	512	22	17	132	23	188	8
2015	187	726	125	688	29	17	117	20	165	7
2005-2015	660	4,728	815	3,604	151	201	2,745	473	2,227	94

Table S15b. Metric equivalent to Table S15a. Gas values are shown as both produced volumes and as m^3 of oil equivalent (m^{3}oe).

Period	Total				All Conventional			
	Oil	Gas		PW	Oil	Gas		PW
	10^6 m^3	10^9 m^3	10^6 m^{3}oe	10^6 m^3	10^6 m^3	10^9 m^3	10^6 m^{3}oe	10^6 m^3
2000	3.8	11.2	10.9	31.7	3.8	11.1	10.7	31.1
2001	4.1	12.6	12.2	34.8	4.0	12.1	11.7	34.2
2002	4.1	12.2	11.8	34.3	4.0	11.6	11.2	33.9
2003	4.2	11.7	11.3	35.4	4.1	11.0	10.6	35.0
2004	4.0	11.4	11.0	36.4	3.8	10.6	10.3	34.4
2005	3.6	11.5	11.1	36.8	3.4	10.2	9.9	35.9
2006	3.6	11.7	11.3	38.6	3.3	10.5	10.1	37.4
2007	3.7	12.1	11.7	38.8	3.2	10.2	9.8	37.3
2008	3.9	11.6	11.2	38.7	3.1	9.3	9.0	36.1
2009	3.9	10.6	10.3	37.2	2.8	8.6	8.3	33.1
2010	4.6	9.6	9.3	36.8	2.7	7.3	7.0	30.6
2011	6.5	9.0	8.7	39.1	2.6	5.8	5.6	27.3
2012	10.2	9.9	9.6	52.6	2.8	4.9	4.7	30.6
2013	14.1	11.8	11.4	63.6	2.7	4.1	4.0	29.6
2014	21.1	15.5	15.0	81.4	2.6	3.7	3.6	29.9
2015	29.7	20.6	19.9	109.3	2.6	3.3	3.2	26.2
2005-2015	104.9	133.9	129.6	572.9	31.9	77.7	75.2	354.1

Table S15c. **Delaware Basin** unconventional annual total oil, gas, and PW production for the period 2000 – 2015. Gas values are shown as both produced volumes and as barrels of oil equivalent (boe).

Period	*All Unconventional*				*Unconventional Vertical*				*Unconventional Horizontal*			
	Oil	*Gas*		*PW*	*Oil*	*Gas*		*PW*	*Oil*	*Gas*		*PW*
	10^6 *bbl*	10^9 *ft³*	10^6 *boe*	10^6 *bbl*	10^6 *bbl*	10^9 *ft³*	10^6 *boe*	10^6 *bbl*	10^6 *bbl*	10^9 *ft³*	10^6 *boe*	10^6 *bbl*
2000	0	4	1	4	0	3	0	4	0	2	0	0
2001	1	17	3	4	0	6	1	3	0	11	2	0
2002	1	22	4	3	0	8	1	3	0	14	2	0
2003	1	24	4	3	0	10	2	2	1	14	2	0
2004	1	28	5	13	0	16	3	12	1	11	2	0
2005	1	44	8	6	0	34	6	5	1	10	2	1
2006	2	44	8	7	1	34	6	6	1	10	2	2
2007	3	69	12	10	1	58	10	7	2	11	2	3
2008	4	81	14	16	1	62	11	8	3	19	3	8
2009	7	74	13	26	2	45	8	12	5	28	5	13
2010	12	83	14	39	2	39	7	15	10	43	7	24
2011	25	114	20	74	4	33	6	21	21	82	14	52
2012	47	179	31	138	7	33	6	35	39	147	25	103
2013	72	272	47	214	8	33	6	41	64	239	41	173
2014	116	414	71	324	9	36	6	41	107	378	65	283
2015	170	609	105	523	7	31	5	32	163	578	100	490
2005-2015	459	1,983	342	1,377	43	437	75	223	416	1,546	267	1,153

Table S15d. Metric equivalent to Table S15c. Gas values are shown as both produced volumes and as m^3 of oil equivalent (m^3oe).

Period	*All Unconventional*				*Unconventional Vertical*				*Unconventional Horizontal*			
	Oil	*Gas*		*PW*	*Oil*	*Gas*		*PW*	*Oil*	*Gas*		*PW*
	10^6 m^3	10^9 m^3	10^6 m^3oe	10^6 m^3	10^6 m^3	10^9 m^3	10^6 m^3oe	10^6 m^3	10^6 m^3	10^9 m^3	10^6 m^3oe	10^6 m^3
2000	0.1	0.1	0.1	0.6	0.1	0.1	0.1	0.6	0.0	0.0	0.0	0.0
2001	0.1	0.5	0.5	0.6	0.1	0.2	0.2	0.5	0.0	0.3	0.3	0.0
2002	0.1	0.6	0.6	0.4	0.1	0.2	0.2	0.4	0.0	0.4	0.4	0.0
2003	0.1	0.7	0.7	0.4	0.1	0.3	0.3	0.4	0.1	0.4	0.4	0.0
2004	0.2	0.8	0.8	2.0	0.1	0.5	0.4	1.9	0.1	0.3	0.3	0.1
2005	0.2	1.2	1.2	0.9	0.1	1.0	0.9	0.8	0.2	0.3	0.3	0.2
2006	0.3	1.3	1.2	1.2	0.1	1.0	0.9	0.9	0.2	0.3	0.3	0.3
2007	0.4	1.9	1.9	1.5	0.1	1.6	1.6	1.1	0.3	0.3	0.3	0.4
2008	0.7	2.3	2.2	2.6	0.2	1.8	1.7	1.3	0.5	0.5	0.5	1.3
2009	1.1	2.1	2.0	4.1	0.3	1.3	1.2	1.9	0.9	0.8	0.8	2.1
2010	1.9	2.3	2.3	6.2	0.4	1.1	1.1	2.4	1.5	1.2	1.2	3.8
2011	3.9	3.2	3.1	11.7	0.6	0.9	0.9	3.4	3.3	2.3	2.2	8.3
2012	7.4	5.1	4.9	22.0	1.2	0.9	0.9	5.6	6.2	4.1	4.0	16.4
2013	11.4	7.7	7.5	34.0	1.3	0.9	0.9	6.5	10.1	6.8	6.5	27.6
2014	18.5	11.7	11.3	51.5	1.4	1.0	1.0	6.5	17.1	10.7	10.4	45.0
2015	27.1	17.3	16.7	83.1	1.2	0.9	0.8	5.1	25.9	16.4	15.9	78.0
2005-2015	73.0	56.2	54.4	218.8	6.8	12.4	12.0	35.5	66.2	43.8	42.4	183.3

Table S16a. Permian, Midland, and Delaware basin field-based HF water intensity relative to oil production (HF water to oil ratio, **HFWOR,** volumetric ratios, unitless) of annual total volumes for unconventional vertical and horizontal wells for the period 2005 – 2015.

Period	*Permian Basin*		*Midland Basin*		*Delaware Basin*	
	Verticals	*Horizontals*	*Verticals*	*Horizontals*	*Verticals*	*Horizontals*
2005	0.7	0.3	0.7	0.7	2.2	0.2
2006	0.8	0.5	0.8	0.6	1.1	0.4
2007	0.9	0.6	0.9	0.7	2.1	0.5
2008	1.0	0.6	1.0	0.8	1.6	0.5
2009	0.7	0.4	0.7	0.5	0.6	0.5
2010	1.0	0.8	1.1	0.9	0.9	0.9
2011	1.3	1.2	1.4	5.1	1.1	1.1
2012	1.3	1.6	1.4	5.5	1.5	1.0
2013	1.0	1.9	1.1	5.0	0.8	1.0
2014	0.8	2.1	0.9	4.0	0.3	1.4
2015	0.4	1.6	0.4	2.7	0.1	1.2
2005-2015	**0.9**	**1.7**	1.0	3.4	0.8	1.2

Table S16b. Permian, Midland, and Delaware basin hydraulic fracturing water intensity relative to oil production and oil + gas production (HF water to oil + gas ratio, HFWOGR, volumetric ratios, unitless). Oil production includes initial (12-month) production and total estimated ultimate recovery (EUR) of oil and oil + gas for unconventional horizontal wells completed each year during the period 2005 – 2015.

Period	*Permian Basin*			*Midland Basin*			*Delaware Basin*		
	12-mo	*EUR*		*12-mo*	*EUR*		*12-mo*	*EUR*	
		Oil	*Oil+Gas*		*Oil*	*Oil+Gas*		*Oil*	*Oil+Gas*
2005	0.8	0.2	0.1	0.7	0.2	0.1	0.4	0.1	0.1
2006	1.4	0.2	0.1	0.9	0.3	0.2	0.4	0.6	0.2
2007	1.1	0.2	0.1	0.8	0.1	0.1	0.5	0.1	0.1
2008	0.7	**0.2**	0.1	1.0	**0.5**	**0.4**	0.4	**0.1**	0.1
2009	0.7	0.2	0.1	1.5	0.2	0.1	0.5	0.2	0.1
2010	0.8	0.4	0.3	1.1	0.4	0.3	0.7	0.5	0.3
2011	1.4	0.5	0.3	3.6	1.0	0.8	1.0	0.5	0.3
2012	1.8	0.6	0.4	4.2	2.1	1.6	1.0	0.5	0.3
2013	2.3	1.0	0.7	4.2	2.7	1.6	1.1	0.6	0.4
2014	2.4	1.6	1.0	3.7	2.7	1.5	1.4	0.9	0.6
2015	3.5	**1.5**	**1.0**	**4.7**	**2.2**	**1.6**	**2.4**	**1.0**	**0.7**
2005-2015	2.5			4.1			1.4		

Table S17a. Permian, Midland, and Delaware basins field based produced water (PW) intensities (PW to Oil ratio, PWOR, volumetric ratios, unitless) relative to annual total oil production for unconventional vertical and horizontal wells for the period 2005 – 2015.

Period	*Permian Basin*			*Midland Basin*		*Delaware Basin*	
	Conv.	*Verticals*	*Horizontals*	*Verticals*	*Horizontals*	*Verticals*	*Horizontals*
2005	11	3.7	3.4	2.8	3.9	10.7	1.1
2006	11	3.9	3.6	3.2	3.5	9.7	1.3
2007	12	3.3	3.1	2.6	3.1	8.5	1.5
2008	12	2.9	3.1	2.3	3.5	7.8	2.4
2009	13	2.7	2.8	2.1	3.6	7.1	2.5
2010	13	2.7	2.9	2.0	3.8	6.2	2.5
2011	13	2.7	2.8	2.2	2.3	5.4	2.5
2012	14	2.8	2.7	2.4	1.8	4.7	2.6
2013	15	2.7	2.8	2.2	1.9	4.9	2.7
2014	15	2.7	2.6	2.1	1.9	4.7	2.6
2015	15	2.8	2.5	2.1	1.4	4.3	3.0
2005-2015	**13**	**2.8**	**2.6**	2.2	1.7	5.2	2.8

Table S17b. Permian, Midland, and Delaware water cuts (%) for unconventional vertical and horizontal wells for the period 2005 – 2015. Water cut is the ratio of total produced water to the sum of produced water and oil.

Period	*Permian Basin*			*Midland Basin*		*Delaware Basin*	
	Conv.	*Verticals*	*Horizontals*	*Verticals*	*Horizontals*	*Verticals*	*Horizontals*
2005	91	79	77	74	80	91	51
2006	92	80	78	76	78	91	56
2007	92	76	76	72	76	90	59
2008	92	75	76	70	78	89	70
2009	92	73	74	68	78	88	71
2010	92	73	74	67	79	86	71
2011	91	73	74	68	70	84	72
2012	91	74	73	70	64	83	72
2013	90	73	74	69	66	83	73
2014	89	73	72	68	65	82	72
2015	87	73	71	68	59	81	75
2005-2015	**91**	**74**	**72**	69	63	84	73

Table S17c. Permian, Midland, and Delaware basin produced water intensities (volumetric ratios, unitless) relative to initial (12-month) oil production and to total estimated ultimate recovery (EUR) of oil and oil + gas for unconventional horizontal basins wells completed each year during the period 2005 – 2015.

Period	*Permian Basin*			*Midland Basin*			*Delaware Basin*		
	12-mo	*EUR*		*12-mo*	*EUR*		*12-mo*	*EUR*	
		Oil	*Oil+Gas*		*Oil*	*Oil+Gas*		*Oil*	*Oil+Gas*
2005	0.6	0.9	0.6	3.2	0.4	0.2	0.6	1.1	0.5
2006	0.2	2.3	1.3	2.1	1.4	0.8	0.9	6.2	1.7
2007	0.1	1.4	1.0	1.2	2.3	2.2	1.0	1.5	1.1
2008	0.5	1.4	0.8	2.0	3.5	3.0	1.8	0.9	0.6
2009	0.8	1.3	0.8	3.3	2.3	1.7	1.6	1.3	0.7
2010	1.1	1.5	1.0	2.2	1.6	1.1	2.4	1.6	0.8
2011	1.4	1.8	1.2	1.4	1.8	1.6	2.5	1.9	1.0
2012	1.3	2.1	1.4	1.6	2.0	1.6	2.1	1.9	1.1
2013	1.5	2.1	1.3	1.9	1.8	1.1	2.1	1.9	1.1
2014	1.3	1.9	1.2	1.6	1.7	1.0	2.1	2.1	1.3
2015	1.3	1.7	1.2	**1.3**	**1.3**	**0.9**	**2.2**	**2.0**	**1.2**
2005-2015	1.3			1.6			2.1		

Table S17d. Permian, Midland, and Delaware basin water cut values (%) for initial (12-month) oil production and relative to total estimated ultimate recovery (EUR) of oil and oil + gas for unconventional horizontal wells completed each year during the period 2005 – 2015.

Period	*Permian Basin*			*Midland Basin*			*Delaware Basin*		
	12-mo	*EUR*		*12-mo*	*EUR*		*12-mo*	*EUR*	
		Oil	*Oil+Gas*		*Oil*	*Oil+Gas*		*Oil*	*Oil+Gas*
2005	69	75	61	71	42	18	16	75	67
2006	70	76	64	63	59	30	51	78	66
2007	75	71	62	56	71	52	56	62	52
2008	76	70	58	68	81	63	67	58	48
2009	62	81	72	72	56	37	61	75	64
2010	67	71	60	63	55	36	67	72	59
2011	70	76	64	57	85	71	71	74	59
2012	67	77	66	61	84	68	70	71	56
2013	68	75	64	65	77	53	67	69	58
2014	66	72	60	60	69	42	66	71	60
2015	63	70	60	56	64	41	66	72	61
2005-2015	66			60			67		

Table S18a. Permian Basin salt water disposal (SWD) and enhanced oil recovery (EOR) water injection volumes. Commercial (SWD) for the Texas region is also shown separately.

Period	*EORI Wells*	*SWD Wells*	*Unknown Wells*	*EORI 10^9 bbl*	*SWD 10^9 bbl*	*Unknown 10^9 bbl*	*Total 10^9 bbl*	*Comm. 10^9 bbl*
2000	22,611	2,859	403	2.86	0.80	0.04	3.70	0.06
2001	22,907	2,873	393	2.85	0.83	0.04	3.72	0.06
2002	22,984	2,823	365	2.92	0.84	0.06	3.81	0.06
2003	22,981	2,813	345	2.92	0.86	0.06	3.83	0.07
2004	22,919	2,809	339	2.97	0.89	0.05	3.91	0.07
2005	22,993	2,822	335	3.03	0.93	0.05	4.01	0.07
2006	23,118	2,835	319	3.15	1.03	0.05	4.22	0.08
2007	**23,304**	**2,834**	426	3.16	1.08	0.04	4.28	0.09
2008	23,699	2,906	316	3.26	1.08	0.04	4.39	0.11
2009	23,959	2,979	334	3.26	1.09	0.05	4.40	0.11
2010	24,210	3,017	338	3.29	1.16	0.05	4.50	0.14
2011	24,455	3,118	331	3.30	1.24	0.05	4.59	0.19
2012	24,499	3,259	336	3.49	1.40	0.05	4.94	0.25
2013	24,574	3,448	328	3.54	1.55	0.05	5.13	0.31
2014	25,019	3,668	321	3.68	1.86	0.04	5.59	0.44
2015	**24,913**	**3,816**	288	3.34	1.98	0.03	5.35	0.50
2005-2015	25,019	3,816	426	**36.51**	**14.39**	0.49	51.39	2.30

Table S18b. Metric equivalent to Table S18a.

Period	*EORI Wells*	*SWD Wells*	*Unknown Wells*	*EORI 10^6 m^3*	*SWD 10^6 m^3*	*Unknown 10^6 m^3*	*Total 10^6 m^3*	*Comm. 10^6 m^3*
2000	22,611	2,859	403	455	127	6	588	10
2001	22,907	2,873	393	453	132	7	592	10
2002	22,984	2,823	365	464	133	9	606	10
2003	22,981	2,813	345	464	136	9	610	10
2004	22,919	2,809	339	471	142	8	621	11
2005	22,993	2,822	335	481	148	7	637	12
2006	23,118	2,835	319	501	163	8	671	13
2007	23,304	2,834	426	502	172	7	681	14
2008	23,699	2,906	316	519	172	7	698	17
2009	23,959	2,979	334	519	174	8	700	18
2010	24,210	3,017	338	523	185	7	715	22
2011	24,455	3,118	331	525	197	7	729	30
2012	24,499	3,259	336	554	222	8	785	40
2013	24,574	3,448	328	563	246	8	816	50
2014	25,019	3,668	321	586	296	7	888	71
2015	24,913	3,816	288	531	314	5	850	79
2005-2015	25,019	3,816	426	3,281	1,460	42	4,783	291

Table S18c. Midland Basin salt water disposal (SWD) and enhanced oil recovery (EOR) water injection volumes. Commercial (SWD) is also shown separately.

Period	*EORI Wells*	*SWD Wells*	*Unknown Wells*	*EORI 10^9 bbl*	*SWD 10^9 bbl*	*Unknown 10^9 bbl*	*Total 10^9 bbl*	*Comm. 10^9 bbl*
2000	3,081	610	58	0.34	0.25	0.01	0.60	0.03
2001	3,086	609	59	0.35	0.25	0.01	0.61	0.03
2002	3,069	606	38	0.36	0.24	0.01	0.61	0.02
2003	3,027	590	37	0.35	0.24	0.01	0.61	0.03
2004	2,972	596	37	0.35	0.25	0.01	0.60	0.03
2005	2,995	598	38	0.35	0.25	0.01	0.61	0.03
2006	2,979	594	39	0.36	0.26	0.01	0.63	0.04
2007	2,963	605	40	0.35	0.26	0.01	0.62	0.04
2008	2,975	631	41	0.35	0.27	0.01	0.63	0.05
2009	2,957	652	40	0.35	0.27	0.01	0.63	0.06
2010	2,967	671	40	0.35	0.31	0.01	0.67	0.07
2011	2,915	703	40	0.36	0.37	0.01	0.73	0.10
2012	2,910	776	40	0.33	0.44	0.01	0.77	0.14
2013	2,915	845	40	0.34	0.49	0.01	0.84	0.18
2014	2,936	942	39	0.35	0.62	0.01	0.98	0.25
2015	2,877	1,011	42	0.30	0.65	0.01	0.96	0.24
2005-2015				3.79	4.20	0.09	8.08	1.21

Table S18d. Metric equivalent to Table S18c.

Period	*EOR Wells*	*SWD Wells*	*Unknown Wells*	*EORI 10^6 m^3*	*SWD 10^6 m^3*	*Unknown 10^6 m^3*	*Total 10^6 m^3*	*Comm. 10^6 m^3*
2000	3,081	610	58	54	40	1	95	4
2001	3,086	609	59	56	40	1	97	4
2002	3,069	606	38	57	39	1	97	4
2003	3,027	590	37	56	39	1	97	4
2004	2,972	596	37	55	39	1	96	5
2005	2,995	598	38	55	41	1	97	5
2006	2,979	594	39	57	42	1	100	6
2007	2,963	605	40	55	42	1	99	7
2008	2,975	631	41	56	44	1	101	9
2009	2,957	652	40	56	43	1	100	9
2010	2,967	671	40	56	50	1	107	11
2011	2,915	703	40	57	58	1	116	15
2012	2,910	776	40	52	69	1	123	23
2013	2,915	845	40	54	78	1	133	29
2014	2,936	942	39	56	98	1	156	40
2015	2,877	1,011	42	48	103	1	152	38
2005-2015				602	668	14	1,285	192

Table S18e. Delaware Basin salt water disposal (SWD) and enhanced oil recovery (EOR) water injection volumes. Commercial (SWD) for the Texas region is also shown separately.

Period	*EOR Wells*	*SWD Wells*	*Unknown Wells*	*EORI 10^9 bbl*	*SWD 10^9 bbl*	*Unknown 10^9 bbl*	*Total 10^9 bbl*	*Comm. 10^9 bbl*
2000	705	399	35	0.05	0.14	0.00	0.19	0.01
2001	715	407	29	0.05	0.15	0.00	0.20	0.01
2002	736	401	26	0.05	0.16	0.00	0.21	0.00
2003	715	409	21	0.06	0.16	0.00	0.22	0.00
2004	732	422	22	0.05	0.19	0.00	0.24	0.01
2005	783	432	22	0.06	0.18	0.00	0.24	0.01
2006	786	449	19	0.08	0.22	0.00	0.30	0.01
2007	791	453	16	0.07	0.21	0.00	0.28	0.01
2008	823	468	13	0.07	0.21	0.00	0.28	0.01
2009	814	484	11	0.06	0.20	0.00	0.26	0.01
2010	892	510	14	0.07	0.20	0.00	0.28	0.02
2011	887	543	15	0.07	0.24	0.00	0.31	0.03
2012	862	595	13	0.08	0.29	0.00	0.38	0.04
2013	830	674	14	0.06	0.37	0.01	0.44	0.06
2014	758	729	14	0.07	0.50	0.01	0.58	0.11
2015	759	807	18	0.06	0.66	0.01	0.73	0.19
2005-2015				0.74	3.28	0.04	4.06	0.48

Table S18f. Metric equivalent to Table S18e.

Period	*EOR Wells*	*SWD Wells*	*Unknown Wells*	*EORI 10^6 m^3*	*SWD 10^6 m^3*	*Unknown 10^6 m^3*	*Total 10^6 m^3*	*Comm. 10^6 m^3*
2000	705	399	35	8	22	0	30	1
2001	715	407	29	9	23	0	32	1
2002	736	401	26	8	25	0	34	1
2003	715	409	21	9	26	0	35	1
2004	732	422	22	8	30	0	38	1
2005	783	432	22	9	29	0	38	1
2006	786	449	19	12	35	0	48	1
2007	791	453	16	11	33	0	44	1
2008	823	468	13	11	33	0	44	1
2009	814	484	11	10	32	0	42	2
2010	892	510	14	11	32	0	44	3
2011	887	543	15	10	38	1	49	4
2012	862	595	13	12	47	1	60	6
2013	830	674	14	10	58	2	70	10
2014	758	729	14	11	80	1	92	17
2015	759	807	18	10	104	1	116	30
2005-2015				117	521	7	645	76

Table S19a. Permian, Midland, and Delaware basin volumetric ratios (unitless) of (field-based) annual total produced water to hydraulic fracturing water use for unconventional vertical and horizontal wells for the period 2005 – 2015.

Period	*Permian Basin*		*Midland Basin*		*Delaware Basin*	
	Verticals	*Horizontals*	*Verticals*	*Horizontals*	*Verticals*	*Horizontals*
2005	5.3	11.9	4.1	5.3	4.9	4.7
2006	5.3	6.7	4.0	5.7	9.0	3.1
2007	3.7	5.0	3.0	4.4	4.0	3.2
2008	2.9	5.1	2.3	4.4	4.9	4.3
2009	3.9	6.9	2.9	7.6	11.3	5.3
2010	2.7	3.6	1.8	4.0	6.7	2.7
2011	2.1	2.3	1.6	0.5	4.9	2.4
2012	2.2	1.7	1.8	0.3	3.2	2.7
2013	2.7	1.5	2.0	0.4	5.9	2.8
2014	3.3	1.2	2.3	0.5	13.4	1.9
2015	7.1	1.5	4.8	0.5	47.2	2.5
2005-2015	**3.1**	**1.5**	**2.2**	**0.5**	**6.5**	**2.4**

Table S19b. Permian, Midland, and Delaware basin volumetric ratios (unitless) of initial (12-month) and Estimated Ultimate Recovery (EUR) produced water to hydraulic fracturing water for unconventional horizontal wells completed each year during the period 2005 – 2015.

Period	*Permian Basin*		*Midland Basin*		*Delaware Basin*	
	12-mo	*EUR*	*12-mo*	*EUR*	*12-mo*	*EUR*
2005	1.4	6.4	2.8	2.9	0.2	10.6
2006	0.1	10.0	1.9	4.2	1.9	7.6
2007	0.2	9.4	1.1	14.2	2.7	13.3
2008	1.5	7.1	1.8	13.0	2.7	7.4
2009	1.7	6.7	2.3	7.9	2.0	7.4
2010	1.4	3.9	2.1	4.2	1.9	3.7
2011	1.5	3.6	0.4	2.1	1.8	3.6
2012	1.4	3.2	0.4	1.0	2.1	3.8
2013	1.0	1.9	0.4	0.7	1.9	3.1
2014	0.8	1.2	0.4	0.6	1.6	2.4
2015	0.5	1.1	0.3	0.6	0.9	1.9
2005-2015	0.8		0.4		1.5	

Table S20. Regional values of 2014 total hydraulic fracturing (HF) water use, total injection for salt water disposal (SWD) and ratios between these values.

Value	Units	*Region*							
		Delaware Basin	*Central Basin Platform*	*Midland Basin*	*Northern Shelf*	*Eastern Shelf*	*Val Verde Basin*	*Marginal Areas*	*Permian Basin*
HF	10^6 gal	6,315	760	15,319	486	508	121	11	23,520
	10^6 m^3	23.9	2.9	58.0	1.8	1.9	0.5	0.0	89.0
SWD	10^6 gal	16,232	16,359	26,021	15,244	3,001	551	726	78,135
	10^6 m^3	61.4	61.9	98.5	57.7	11.4	2.1	2.7	295.7
SWD/HF	Ratio	**2.6**	21.5	**1.7**	31.3	5.9	4.6	66.2	3.3

Table S21. Ratios between total 2014 salt water disposal (SWD) and hydraulic fracturing (HF) water use for selected counties areas located within different regions of the Permian Basin.

County	SWD/HF
Delaware Basin	
Eddy	3.3
Lea	1.3
Culberson	1.3
Loving	3.0
Reeves	2.1
Ward	4.5
Midland Basin (South)	
Crockett	1.5
Glasscock	1.3
Howard	2.8
Irion	**0.4**
Martin	2.2
Midland	1.6
Reagan	1.5
Upton	1.2

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