U.S. Department of the Interior
Bureau of Land Management

2019 BLM New Mexico Water Support Document

U.S. Department of the Interior
Bureau of Land Management:
New Mexico State Office
301 Dinosaur Trail
Santa Fe, New Mexico 87508
505-954-2000

TABLE OF CONTENTS

Appendices

List of Figures

List of Tables

LIST OF ACRONYMS AND ABBREVIATIONS

AF	Acre-feet
Ag	Silver
Al	Aluminum
APD	Application for Permit to Drill
As	Arsenic
Ba	Barium
Bbls	Barrels
BLM	Bureau of Land Management
Br	Bromide
BS&W	Basic sediment and water
Ca2	Calcium
CaCO3	Alkalinity
Cd	Cadmium
Cl	Chloride
COA	Conditions of approval
CO3-	Carbonate
CFR	Code of Federal Regulations
Cu	Copper
CWA	Clean Water Act
EIS	Environmental Impact Statement
F	Fluoride
Fe	Iron
FO	Field Office
gpm	gallons per minute
HCO3	Bicarbonate
HPA	high potential areas
K+	Potassium
L	Liter
Li	Lithium
MCF	thousand cubic feet
mg	milligrams
mg/L	milligrams per Liter
Mg2	Magnesium
Mn	Manganese
Na+	Sodium
NEPA	National Environmental Policy Act
Ni	Nickel

NMAC	New Mexico Administrative Code
NMOCD	State of New Mexico Oil Conservation Division
NMOSE	State of New Mexico Office of the State Engineer
NMWQCC	New Mexico Water Quality Control Commission
NO2	Nitrite
NO3	Nitrate
Pb	Lead
psi	Pounds per square inch
RFFA	Reasonably Foreseeable Future Actions
RMP	Resource Management Plan
RFD	Reasonable Foreseeable Development
Si	Silicon
SO42	Sulfate
Sr2	Strontium
TDS	total dissolved solids
TDS	Total Dissolved Solids
TMDLs	total maximum daily loads
U.S.	United States
USGS	U.S. Geological Survey
V	Vanadium
WIPP	Waste Isolation Pilot Plant
μmhos/cm	Specific Conductance

CHAPTER 1. INTRODUCTION

1.1. Purpose of the Report

The intent of this document is to collect and present the data and information needed for water resources analysis to be incorporated by reference into National Environmental Policy Act (NEPA) documents, most specifically the proposed NEPA analysis related to federal oil and gas development under the jurisdiction of the Bureau of Land Management (BLM) New Mexico State Office. This includes federal mineral rights within the Pecos District, Farmington Field Office (FO), and Rio Puerco FO.

1.2. Report Organization

Chapter 2 summarizes water quantity and quality data for the Pecos District, which comprises the Carlsbad and Roswell FOs and the Hobbs Field Station. Chapters 3and 4 summarize water quantity and quality data for the Farmington FO and the Rio Puerco FO, respectively. Chapter 5 summarizes how to use this report to inform analyses of water use at the site-specific level. Each chapter contains the references that are pertinent to the analysis.

1.3. Updating of the Report

The BLM will update this report with new data as it becomes available. FracFocus data on actual water use is released annually. As this data is released the BLM will review it to consider if the cumulative analysis of water use requires updating. The State of New Mexico Office of the State Engineer (NMOSE) and U.S. Geological Survey (USGS) data, “Water Use by Category,” is updated every five years. The reporting on the spills data will be updated annually (Appendix B).

CHAPTER 2. PECOS DISTRICT

The BLM Pecos District Office, which oversees the Carlsbad and Roswell FOs and the Hobbs Field Station, encompasses over 3.5 million acres of public lands and over 7 million acres of federal mineral estate. The Pecos District includes the New Mexico portion of the Permian Basin, a sedimentary depositional basin. The Permian Basin is one of the premier oil and gas producing regions in the United States (U.S.), and prolific producing horizons occur in the New Mexico portion of the basin in Eddy and Lea Counties. The Permian Basin has been a producing oil and natural gas field since the early 1900s. According to available GIS data and the Petroleum Recovery Research Center, approximately 17,735 active federal wells are within the boundaries of the Pecos District.

This chapter presents information on existing and projected water quantity and water quality data for the Pecos District as summarized from information gathered from the following sources: 1) the Reasonable Foreseeable Development (RFD) Scenario for the BLM New Mexico Pecos District (Engler and Cather 2012; 2014), 2) data compiled from a 2015 USGS report, Estimated Use of Water in the United States in 2015 (Dieter et al. 2018), and 3) FracFocus, a national hydraulic fracturing chemical registry managed by the Ground Water Protection Council and Interstate Oil and Gas Compact Commission (FracFocus 2018).

2.1. Water Quantity

2.1.1. Existing Surface and Groundwater Water Use

Pecos District

The 2015 USGS Report, Estimated Use of Water in the United States in 2015 (Dieter et al. 2018), lists total water withdrawals across eight water use categories: aquaculture, domestic, industrial, irrigation, livestock, mining, public water supply, and thermoelectric power. Table 2-1 through Table 2-3 list the total 2015 water withdrawals for the eight water use categories for each of the three counties within the Pecos District ("Pecos District Tri-County Area"). Table 2-4 presents combined water use for the Pecos District Tri-County Area. This area is roughly analogous to the New Mexico portion of the Permian Basin. As shown in the tables, *Irrigation* is the largest category of water use in all counties, accounting for an average of 75 percent (466,784 acre-feet ([AF]) of the total water withdrawal for the Pecos District Tri-County Area (620, 416 AF). Approximately 88 percent (546,195 AF) of the total water use for the Pecos District Tri-County Area is from groundwater. *Mining* (which includes oil and gas development) comprises approximately 15 percent of Pecos District Tri-County Area water withdrawals. All mining-related water use (95,800 AF) is from groundwater. Of that total, 99 percent of withdrawals are from saline sources. Most (87 percent) of mining-related water use occurs in Lea County, where mining comprises 31 percent of the total county withdrawals. The relative use of water by industry within the Pecos District Tri-County Area is depicted in Figure 2.1. The relative use of surface water and fresh/saline groundwater by industry within the Pecos District Tri-County Area is depicted in Figure 2.2.

Table 2-1. Lea County 2015 Water Use by Category (AF)

Category	Surface Water				Groundwater				Total Withdrawals					
	AF Fresh	Saline	Total	% of Total Use	Fresh	Saline	Total Ground water	% of Total Use	Fresh	% of Total Use	Saline	% of Total Use	Total	% of Total Use
Public Water Supply	0	0	0	0%	11,423	0	11,423	100%	11,423	100%	0	0%	11,423	4%
Industrial	0	0	0	0%	78	0	78	100%	78	100%	0	0%	78	0%
Irrigation	0	0	0	0%	166,099	0	166,099	100%	166,099	100%	0	0%	166,099	62%
Livestock	56	0	56	2%	2,870	0	2,870	98%	2,926	100%	0	0%	2,926	1%
Aquaculture	0	0	0	0%	0	0	0	0%	0	0%	0	0%	0	0%
Mining	0	0	0	0%	325	81,642	81,968	100%	325	0.4%	81,642	99.6%	81,968	31%
Thermoelectric Power	0	0	0	0%	1,827	0	1,827	100%	1,827	100%	0	0%	1,827	1%
Domestic	0	0	0	0%	1,513	0	1,513	100%	1,513	100%	0	0%	1,513	1%
County Totals	**56**	**0**	**56**	**0%**	**184,136**	**81,642**	**265,778**	**100%**	**184,192**	**69%**	**81,642**	**31%**	**265,834**	**100%**

Source: Dieter et al. 2018.
Note: AF is acre-feet

Table 2-2. Eddy County 2015 Water Use by Category (AF)

Category	Surface Water				Groundwater				Total Withdrawals					
	AF Fresh	AF Saline	AF Total	% of Total Use	AF Fresh	AF Saline	AF Total	% of Total Use	AF Fresh	% of Total Use	AF Saline	% of Total Use	AF Total	% of Total Use
Public Water Supply	0	0	0	0%	15,077	0	15,077	100%	15,077	100%	0	0	15,077	8%
Industrial	0	0	0	0%	1,043	0	1,043	100%	1,043	100%	0	0%	1,043	1%
Irrigation	64,054	0	64,054	42%	89,994	0	89,994	58%	154,048	100%	0	0%	154,048	84%
Livestock	34	0	34	3%	1,289	0	1,289	97%	1,323	100%	0	0%	1,323	1%
Aquaculture	0	0	0	0%	0	0	0	0%	0	0%	0	0%	0	0%
Mining	0	0	0	0%	1,169	10,993	12,162	100%	1,169	10%	10,993	90%	12,162	6%
Thermoelectric Power	0	0	0	0%	0	0	0	0%	0	0%	0	0%	0	0%
Domestic	0	0	0	0%	258	0	258	100%	258	100%	0	0%	258	0%
County Totals	**64,088**	**0**	**64,088**	**35%**	**108, 830**	**10,993**	**119,823**	**65%**	**172,918**	**94%**	**10,993**	**6%**	**183,910**	**100%**

Source: Dieter et al. 2018. Note: AF is acre-feet

Table 2-3. Chavez County 2015 Water Use by Category (AF)

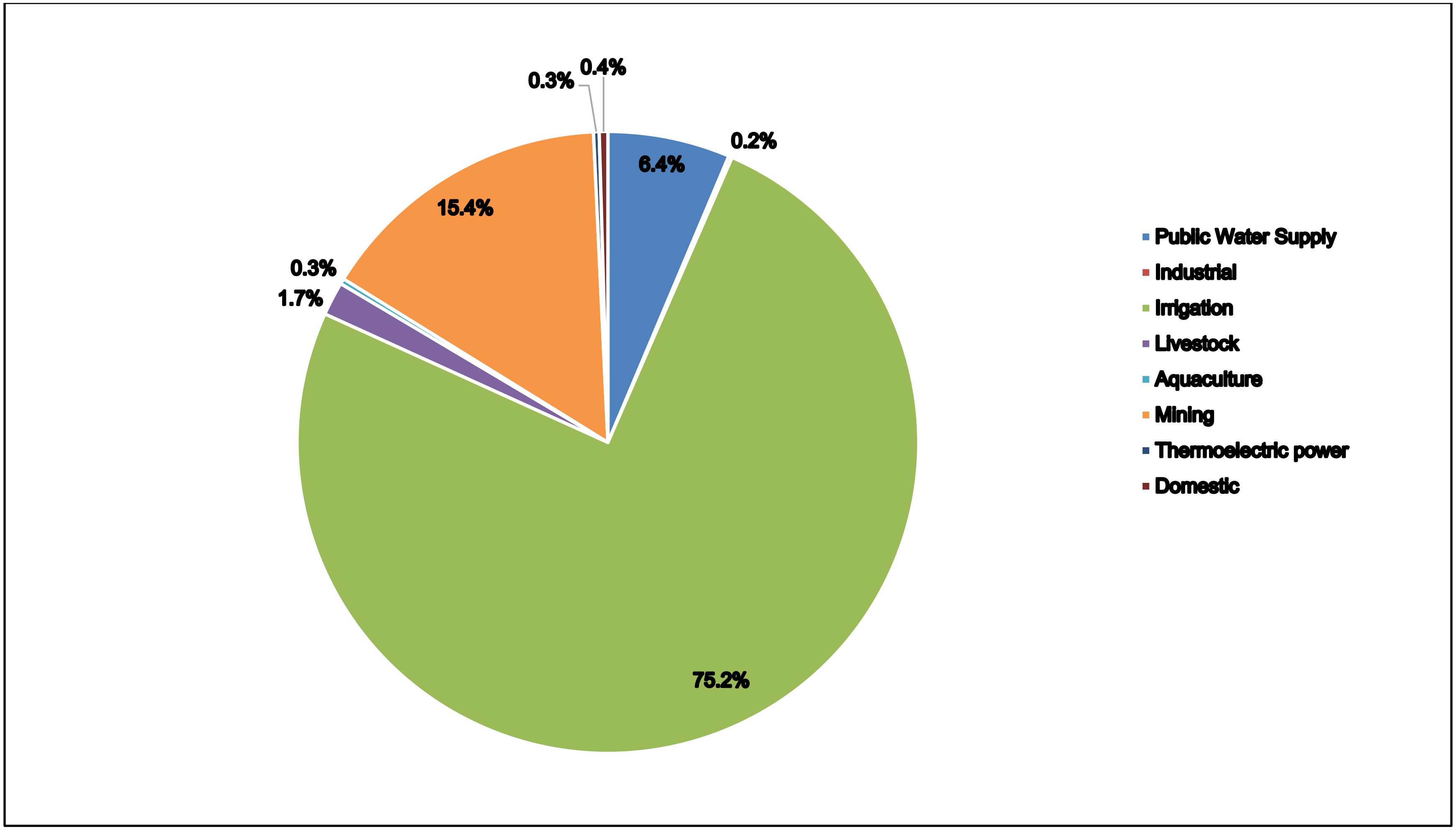
Category	Surface Water				Groundwater				Total Withdrawals					
	AF Fresh	AF Saline	AF Total	% of Total Use	AF Fresh	AF Saline	AF Total	% of Total Use	AF Fresh	% of Total Use	AF Saline	% of Total Use	AF Total	% of Total Use
Public Water Supply	0	0	0	0%	12970	0	12,970	100%	12,970	100%	0	0	12,970	8%
Industrial	0	0	0	0%	0	0	0	0%	0	0%	0	0%	0	0%
Irrigation	9,854	0	9,854	7%	136,784	0	136,784	93%	146,638	100%	0	0%	146,638	86%
Livestock	224	0	224	3%	6,378	0	6,378	97%	6,603	100%	0	0%	6,603	4%
Aquaculture	0	0	0	0%	1,782	0	1,782	100%	1,782	100%	0	0%	1,782	1%
Mining	0	0	0	0%	78	1,592	1,670	100%	78	5%	1,592	95%	1,670	1%
Thermoelectric Power	0	0	0	0%	0	0	0	0%	0	0%	0	0%	0	0%
Domestic	0	0	0	0%	1,009	0	1,009	100%	1,009	100%	0	0%	1,009	1%
County Totals	**10,078**	**0**	**10,078**	**6%**	**159,003**	**1,592**	**160,594**	**94%**	**169,080**	**99%**	**1,592**	**1%**	**170,672**	**100%**

Source: Dieter et al. 2018.

Table 2-4. Pecos District Tri-County Area 2015 Water Use by Category (AF)

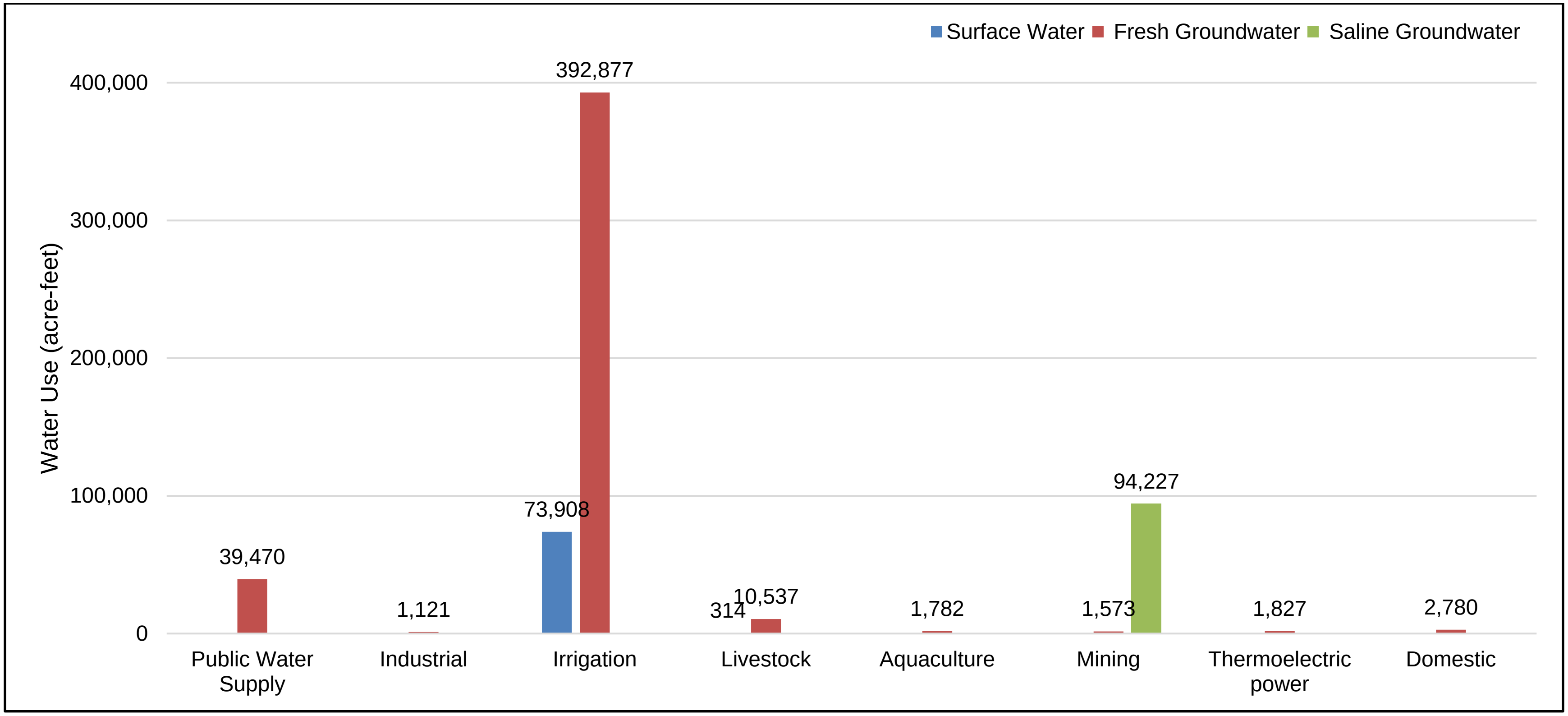
Category	Surface Water				Groundwater				Total Withdrawals					
	AF Fresh	AF Saline	AF Total	% of Total Use	AF Fresh	AF Saline	AF Total	% of Total Use	AF Fresh	% of Total Use	AF Saline	% of Total Use	AF Total	% of Total Use
Public Water Supply	-	-	-	0%	39,470	-	39,470	100%	39,470	100%	0	0	39,470	6%
Industrial	-	-	-	0%	1,121	-	1,121	100%	1,121	100%	0	0%	1,121	0%
Irrigation	73,908	-	73,908	16%	392,877	-	392,877	84%	466,784	100%	0	0%	466,784	75%
Livestock	314	-	314	3%	10,537	-	10,537	97%	10,851	100%	0	0%	10,851	2%
Aquaculture	-	-	-	0%	1,782	-	1,782	100%	1,782	100%	0	0%	1,782	0%
Mining	-	-	-	0%	1,573	94,227	95,800	100%	1,573	1%	24,227	99%	95,800	15%
Thermoelectric Power	-	-	-	0%	1,827	-	1,827	100%	1,827	100%	0	0%	1,827	0%
Domestic	-	-	-	0%	2,780	-	2,780	100%	2,780	100%	0	0%	2,780	0%
District Totals	**74,221**	**-**	**74,221**	**12%**	**451,968**	**24,227**	**546,195**	**88%**	**526,195**	**85%**	**24,227**	**15%**	**620,416**	**100%**

Source: Dieter et al. 2018. Note: AF is acre-feet.



Source: Dieter et al. 2018.

Figure 2.1. Pecos District Tri-County Area 2015 water use (in acre-feet) by category.



Source: Dieter et al. 2018.

Figure 2.2. Pecos District Tri-County Area 2015 water use (acre-feet) by water type and category.

State of New Mexico Water Use

In 2015, withdrawals for all water use categories across the State of New Mexico totaled 3,249,667 AF (Dieter et al. 2018). Pecos District Tri-County Area total water usage (620,416 AF) accounted for about 19 percent of the total state withdrawals. Table 2-5 lists the water for the major categories in New Mexico. As shown in the table, *Mining* water withdrawals totaled 163,901 AF, or about 5 percent of the total water withdrawals for the State of New Mexico. While the data presented in this table are for the state as a whole, most water use in this category is from the Permian Basin with some water use from the San Juan Basin. Table 2-6 presents water use associated with oil and gas development in New Mexico, by county. As shown in Table 2-6, over 99 percent of the water use associated with oil and gas development occurs in the Pecos District Tri-County Area (3,994 AF). Water use associated with oil and gas development comprises approximately 2.5 percent of the statewide *Mining* water use (163,901 AF, see Table 2-5) and 4.2 percent of the Pecos District Tri-County Area *Mining* water use (95,800 AF, see Table 2-4.

Table 2-5. State of New Mexico 2015 Use by Category (AF)

Category	Surface Water				Groundwater				Total Withdrawals					
	AF Fresh	AF Saline	AF Total	% of Total Use	AF Fresh	AF Saline	AF Total	% of Total Use	AF Fresh	% of Total Use	AF Saline	% of Total Use	AF Total	% of Total Use
Public Water Supply	87,752	-	87,752	30%	205,715	-	205,715	70%	293,467	100%	-	-	293,467	9%
Industrial	-	-	-	0%	3,811	-	3,811	100%	3,811	100%	-	-	3,811	0%
Irrigation	1,485,112	-	1,485,112	56%	1,175,312	-	1,175,312	44%	2,660,424	100%	-	-	2,660,424	82%
Livestock	2,522	-	2,522	7%	33,372	-	33,372	93%	35,894	100%	-	-	35,894	1%
Aquaculture	6,109	-	6,109	23%	20,929	-	20,929	77%	27,039	100%	-	-	27,039	1%
Mining†	19,550	-	19,550	12%	44,111	100,240	144,351	88%	63,662	39%	100,240	61%	163,901	5%
Thermoelectric Power	30,637	-	30,637	82%	6,872	-	6,872	18%	37,509	100%	-	-	37,509	1%
Domestic	-	-	-	0%	27,621	-	27,621	100%	27,621	100%	-	-	27,621	1%
Totals	1,631,683	-	1,631,683	50%	1,517,744	100,240	1,617,984	50%	3,149,427	97%	100,240	3%	3,249,667	100%

Source: Dieter et al. 2018; updated with additional information provided to the BLM from the New Mexico Office of the State Engineer (NMOSE) regarding water use of the Navajo Power Plant (BLM 2019a).

† Approximately 19,550 AF of the freshwater use within the Mining industry is from surface water; the remainder of all other water use is from groundwater. The Mining category includes the following self-supplied enterprises that extract minerals occurring naturally in the earth's crust: solids, such as potash, coal, and smelting ores; liquids, such as crude petroleum; and gases, such as natural gas. This category includes water used for oil and gas production (well drilling and secondary recovery of oil), quarrying, milling (crushing, screening, washing, flotation, etc.), and other processing done at the mine site or as part of a mining activity, as well as water removed from underground excavations (mine dewatering) and stored in—and evaporated from—tailings ponds. The Mining category also includes water used to irrigate new vegetative covers at former mine sites that have been reclaimed. It does not include the processing of raw materials, such as smelting ores, unless this activity occurs as an integral part of a mining operation and is included in an NMOSE permit.
Note: AF is acre-feet.

Table 2-6. 2015 State of New Mexico Water Use Associated with Oil and Gas Development (AF)

County	Surface Water	Groundwater	Total	% of Total
Bernalillo	0	7	7	0%
Chaves	0	84	84	2%
Eddy	0	2,635	2,635	65%
Lea	0	1,275	1,275	32%
San Juan	30	0	30	1%
Sierra	0	1	1	0%
State Total	**30**	**4,002**	**4,032**	**100%**

Source: NMOSE 2019.
Note: AF is acre-feet.

2.1.2. Water Use Associated with Reasonably Foreseeable Oil and Gas Development

The reasonable foreseeable development (RFD) scenario for the BLM New Mexico Pecos District (Engler and Cather 2012; 2014) was developed as a reasonable estimate of development associated with hydrocarbon production in southeast New Mexico for the next 20 years in the New Mexico portion of the Permian Basin. The RFD is a comprehensive study of all existing plays and an analysis of recent activity, historical production, emerging plays for future potential, and completion trends. Table 2-7 presents planning factors from the RFD.

Table 2-7. RFD Planning Factors

Factor	RFD
Time Frame	2015–2035
Number of wells	16,000 (approximately 800 per year, federal and non-federal)
Average Water Use, Horizontal Well	7.3 AF (2.4 million gallons)[+]
Average Water Use, Vertical Well	1.53 AF (500,000 gal)
Number of Wells Needed for Reservoir Development (play)	4 wells per section per play (horizontal wells)
Percentage of horizontal wells in Bone Spring Formation	84% horizontal
Percentage of horizontal wells in Leonard Formation	14% horizontal

Source: Engler and Cather 2012; 2014
[+] Although the RFD (Engler and Cather 2012; Engler and Cather 2014) estimates water use for a single horizontal well to be 7.3 AF, additional information (FracFocus 2018; Kondash et al. 2018) has shown that water use in the Permian Basin has increased based on an increased use of hydraulic fracturing.
Note: AF is acre-feet.

As shown in the table above, the RFD concluded that the average water use for a single horizontal well was 7.3 AF. This figure was based on a study of the Bone Spring Formation using data from 2013. Since that time, an estimate of 34.4 AF/horizontal well for the Permian Basin in 2016 was provided by Kondash et al. (2018). The report concluded that "…the Permian Basin (Texas and New Mexico) had the largest increase in water use (770 percent), from 4900 m^3 per well (3.97 AF) in 2011 to 42500 m^3 per well (34.4 AF) in 2016" (Kondash et al. 2018). Because of this new information, BLM conducted studies using calendar year 2017 and 2018 data from FracFocus, a national hydraulic fracturing chemical registry managed by the Ground Water Protection Council and Interstate Oil and Gas Compact Commission, to provide objective information on hydraulic fracturing. Operators are required by the State of New Mexico to disclose chemistry and water use information on FracFocus.

Reported water use in 2017 was 13,962 AF, of which 21 percent (2,959 AF) was associated with federal wells (FracFocus 2017). Reported water use in 2018 was 21,742 AF, of which 32 percent (6,936 AF) was associated with federal wells (FracFocus 2018). These figures are higher than 2015 reported oil and gas water use (see Table 2-6) and corroborate that water use associated with hydraulic fracturing in the Permian Basin has been increasing in recent years. Analysis of the 2017 data set, consisting of 522 records, resulted in an expected value of 26.9 AF, standard deviation of 17.47 AF, and a median of 24.78 AF. Analysis of the 2018 data set, consisting of 696 records, resulted in a mean of 31.2, standard deviation of 18.8 AF, and a median of 27.98 AF. As a result of these studies, the BLM considers the estimate of 31.2 AF as the best current estimate of water use per horizontal well in the Pecos District.

Note that if more water-intensive stimulation methods (e.g., slick water fracturing) are implemented or if laterals become longer, water use could increase from this estimate. Alternatively, water use estimates could be lower if produced water is reused or recycled for use in hydraulic fracturing. Public concern about water use from hydraulic fracturing is especially high in semiarid regions, where water withdrawals for hydraulic fracturing can account for a significant portion of consumptive water use within a given region. The BLM will continue to evaluate reported water use in FracFocus and other data and will revise water use estimates to be used in NEPA evaluations accordingly.

2.1.3. Cumulative Water Use Estimates

Past and Present Actions

Pecos District total water usage (620,416 AF) accounted for about 19 percent of the total state withdrawals (3,249,667 AF). Mining (which includes oil and gas development) comprises approximately 15 percent of Pecos District water withdrawals. Water use associated with oil and gas development (4,032 AF) comprises approximately 2.5 percent of the statewide Mining water use (163,901 AF), 4.3 percent of the Pecos District Tri-County Area Mining water use (95,800 AF), and 0.7 percent of Pecos District total water usage. The largest water use category within the county and the state is agricultural, comprising 75 percent of all water use within the Pecos District and 82 percent of all water use within the state. This trend is expected to continue.

The BLM examined FracFocus data reported for the calendar years of 2014 to 2018 (FracFocus 2019) to ascertain water use, cumulative water use, and water use trends in the New Mexico portion of the Permian Basin; that is, for Chaves, Eddy, and Lea Counties (Table 2-8).

Consumptive water use by municipal, industrial, and agricultural activities (including oil and gas activities) represents a single element of a hypothetical water budget for the planning area. While a detailed water budget quantifying hydrologic inputs and outputs for the planning area is outside the scope of this document, it should be noted that various hydrologic inputs are occurring alongside the consumptive water use depicted in Figure 2.4 and Figure 2.5. Groundwater can be recharged through a variety of processes such as precipitation, irrigation return flow, and seepage from rivers and streams. Similarly, groundwater discharge in the planning area occurs not only through consumptive water use, but also through evapotranspiration and discharge from springs and seeps.

Table 2-8. Actual Water Use in the New Mexico Portion of the Permian Basin for Calendar Years 2014-2018

Year	Federal Water Use (AF)	Non-Federal Water Use (AF)	Total Water Use (AF)	Federal Water Use (Percent)	Federal Cumulative Water Use (AF)	Total Cumulative Water Use (AF)	Average Water Use per Well (AF)	Total # of Wells Reported to FracFocus
2014	1,307	2,509	3,816	34%	1,307	3,816	6.82	559
2015	4,033	4,336	8,369	48%	5,340	12,185	15.82	529
2016	710	6,091	6,801	10%	6,050	18,986	21.66	314
2017	2,964	11,418	14,382	21%	9,014	33,368	26.44	544
2018	8,411	19,681	28,092	30%	17,425	61,460	31.04	905
Total	**17,425**	**44,035**	**61,460**	**--**	**--**	**--**	**--**	**2,851**

Source: FracFocus 2019
Note: The New Mexico portion of the Permian Basin is comprised of Lea, Chaves, and Eddy Counties.

Water use has increased from 3,816 AF in 2014 to 28,092 AF in 2018, with a corresponding basin-wide average water use per well increase from 6.82 AF per well to 31 AF per well (FracFocus, 2019). A cumulative total of 61,460 AF of water was used for oil and gas between the years 2014–2018 (FracFocus 2019). Total federal cumulative water use in the basin for the same time period was 17,425 AF, accounting for 28 percent of the total water use. The total number of wells that were reported to FracFocus increased from 559 wells in 2014 to 905 wells in 2018 (FracFocus 2019).

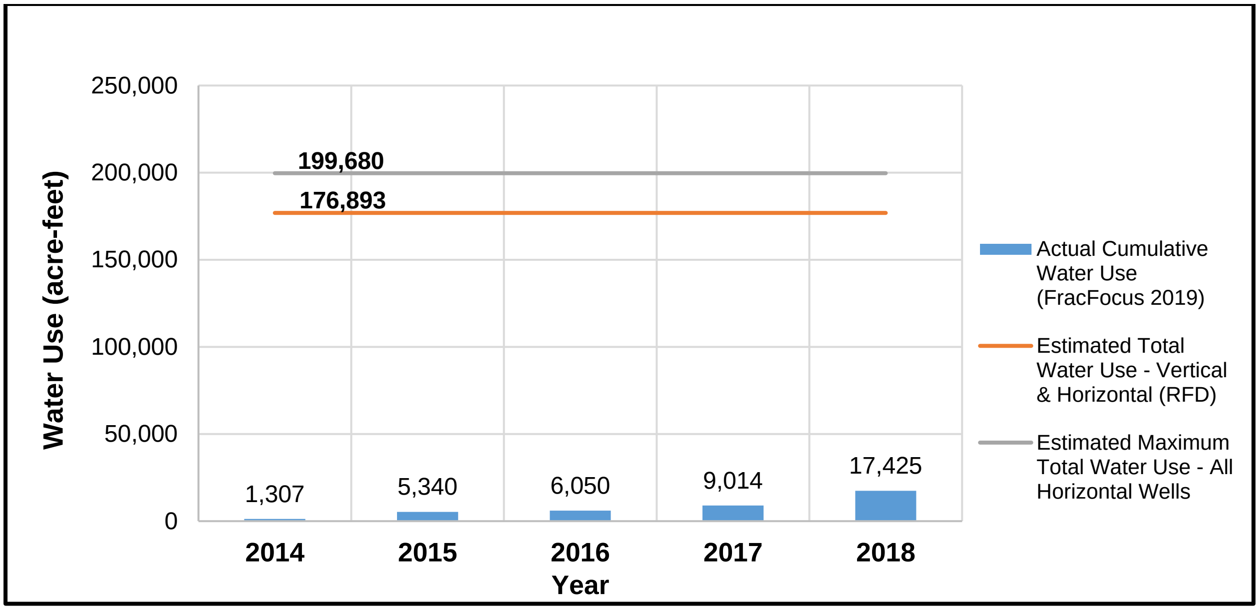
Reasonably Foreseeable Future Actions (RFFAs)

Oil and Gas Development RFFAs

RFD Scenario

Between 2012 and 2014, the BLM prepared an RFD scenario for the Pecos District that projected approximately 800 new wells per year, for a total of 16,000 wells over a 20-year period (Engler and Cather 2012; 2014). Of that total, approximately 6,400 wells would be developed on BLM-administered lands (federal surface or subsurface); the remaining 9,600 wells would be developed on state or private lands. Well development projected as a result of ongoing BLM and state lease sales is already considered in the RFD. Well development associated with recent or reasonably foreseeable Applications for Permit to Drill (APDs) or master development plans is also included in the RFD.

Figure 2.3 shows past cumulative water use between 2014 and 2018 for the 6,400 federal wells in the Permian Basin (FracFocus 2019) compared to water use estimates from the RFD scenario (Engler and Cather 2012; 2014). Two water use scenarios are depicted for the RFD. The upper end estimate (shown in grey in Figure 2.3) is derived by assuming all new wells would be horizontal. If all 6,400 wells were drilled horizontally, the total water use is estimated to be 199,680 AF, or 9,984 AF in any given year. The alternative scenario (shown in orange in Figure 2.3 is derived by using the estimated vertical and horizontal breakout of federal wells provided in the RFD (88 percent horizontal and 12 percent vertical). Under this scenario, development of 6,400 new federal wells would require 176,893 AF, or 8,845 AF in any given year



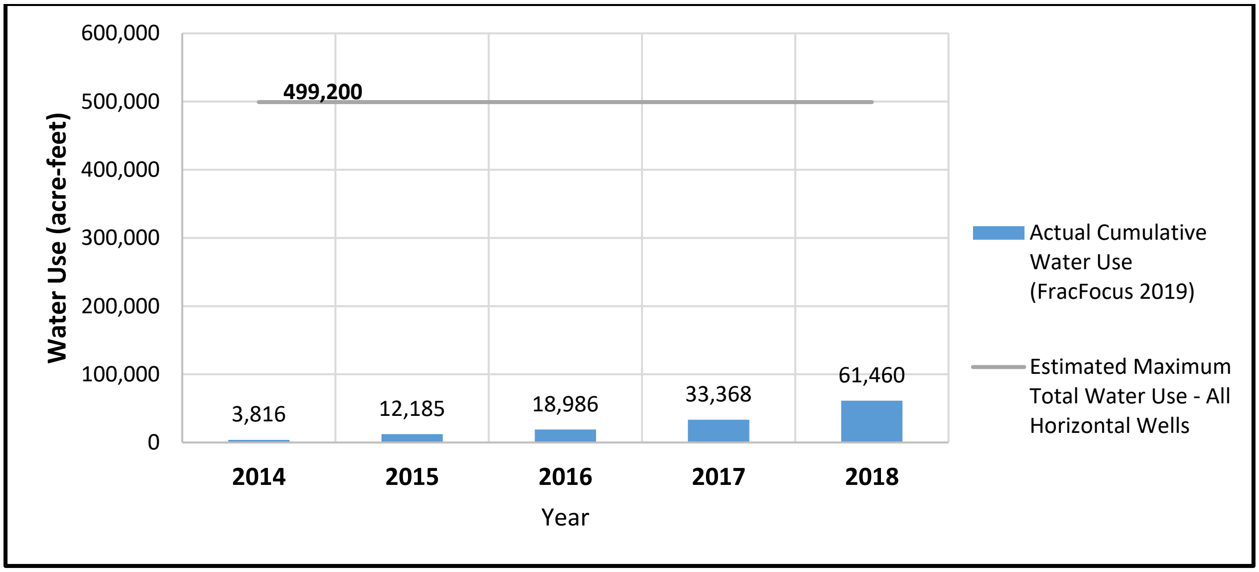
Note: Actual past cumulative federal well water use is calculated by adding the sum of all previous actual water use to the actual water use for any given year (data from 2014-2018 from FracFocus 2019). Projected water use for the federal well component of the RFD (6,400 wells; Engler and Cather 2012; 2014) is displayed for two potential scenarios providing an upper and lower end estimate of water use. The upper end estimate (shown in grey) comes from assuming all 6,400 new wells to be horizontal, while the lower end estimate (shown in orange) uses the revised water use estimates discussed in Section 2.1.2 (31.2 AF per horizontal wells), and assumes 88% of the 6,400 new wells will be drilled horizontally.

Figure 2.3. Actual Water Use (2014-2018) Compared to Projected Water Use for Federal Wells in the Permian Basin.

With consideration of the revised water use estimates presented above (31.2 AF per horizontal well), development of all 16,000 wells in the RFD (assuming all wells would be drilled horizontally) would require 499,200 AF of water, or 24,960 AF in any given year. Figure 2.4 shows actual cumulative water use between 2014 and 2018 for all wells (both federal and non-federal) in the Permian Basin (FracFocus 2019) compared to water use estimates from the RFD scenario (Engler and Cather 2012; 2014).
The upper end estimate (shown in grey in Figure 2.4) is derived by assuming all 16,000 wells in the RFD scenario would be drilled horizontally.

2019 Water Use Trends

Based on APDs received by the BLM Carlsbad Field Office and Roswell Field Office in 2019, the water use volumes for 2019 are expected to be very similar to those in 2018. In 2020, once the 2019 FracFocus actual water use data is released, these projections would be compared to the actual water use, and this report would be updated accordingly.



Note: Actual water use from FracFocus 2019. Cumulative water use for each year is calculated by adding the sum of all previous actual water use to the actual water use for any given year. The maximum water use estimate comes from assuming all new wells to be horizontal.

Figure 2.4. Actual Water Use (2014-2018) Compared to Projected Water Use for All Wells in the Permian Basin Reasonably Foreseeable Future Actions (RFFAs)

Other RFFAs

There are no mining RFFAs that would contribute to cumulative water withdrawals within the Pecos District. Some water use would be required during construction and operation of some reasonably foreseeable transmission lines and pipelines; these uses may vary depend on local conditions (for example, the need for dust control) and therefore are not quantified in this analysis. Future water use for the other reported water use categories in the Pecos District is assumed to continue at current levels.

Cumulative Impacts

Development of all RFFAs (as represented by the full RFD) would require 24,960 AF of water in any given year. This is about 4 percent of Pecos District Tri-County 2015 total water withdrawals (620,416 AF, which already includes past and present actions. Agriculture would remain by far the largest water use within the county (currently 75 percent of all water use within the Pecos District and 82 percent of all water use within the state).

2.1.4. Potential Sources of Water for Project Development

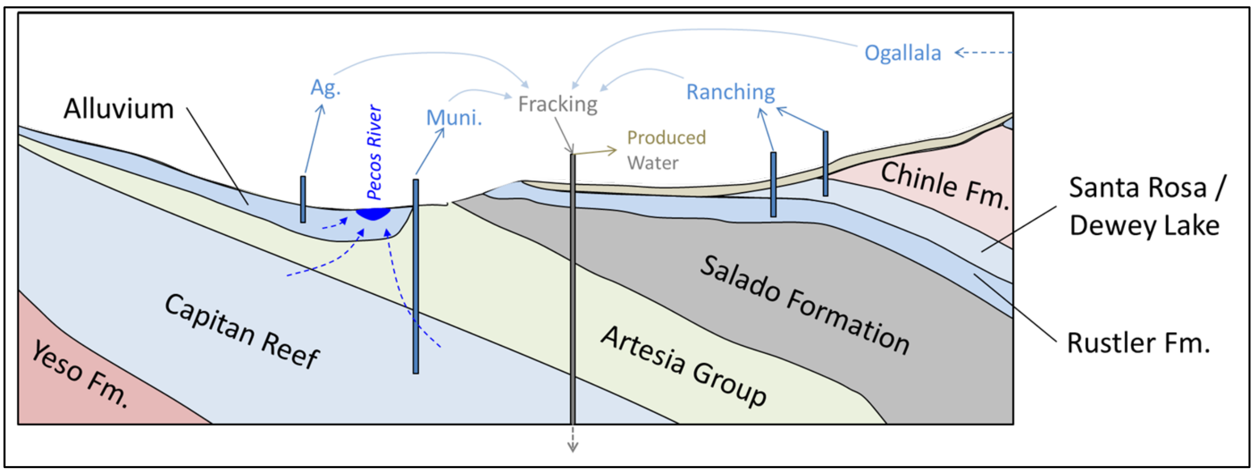
The Pecos District contains a variety of surface waters, from springs and seeps to lakes, playas, rivers, and ephemeral drainages and draws. Waters from spring developments, reservoirs or streams, and stream diversions within the planning area are used primarily for irrigation, livestock, and wildlife. No surface waters used for domestic purposes originate on BLM-managed land. Diversions on BLM-managed lands support private land crop irrigation and stock water needs. Water use associated with oil and gas drilling is primarily from groundwater. Table 2-9 shows the potential sources of groundwater in the Pecos District. Figure 2-6 is an idealized cross section of these aquifers. It is speculative to predict the actual source of water that would be used for development of the RFD (or the development of any specific lease sales). However, because approximately 88 percent of all water use and 100 percent of all mineral use in the Pecos District is currently from groundwater, it is reasonable to assume that water used for development of the RFD would likely be groundwater. Water used for oil and gas drilling and completion would be purchased legally from those who hold water rights in or around the Permian Basin.

The transaction would be handled by the New Mexico Oil Conservation Division, as well as the NMOSE. All water uses would be evaluated at the APD stage in site-specific NEPA analysis and subject to standard lease terms and conditions; however, it is important to note that sources of water for lease development are also not always known at the APD stage.

Table 2-9. Potential Sources of Groundwater in the Pecos District

Aquifer Name	Description
Pecos Valley Alluvium	Surficial deposits along the Pecos River. No known recharge areas.
Dewey Lake and Santa Rosa	Redbed sandstones. Inconsistent water source. Recharge occurs closer to the surface, as a result of weather events.
Rustler Formation (Culebra and Magenta)	Dolomite, fractured and dissolution zones. Local recharge occurs, largely as a result of weather events.
Capitan Reef	Limestone, Karstic formation. Good quality west of the Pecos, low quality towards the east. Recharge in the west occurs mainly in the vicinity of the Guadalupe Mountains. Recharge in the east occurs in the vicinity of the Glass Mountains (in Texas). The New Mexico portion of the eastern part of the Capitan Reef is recharging at a high rate.
Ogallala	Sand and gravel. Offsite aquifer where water imported to area.

Source: Lowry et al 2018.



Source: Summers 1972.

Figure 2.5. Idealized geologic cross-section of potential water sources in the Pecos District.

A recent study conducted by Sandia National Laboratory (Lowry et al. 2018) was completed in portions of Eddy and Lea Counties that were identified as having of high potential for oil and gas development in the RFD. The study was undertaken to establish a water-level and chemistry baseline and develop a modeling tool to aid the BLM in understanding the regional water supply dynamics under different management, policy, and growth scenarios and to pre-emptively identify risks to water sustainability. The following section summarizes key information in that report related to groundwater sources.

Four high potential areas (HPAs) were studied. The HPAs were associated with the Alto Platform, Bone Spring, and Delaware Mountain Group plays and were limited the extent of each to development on federal lands managed by the BLM.

Most of the wells that were sampled in each HPA appeared to have a mix of source waters, and establishing definitive signatures for each aquifer was not possible. However, evidence shows that the main water source for wells in the North HPA (which included Loco Hills and areas along the Pecos River) are from the Dewey Lake and Santa Rosa aquifer or another perched source in the host Dockum Formation. For the Center North HPA (which encompasses a region known as Burton Flats), the main sources are from the Dewey Lake and Santa Rosa aquifer and the Rustler Formation. For the South HPA (located near Malaga and Loving), the main water sources are the Dewey Lake and Santa Rosa aquifer. The east HPA, which primarily represents the Ogallala aquifer, was excluded from the study because only a small percentage of the land is managed by the BLM and because the aquifer is heavily pumped for agricultural purposes throughout several states, which would require a broader study of the overall aquifer (Lowry et al. 2018). The study also sampled wells that access water from the Capitan Reef, located near the community of Carlsbad.

Select wells were also monitored using both continuous and manual water level measurements throughout the study:

- Water levels in the two sampling water wells located in the North HPA fluctuated only slightly (>1 pounds per square inch [psi]) and carried no obvious trend, indicating a high likelihood that the water level variations are naturally occurring through seasonal and barometric pressure fluctuations.
- Of the two monitoring wells located in the Center North HPA, one showed only water level changes suggestive of barometric effects and seasonal change; the other well displayed a sharp water level increase. The cause of this change is conjectured to be from active drilling, pumping, or injecting near the well.
- Of the 16 wells monitoring the South HPA:
    - Two wells showed minimal water level change with a slight increasing trend over time, indicating that the aquifer is not being locally impacted by pumping or aquifer development.
    - Two wells showed pressure variations that are typical to nearby pumping. One well was located near a known oil supply well which is the likely driver to the drawdown and recovery response; the other was located near a municipal water supply well and its erratic response is indicative of pumping cycles associated with a small community water supply.
    - Five wells displayed water level changes that are typical for aquifers affected by seasonal variations in pressure and barometric effects.
    - Three wells showed minor water level changes likely due to activity in adjacent wells. The origins of the aquifer activity affecting each well are unknown, but likely due to oilfield drilling activities.
    - One well had drastic changes in water level as a result of nearby pumping tests conducted as part of monitoring of the Waste Isolation Pilot Plant (WIPP).
    - Three wells displayed water level changes due to high production pumping by a local ranch.
- Of the five wells monitoring the Capitan Reef, two wells recorded pressure decreases. The source of the pressure change is undetermined; however, it is likely these wells are influenced by precipitation given their shallow depth and the karstic nature of the formation, as well as from localized municipal pumping by the City of Carlsbad. The remaining three wells recorded water levels increasing at a relatively constant rate. This suggests that the aquifer in the eastern part of the Capitan Reef is experiencing recharge.

A model is being developed as part of the Sandia Report to simulate water availability over a range of different future scenarios, including drilling activity and water demand to identify areas that are most vulnerable and to estimate the risk to water sustainability. The model is still under development, but when completed, it will allow BLM to look at the balances between water demand and water availability to predict and track both risks to each aquifer as well as calculate well drawdown. The intent is to screen future water extraction that may be unsustainable. The Carlsbad FO will have the capacity to apply this model during future NEPA actions.

2.1.5. Water Use Mitigations

Overall, there have been calls to increase the use of alternative water sources such as brackish water or recycling produced water, minimizing the strain on local freshwater resources (Kondash et al. 2018). The BLM encourages the use of recycled water in hydraulic fracturing techniques.

Moreover, recent studies indicate that the water used for hydraulic fracturing may be retained within the shale formation, with only a small fraction of the fresh water injected into the ground returning as flowback water; water returning to the surface is highly saline, is difficult to treat, and is often disposed through deep-injection wells (Kondash et al. 2018). Thus, the ability to recycle water may be more limited than previously reported. Note that the water use calculations above do not assume the use of recycled water.

2.2. Water Quality

2.2.1. Groundwater

As noted in Section 2.1, the BLM contracted with Sandia National Laboratory to prepare a report (Lowry et al. 2018) on water sustainability in the Permian Basin related to oil and gas development. The following section summarizes key information in the report related to groundwater quality.

Total dissolved solids (TDS) concentration is a measure of all the dissolved matter in a sample of water. TDS is the primary indicator of groundwater quality as higher TDS concentrations typically make water less suitable for drinking or for agricultural purposes like irrigation. In groundwater, TDS is influenced by the dissolution of natural materials such as rock, soil, and organic material. Anthropogenic activities also contribute to TDS concentrations in shallow unconfined aquifers. Groundwater quality in Eddy and Lea Counties and in the Lower Pecos Valley varies considerably depending on the aquifer and location. In general, groundwater on the west side of the Pecos River is fresher than groundwater on the river's east side. East of the Pecos River, salinity is higher and can reach concentrations of 35,000 milligrams per Liter (mg/L). Shallow groundwater quality can be very good in the alluvial aquifers, but of poor quality in deeper geologic formations due to the presence of salt, gypsum, and other evaporite deposits. Groundwater tends to be mineralized or 'hard' west of the Ogallala aquifer (Lowry et al. 2018). Typical ranges of total dissolved solids (TDS) along with the general aquifer materials are shown in Table 2-9.

Table 2-10. Typical TDS Ranges Found in the Main Aquifers of the Pecos District

Aquifers	Aquifer Material	Typical TDS Range (mg/L)
Pecos	Alluvium	<200 to 10,000
Rustler (includes Culebra and Magenta)	Carbonates and Evaporites	<1,000 to 4,600
Dockum (includes Dewey Lake and Santa Rosa)	Sandstone and Conglomerates	<5,000 to >10,000
Capitan Reef	Dolomite and Limestone	300 to >5,000

Source: Lowry et al. 2018.

Overall 30 wells in the South HPA, 11 wells in the Center North HPA, and 19 wells in the North HPA were selected for water quality analysis. The predominant water types for each of the HPAs and the Capitan Reef are listed below

1. North – calcium and magnesium dominant
2. Center North – sodium and calcium dominant
3. South – sodium and calcium dominant
4. WIPP – sodium and chloride dominant
5. Capitan Reef – sodium dominant

The samples were also compared to the New Mexico Water Quality Control Commission (NMWQCC) human health, domestic water supply, and irrigation use standards for groundwater with a TDS concentration of 10,000 mg/L or less (20.6.2.3103 New Mexico Administrative Code [NMAC]). Table 2-10 presents a listing of the sampled water quality parameters by HPA against the NMWQCC standards for drinking water.

Table 2-11. Sampled Water Quality Parameters Against NMWQCC Drinking Water Standards

Parameter	NMWQCC Standard	North HPA	Central North HPA	South HPA and WIPP	Capitan Reef
pH (pH units)	6 to 9	7.07 - 7.97	7.53 - 7.97	6.18 - 8.59	8.08 - 8.86
Specific Conductance (μmhos/cm)	--	1000 - 3905	1300 - 83000	600 - 270000	2770 - 174500
Total Dissolved Solids (TDS)	1000	331 - 3550	869 - 43000	322 - 330000	1951 - 141875
Calcium (Ca2+)	--	0.73 - 590	2.6 - 920	0.7 - 1900	1.4 - 5902
Magnesium (Mg2+)	--	23 - 200	44 - 1492	2.10 - 10000	82.26 - 1420
Sodium (Na+)	--	18 - 262	92.58 - 12000	26 - 95000	225 - 46700
Potassium (K+)	--	0 - 30	4 - 1136	0 - 21000	6.58 - 3352
Chloride (Cl-)	250	16 - 1000	97 - 21000	11 - 190000	388.80 - 82602.1
Alkalinity (CaCO3)	--	139 - 312	19.9 - 181.2	23 - 297.10	18.53 - 250.10
Bicarbonate (HCO3-)	--	139 - 312	19.8 - 181.2	39.72 - 297.10	18.74 - 249.27
Carbonate (CO3-)	--	0 - <2	0 - <2	0 - 16.08	0 - 0.83
Sulfate (SO42-)	600	0 - 1900	306.71 - 6400	0 - 15000	0 - 1975.67
Fluoride (F-)	1.6	0 - 1.3	0.82 - 2.60	0.00 - 3.63	0.09 - 0.52
Nitrite (NO2)	10	0 - 6.27	0 - 8.8	0.00 - 20.08	0.05 - 7.60
Nitrate (NO3)	10	0 - 10	2.6 - 8.8	0 - 19	0.04 - 7.60
Silver (Ag)	0.05	--	--	--	0
Aluminum (Al)	5	--	0.18	0 – 4.06	--
Arsenic (As)	0.1	0.02 – 0.06	0.03 - 0.32	0 – 0.29	0.10
Barium (Ba)	1	0.01 – 0.13	0.01 - 0.03	0- 0.1	0.02 - 0.25
Bromide (Br)	--	0 - 7.8	0.28 - 12.00	0 - 1400	0.3 - 12.73
Cadmium (Cd)	0.01	--	--	--	--
Copper (Cu)	1	0.02	0.03	0.06 - 0.37	--
Iron (Fe)	1	3.34	0.04	0.01 - 1.62	3.41
Lithium (Li)	--	0.14 - 1.70	0.140 - 1.695	0.05 - 0.85	0.04 - 4.49
Manganese (Mn)	0.2	0 - 0.06	0 - 0.20	0 - 0.06	0 - 7.61

Parameter	NMWQCC Standard	North HPA	Central North HPA	South HPA and WIPP	Capitan Reef
Nickel (Ni)	0.2	--	0 - 0.02	0 - 0.01	0.01
Lead (Pb)	0.05	0.04	--	0.02 - 0.06	--
Silicon (Si)	--	2.67 - 18.38	1.9 - 23.4	4.91 - 47.0	0 - 7.10
Strontium (Sr2+)	--	0.63 - 8.47	2.73 - 13.75	0.05 - 32.0	2.52 - 104.8
Vanadium (V)	--	--	0.01 - 0.03	0 - 0.1	--

Source: Lowry et al. 2018.
Notes: Units are milligrams per liter (mg/L) unless otherwise noted. "—" = not applicable or not detected. Values rounded to two decimal places.

Key observations related to the comparison of results to the standards:

- Seventeen of the water quality parameters analyzed have applicable NMWQCC standards: pH, TDS, Cl-, SO42-, F-, NO3-+ NO2-, Ag, Al, As, Ba, Cd, Cr, Cu, Fe, Mn, Ni, Pb.
- No exceedances were observed for eight of the parameters with NMWQCC standards: pH, Ag, Al, Ba, Cd, Cr, Cu, and Ni.

2.2.2. Surface Water

Stream and river conditions vary widely, from completely undisturbed river and vegetative communities in the mountainous highlands, to deep, erodible soil banks at lower elevations where livestock, recreationists, and other public users have access to streams and riverbanks.

Water quality in streams flowing on BLM-managed land is influenced by both natural water quality with regard to salinity content and the intensity of human and industrial activity in the watershed. For example, water quality may be vastly different in a remote mountain spring creek than in waters with natural brine discharge, or where there are human impacts due to urban, farming, ranching, or industrial activity. Chemistry samples of surface water in the planning region are needed in order to establish a baseline chemistry data for the waters. Variances in baseline chemistry can indicate water quality changes attributable to land use development. The most common pollutants for waters in the planning area are sediment and mercury. Beneficial uses listed for these waters are industrial water supply, irrigation storage, livestock watering, recreation, warm water fishery, and wildlife habitat. The dominant legislation affecting national water quality and BLM compliance with New Mexico water quality requirements is the Clean Water Act (CWA) or Federal Water Pollution Control Act. Within the planning area, total maximum daily loads (TMDLs) determinations are not in place for any of the watersheds with 303(d)-listed streams. Thus, an assessment of their condition via this metric is not possible at the time.

2.2.3. Potential Sources of Surface Water or Groundwater Contamination

Spills

Spills associated with oil and gas development may reach surface water directly during the spill event. Spills may also reach surface waters indirectly, when the spill has occurred, and a rain event moves contaminants into nearby surface water bodies through surface water flow or even subsurface groundwater flow into springs that discharge into a surface water body.

There are approximately 15,660 federal wells within the New Mexico portion of the Permian Basin. planning area (BLM 2018). As shown in Table 2-11, there were a total of 1,261 spills in the Permian Basin in 2018. The rate of recovery varies by spill type but, in general, most spills are not recovered. No spills occurring in the Pecos District were reported as having affected surface or groundwater. Appendix C contains the methodology for spill analysis.

The BLM works with the State of New Mexico Oil Conservation Division (NMOCD) to remediate spills on public BLM lands. Per NMAC 19.15.29.11, the responsible person shall complete division-approved corrective action for releases that endanger public health or the environment in accordance with a remediation plan submitted to and approved by the division or with an abatement plan submitted in accordance with 19.15.30 NMAC. The remaining contaminates from unrecovered spills are remediated in accordance with federal and state standards. Some remediation consists of removing contaminated soil and replacing it with uncontaminated soil and corresponding chemical testing.

Table 2-12. Summary of 2018 Spills in the New Mexico Portion of the Permian Basin

Material Type	Count of Spills	Volume Spilled	Volume Lost	Units	% Lost
Acid	1	20	1	Barrels	5%
Basic sediment and water (BS&W)	5	19	9	Barrels	47%
Brine Water	3	1,570	1,531	Barrels	98%
Chemical	9	1,342	1,165	Barrels	87%
Condensate	13	405	258	Barrels	64%
Crude Oil	435	15,388	6,595	Barrels	43%
Diesel	3	24	16	Barrels	67%
Drilling Mud/Fluid	6	615	353	Barrels	57%
Other	26	15,049	14,060	Barrels	93%
Produced Water	606	90,931	44,775	Barrels	49%
Sulphuric Acid	1	20	15	Barrels	75%
Total	**1,108**	**125,383**	**68,778**	**Barrels**	**55%**
Natural Gas (Methane) and Natural Gas Liquids	153	144,813	144,813	MCF	100%
Total Number of Spills	**1,261**				

Source: NMOCD 2019.
Note: MCF is one thousand cubic feet

Drilling and Completion Activities

The BLM and NMOCD has casing, cementing, and inspection requirements in place to limit the potential for groundwater reservoirs and shallow aquifers to be impacted by fracking or the migration of hydrocarbons on the nominated lease parcels. Prior to approving an APD, a BLM geologist would identify all potential subsurface formations that would be penetrated by the wellbore including groundwater aquifers and any zones that would present potential safety or health risks that would need special protection measures during drilling, or that could require specific protective well construction measures. Casing programs and cement specifications would be submitted to the BLM and NMOCD for approval to ensure that well construction design would be adequate to protect the subsurface environment, including known or anticipated zones with potential risks or zones identified by the geologist. Surface casing would be set to an approved depth, and the well casing and cementing would stabilize the wellbore and provide protection to any overlying freshwater aquifers by isolating hydrocarbon zones from overlying freshwater aquifers. Before hydraulic fracturing takes place, all surface casings and intermediate zones would be required to be cemented from the bottom of the cased hole to the surface. The cemented well would be pressure tested to ensure there are no leaks, and a cement bond log would be run to confirm that the cement has bonded to the steel casing strings and to the surrounding formations.

The BLM requires operators to comply with the regulations at 43 Code of Federal Regulations (CFR) 3160. These regulations require oil and gas development to comply with directives in the Onshore Orders and the orders of the Authorized Officer. Onshore Order No. 2 and the regulations at 43 CFR 3162.3-3 provide regulatory requirements for hydraulic fracturing, including casing specifications, monitoring and recording, and management of recovered fluids. The State of New Mexico also has regulations for drilling, casing and cementing, completion, and plugging to protect freshwater zones (19.15.16 New Mexico Administrative Code). Complying with the aforementioned regulations requires producers and regulators to verify the integrity of casing and cement jobs. Casing specifications are designed and submitted to the BLM together with an APD. The BLM petroleum engineer independently reviews the drilling plan and, based on site-specific geologic and hydrologic information, ensures that proper drilling, casing, and cementing procedures are incorporated in the plan in order to protect usable groundwater. This isolates usable water zones from drilling, completion/hydraulic fracturing fluids, and fluids from other mineral bearing zones, including hydrocarbon bearing zones. Conditions of Approval (COAs) may be attached to the APD if necessary to ensure groundwater protection. Installations of the casing and cementing operations are witnessed by certified BLM Petroleum Engineering Technicians. At the end of the well's economic life, the operator must submit a plugging plan. The plugging plan is reviewed by the BLM petroleum engineer prior to well plugging, and ensures permanent isolation of usable groundwater from hydrocarbon bearing zones. BLM inspectors ensure planned procedures are properly followed in the field.

Surface casing and cement would be extended beyond usable water zones. Production casing will be extended and adequately cemented within the surface casing to protect other mineral formations, in addition to usable water bearing zones. These requirements ensure that drilling fluids, hydraulic fracturing fluids, and produced water and hydrocarbons remain within the well bore and do not enter groundwater or any other formations. Since the advent of hydraulic fracturing, more than 1 million hydraulic fracturing treatments have been conducted, with perhaps only one documented case of direct groundwater pollution resulting from injection of hydraulic fracturing chemicals used for shale gas extraction (Gallegos and Varela 2015). Requirements of Onshore Order No. 2 (along with adherence to state regulations) make contamination of groundwater resources highly unlikely, and there have not been any documented past instances of groundwater contamination attributed to well drilling. This is an indication of how effective the use of casing and cement is at preventing leaks and contamination.

CHAPTER 3. FARMINGTON FIELD OFFICE

Located in north-central New Mexico, the Farmington Field Office (FO) includes approximately 1.4 million acres of public lands, and encompasses all of San Juan County, most of McKinley County, western Rio Arriba County, and northwestern Sandoval County. The Farmington FO is also a part of the New Mexico portion of the San Juan Basin, an oil and gas basin that is in the northwestern portion of New Mexico and the southwestern portion of Colorado (BLM 2003).

Chapter 3 outlines existing and projected (reasonably foreseeable) water quantity and water quality for the Farmington FO based on information gathered from the following sources: 1) the Farmington Resource Management Plan and Final Environmental Impact Statement (BLM 2003), 2) the Reasonable Foreseeable Development Scenario for Oil and Gas Activities, Mancos-Gallup RMPA Planning Area, Farmington Field Office, northwestern New Mexico ("2018 RFD", Crocker and Glover 2018), 3) data compiled from a 2015 USGS report, Estimated Use of Water in the United States in 2015 (Dieter et. al. 2018), and 4) FracFocus, a national hydraulic fracturing chemical registry managed by the Ground Water Protection Council and Interstate Oil and Gas Compact Commission (FracFocus 2018).

3.1. Water Quantity

Sections 3.1.1 and 3.1.2 detail water quantity, existing groundwater use, and water use associated with oil and gas development and hydraulic fracturing operations in the Farmington FO and the New Mexico portion of the San Juan Basin.

3.1.1. Existing Surface and Groundwater Water Use

Farmington FO Water Use (Rio Arriba County, San Juan County, Sandoval County, and McKinley County)

The 2015 USGS Report, Estimated Use of Water in the United States in 2015 (Dieter et. al. 2018), lists total water withdrawals for the counties comprising the Farmington FO across eight water use categories: aquaculture, domestic, industrial, irrigation, livestock, mining, public water supply, and thermoelectric power. Water use totals (in acre feet per year [AF/yr]) for each of these industries are summarized by surface water and groundwater, which is further divided into fresh water and saline water use for each category.

Table 3-1 through Table 3-4 list the total 2015 water withdrawals for the eight water use categories as reported by USGS (Dieter et al. 2018) for each of the counties within the Farmington FO: Rio Arriba, San Juan, Sandoval, and McKinley.

In Rio Arriba County, where most of the oil and gas development is expected to take place within the Farmington FO, irrigation is the largest category of water use in Rio Arriba County, accounting for an average of 93 percent (109,129 acre-feet [AF]) of the total water withdrawal for Rio Arriba County (118,120 AF, Table 3-1). Approximately 8 percent (9,698 AF) of the total water use for Rio Arriba County is from groundwater. Mining (which includes oil and gas development) comprises approximately 1 percent of Rio Arriba County water withdrawals. All mining-related water use (1,682 AF) is from groundwater; of that total, 74 percent of withdrawals is from saline sources. The relative use of water by industry within Rio Arriba County is depicted in Figure 3-1. The relative use of surface water and fresh/saline groundwater by industry within Rio Arriba County is depicted in Figure 3-2.

In San Juan County, Irrigation accounts for 79 percent (223,942 AF/yr) of the total water withdrawal in San Juan County (283,748 AF/yr; Table 3-2). *Mining* accounts for 2 percent (6,356 AF/yr) of total water withdrawals in the county.

In Sandoval County, Mining accounts for 2 percent (1,312 AF/yr) of the total water use **(**Table 3-3**)**. All water used by mining activities in Sandoval County comes from groundwater. The largest water use categories in Sandoval County are irrigation (79 percent), followed by public water supply (8 percent). Most drilling activities in Sandoval County are expected to take place in the northwest corner of the county, which falls within the San Juan Basin where there is a much greater development potential for oil and gas than in other areas of the county. This determination is based on a 2018 report submitted to the Sandoval County Planning and Zone Commission about the oil and natural gas potential of Sandoval County, which included a discussion on the potential for aquifer contamination (Broadhead et al. 2018). According to this report, the oil and gas development in Sandoval County has thus far occurred in the northern part of the county that is within the San Juan Basin. This trend is likely to continue because “oil and gas potential decreases southward primarily because petroleum source rocks, including the Mancos Shale, become less mature in this direction” (Broadhead et al. 2018:8).

Consumptive water use from mining activities in McKinley County accounts for 17 percent (2,309 AF/yr) of the total water use (Dieter et al. 2018) for the county (13,217 AF/yr, Table 3-4). The 2015 USGS data show water use by county, not by BLM field office boundary; therefore, it is not known if mining activities accounting for 17 percent of the total water use are within the Farmington FO or within the neighboring Rio Puerco FO.

San Juan Basin (Sandoval, Rio Arriba, McKinley, and San Juan Counties)

Table 3-5 summarizes the water withdrawals within the San Juan Basin, which is comprised of Sandoval, Rio Arriba, McKinley, and San Juan Counties, because the San Juan Basin presents the highest potential for oil and gas development in the Farmington FO. The 2018 Reasonably Foreseeable Development (RFD) scenario states that “unless significant new oil and gas discoveries are made in the area, future activity will be primarily horizontal drilling for oil in the Mancos-Gallup play, with minor development targeted at natural gas production” (Crocker and Glover 2018:2). In 2015 water withdrawals for the mining category accounted for 2 percent of the total water use in the San Juan Basin. Most of the mining water was saline groundwater.

Table 3-1. Rio Arriba County 2015 Water Use by Category (AF)

Category	Surface Water				Groundwater				Total Water			
	Fresh	Saline	Total Surface Water	% of Total Water	Fresh	Saline	Total Groundwater	% of Total Water	Total Fresh Water	Total Saline Water	Total Water	% of Total Water
Aquaculture	0	0	0	0	3,554	0	3,554	100%	3,554	0	3,554	3%
Domestic	0	0	0	0	1,345	0	1345	100%	1,345	0	1,345	1%
Industrial	0	0	0	0	0	0	0	0	0	0	0	0
Irrigation	107,874	0	107,874	99%	1,256	0	1,256	1%	109,129	0	109,129	93%
Livestock	168	0	168	47%	191	0	191	53%	359	0	359	0%
Mining	0	0	0	0	437	1,244	1,682	100%	437	1,244	1,682	1%
Public Water Supply	381	0	381	19%	1,670	0	1,670	81%	2,051	0	2,051	2%
Thermoelectric Power	0	0	0	0	0	0	0	0	0	0	0	0
County Totals	**108,423**	**0**	**108,423**	**92%**	**8,453**	**1,244**	**9,698**	**8%**	**116,875**	**1,244**	**118,120**	**100%**

Source: Dieter et al. 2018.

Table 3-2. San Juan County 2015 Water Use by Category (AF)

Category	Surface Water				Groundwater				Total Water			
	Fresh	Saline	Total Surface Water	% of Total Water	Fresh	Saline	Total Groundwater	% of Total Water	Total Fresh Water	Total Saline Water	Total Water	% of Total Water
Aquaculture	0	0	0	0%	0	0	0	0%	0	0	0	0%
Domestic	0	0	0	0%	1,312	0	1,312	100%	1,312	0	1,312	0%
Industrial	0	0	0	0%	22	0	22	100%	22	0	22	0%
Irrigation	223,942	0	223,942	100%	0	0	0	0%	223,942	0	223,942	79%
Livestock	67	0	67	18%	303	0	303	82%	370	0	370	0%
Mining	2,724	0	2,724	43%	549	3,083	3,632	57%	3,273	3,083	6,356	2%
Public Water Supply	21,097	0	21,097	100%	11	0	11	0%	21,108	0	21,108	7%
Thermoelectric Power	30,637	0	30,637	100%	0	0	0	0%	30,637	0	30,637	11%
County Totals	**278,468**	**0**	**278,468**	**98%**	**2,197**	**3,083**	**5,280**	**2%**	**280,665**	**3083**	**283,748**	**100%**

Source: Dieter et. al. 2018.

Table 3-3. Sandoval County 2015 Water Use by Category (AF)

	Surface Water				Groundwater				Total Water			
Category	**Fresh**	**Saline**	**Total Surface Water**	**% of Total Water**	**Fresh**	**Saline**	**Total Groundwater**	**% of Total Water**	**Total Fresh Water**	**Total Saline Water**	**Total Water**	**% of Total Water**
Aquaculture	0	0	0	0%	1,087	0	1,087	100%	1,087	0	1,087	1%
Domestic	0	0	0	0%	3,128	0	3,128	100%	3,128	0	3,128	2%
Industrial	0	0	0	0%	2,578	0	2,578	100%	2,578	0	2,578	1%
Irrigation	48,326	0	48,326	95%	2,3201	0	2,321	5%	50,647	0	50,647	79%
Livestock	101	0	101	45%	123	0	123	55%	224	0	224	0%
Mining	0	0	0	0%	1,065	247	1,312	77%	1,065	246.6	1,312	2%
Public Water Supply	135	0	135	55%	12,466	0	12,466	45%	12,600	0	12,600	8%
Thermoelectric Power	0	0	0	0%	0	0	0	0%	0	0	0	7%
County Totals	**48,562**	**0**	**48,562**	**90%**	**22,768**	**247**	**23,014**	**32%**	**71,329**	**246.6**	**71,576**	**100%**

Source: Dieter et al. 2018

Table 3-4. McKinley County 2015 Water Use by Category (AF)

	Surface Water				Groundwater				Total Water			
Category	**Fresh**	**Saline**	**Total Surface Water**	**% of Total Water**	**Fresh**	**Saline**	**Total Groundwater**	**% of Total Water**	**Total Fresh Water**	**Total Saline Water**	**Total Water**	**% of Total Water**
Aquaculture	0	0	0	0%	0	0	0	0%	0	0	0	0%
Domestic	0	0	0	0%	3,195	0	3,195	100%	3,195	0	3,195	24%
Industrial	0	0	0	0%	34	0	34	100%	34	0	34	<1%
Irrigation	1,099	0	1,099	100%	0	0	0	0%	1,099	0	1,099	8%
Livestock	101	0	101	21%	370	0	370	79%	471	0	471	4%
Mining	0	0	0	0%	1,626	684	2,309	100%	1,626	684	2,309	17%
Public Water Supply	0	0	0	0%	3,811	0	3,811	100%	3,811	0	3,811	29%
Thermoelectric Power	0	0	0	0%	2,298	0	2,298	100%	2,298	0	2,298	17%
County Totals	**1,200**	**0**	**1,200**	**9%**	**11,333**	**684**	**12,017**	**91%**	**12,533**	**684**	**13,217**	**100%**

Source: Dieter et al. 2018

Table 3-5. San Juan Basin 2015 Water Use by Category (AF)

	Surface Water				Groundwater				Total Water			
Category	Fresh	Saline	Total Surface Water	% of Total Water	Fresh	Saline	Total Groundwater	% of Total Water	Total Fresh Water	Total Saline Water	Total Water	% of Total Water
Aquaculture	0	0	0	0%	4,641	0	4,641	100%	4,641	0	4,641	1%
Domestic	0	0	0	0%	8,979	0	8,979	100%	8,979	0	8,979	2%
Industrial	0	0	0	0%	2,634	0	2,634	100%	2,634	0	2,634	1%
Irrigation	381,241	0	381,241	99%	3,576	0	3,576	1%	384,817	0	384,817	79%
Livestock	437	0	437	31%	987	0	987	69%	1,424	0	1,424	<1%
Mining	2,724	0	2,724	23%	3,677	5,258	8,934	77%	6,401	5,258	11,658	2%
Public Water Supply	21,6123	0	21,613	55%	17,958	0	17,958	45%	39,571	0	39,571	8%
Thermoelectric Power	30,637	0	30,637	93%	2,298	0	2,298	7%	32,935	0	32,935	7%
Basin Totals	**436,652**	**0**	**436,652**	**90%**	**44,750**	**5,258**	**50,008**	**10%**	**481,402**	**5,258**	**486,660**	**100%**

Source: Dieter et al. 201

State of New Mexico Water Use

In 2015, withdrawals for all water use categories across the State of New Mexico totaled 3,249,667 AF (Dieter et. al 2018). The New Mexico portion of the San Juan Basin water use totals (486,660 AF) accounted for about 15 percent of total 2015 statewide withdrawals. Table 3-6 presents water use associated with oil and gas development in New Mexico, by county. As shown in the table, over 99 percent of the water use associated with oil and gas development occurs in the Pecos District (Chaves, Eddy, and Lea Counties [3,994 AF]), in the Permian Basin.

Table 3-6. 2015 State of New Mexico Water Use Associated with Oil and Gas Development

County	Surface Water	Groundwater	Total	% of Total
Bernalillo	0	7	7	0%
Chaves	0	84	84	2%
Eddy	0	2,635	2,635	65%
Lea	0	1,275	1,275	32%
Rio Arriba	0	0	0	0%
Sandoval	0	0	0	0%
San Juan	30	0	30	0.7%
Sierra	0	1	1	0%
State total	30	4,002	4,032	100%

Source: NMOSE 2019

Table 3-7 lists the water withdrawals for the major industries in New Mexico. As shown in the table, *Mining* water withdrawals totaled 163,901 AF, or about 5 percent of the total water withdrawals for the State of New Mexico. It is important to note that *Mining* accounts for all withdrawals of a variety of mining activities, and oil and gas development is only a small portion of this percentage.

Table 3-7. State of New Mexico Water Use by Category (AF)

Category	Surface Water				Groundwater				Total Water			
	Fresh	Saline	Total Surface Water	% of Total Water	Fresh	Saline	Total Groundwater	% of Total Water	Fresh	Saline	Total Water	% of Total Water
Aquaculture	6,109	0	6,109	23%	20,929	0	20,929	77%	27,039	0	27,039	1%
Domestic	0	0	0	0%	27,621	0	27,621	100%	27,621	-	27,621	1%
Industrial	0	0	0	0%	3,811	0	3,811	100%	3,811	0	3,811	0%
Irrigation	1,485,112	0	1,485,112	56%	1,175,312	0	1,175,312	44%	2,660,424	0	2,660,424	82%
Livestock	2,522	0	2,522	7%	33,372	0	33,372	93%	35,894	0	35,894	1%
Mining†	19,550	0	19,550	12%	44,111	100,240	144,351	88%	63,662	100,240	163,901	5%
Public Water Supply	87,752	0	87,752	30%	205,715	0	205,715	70%	293,467	0	293,467	9%
Thermoelectric Power	30,637	0	30,637	82%	6,872	0	6,872	18%	37,509	-	37,509	1%
State-wide Totals	**1,631,683**	**0**	**1,631,683**	**50%**	**1,517,744**	**100,240**	**1,617,984**	**50%**	**3,149,427**	**100,240**	**3,249,667**	**100%**

Source: Source: Dieter et al. 2018; updated with additional information provided to the BLM from the NMOSE regarding water use of the Navajo Power Plant (BLM 2019a).

† Approximately 19,550 AF of the freshwater use within the Mining industry is from surface water; the remainder of all other water use is from groundwater. The Mining category includes the following self-supplied enterprises that extract minerals occurring naturally in the earth's crust: solids, such as potash, coal, and smelting ores; liquids, such as crude petroleum; and gases, such as natural gas. This category includes water used for oil and gas production (well drilling and secondary recovery of oil), quarrying, milling (crushing, screening, washing, flotation, etc.), and other processing done at the mine site or as part of a mining activity, as well as water removed from underground excavations (mine dewatering) and stored in—and evaporated from—tailings ponds. The Mining category also includes water used to irrigate new vegetative covers at former mine sites that have been reclaimed. It does not include the processing of raw materials, such as smelting ores, unless this activity occurs as an integral part of a mining operation and is included in an NMOSE permit.

.

3.1.2. Water Use Associated with Reasonably Foreseeable Oil and Gas Development

The 2018 RFD (Crocker and Glover 2018) was used to forecast the potential quantity of oil and gas wells in the Mancos-Gallup Resource Management Plan Amendment (RMPA) Planning Area, which includes most of the Farmington FO and is where most potential oil and gas development is assumed to occur. The RFD was also used to forecast estimates of the quantity of water that would be required for hydraulic fracturing of the forecasted wells. These water use estimates assume that 100% of wells will be hydraulically fractured, and do not account for re-use or recycling of hydraulic fracturing fluid.

The 2018 RFD (Crocker and Glover 2018) is a reasonable estimate of the development and consumptive water use associated with hydrocarbon production in the New Mexico portion of the San Juan Basin for the next 20 years (2018–2037). According to the 2018 RFD 3,200 wells are expected to be drilled in the planning area between 2018 and 2037 based on actualized data. Water use associated with hydraulic fracturing is dependent on many factors, including (but not limited to) the drilling method (horizontal or vertical) and the geologic formation at the well site. Of the 3,200 wells projected to be drilled between 2018 and 2037, 2,300 are expected to be horizontal and 900 are expected to be vertical.

The 2018 RFD (Crocker and Glover 2018) scenario utilizes water use estimates from a 2014 RFD scenario prepared by the New Mexico Bureau of Geology and Mineral Resources entitled *Hydrologic Assessment of Oil and Gas Resource Development of the Mancos Shale in the San Juan Basin* by Kelley et al. (2014). According to Kelley et al. (2014:4), "vertical wells drilled into the Mesaverde Group, Gallup Sandstone, and the Dakota Sandstone account for 83 percent of the hydraulically fractured completions [in the San Juan Basin] since 2005."

Water use associated with hydraulic fracturing is dependent on many factors, including the geologic formation. On average, the water use for vertical wells in the New Mexico portion of the San Juan Basin is 0.537 AF/well (Crocker and Glover 2018). Horizontal wells require more water than vertical wells. The 2018 RFD (Crocker and Glover 2018) reported that horizontal wells in the San Juan Basin require on average approximately 3.13 AF of water. More recent information on horizontal well development in the San Juan Basin has indicated water use is higher. Because of this uncertainty, the BLM conducted studies using calendar year 2018 data from FracFocus, a national hydraulic fracturing chemical registry managed by the Ground Water Protection Council and Interstate Oil and Gas Compact Commission, to provide objective information on hydraulic fracturing. Operators are required by the State of New Mexico to disclose chemistry and water use information on FracFocus. Analysis of 2018 FracFocus data for the New Mexico portion of the San Juan Basin (which included 126 records) resulted in a value of 4.8 AF of water per horizontal well completion. As a result of these studies, the BLM considers the estimate of 4.8 AF the most accurate current estimate of water use per horizontal well completions in the San Juan Basin based on historical data. Table 3-8 provides a comparison of the water use estimates used in the 2018 RFD and the BLM's revised water use estimates. Some factors have been modified based on best available information (for example, the projected water use associated with horizontal drilling methods discussed above) as well as best professional judgment of BLM engineering staff and resource specialists.

Table 3-8. Projected Water Use (AF) in San Juan Basin (Farmington FO)

Factor	Water Use in RFD (Crocker and Glover 2018)	Revised Water Use	Rationale for Change
Average Water Use per Horizontal Well during a hydraulic fracturing operation	3.13 AF	4.84 AF[1]	Reflects actual use as reported in FracFocus
Average Water Use per Vertical Well during a hydraulic fracturing operation	0.537 AF	0.537 AF[2]	No change
Total Water Use (2018-2037)	**7,683 AF[3]**	**11,615 AF[3]**	

[1]Source: Derived from Crocker and Glover 2018.
[2] Source: FracFocus, 2018
[3] Source: BLM 2019b
[4] Total water use = (2,300 horizontal wells[1] * horizontal well water use estimate) + (900 vertical wells[1] * vertical well water use estimate)
Note: AF is acre-feet.

Water used for hydraulic fracturing of the estimated 3,200 wells in the 2018 RFD (Crocker and Glover 2018) is assumed to come primarily from fresh groundwater sources based on historic oil and gas development in the area and from county water use data summarized in Table 3-1 through Table 3-5 above (Dieter et al. 2018). Drilling and completion of the 3,200 wells estimated to occur in the planning area would require approximately 7,683 AF using the water use estimates contained in the Crocker and Glover RFD scenario. Using the BLM's revised water use estimates discussed above (4.84 AF per horizontal well), development of the 3,200 wells in the 2018 RFD would require 11,615 AF of water, or 580 AF of water in any given year. The estimated amount of water needed to develop the RFD in any given year (580 AF) is approximately 0.12 percent of the 2015 water use in the San Juan Basin.

Water use could increase if more water-intensive stimulation methods (e.g., slick water fracturing) are implemented or if laterals become longer. Alternatively, water use estimates could be lower if produced water is reused or recycled for use in hydraulic fracturing. Additionally, as technology changes, other sources of water become available for use.

3.1.3. Water Use Associated with Slick Water Stimulation

Fluid mineral development in the New Mexico portion of the San Juan Basin has experienced technological advances with the introduction of slick water stimulation beginning in 2015. Since the development of the 2018 RFD (Crocker and Glover 2018), additional information regarding the slick water stimulation technique has been gathered by the Farmington FO through outreach conducted with local operators actively drilling and producing mineral resources in the New Mexico portion of the San Juan Basin. To date, 20 wells have been drilled using long laterals with slick-water stimulation within the Farmington FO. Horizontal well bores are stimulated in intervals, each interval is called a stage. For the 20 completed wells, the Farmington FO calculated the average stage length to be 200 feet and the average water used per stage to stimulate the formation to be 334,000 gallons (~ 1 acre-foot). The equation for calculating estimated water volume is indicated below:

(Total water volume) = (stage water volume/stage length) x (number of stages/lateral length)

According to data from FracFocus, the average water use associated with slick water stimulation of the 20 wells was 41 AF. Using this information, and an average lateral well bore of 1.5 miles (as obtained from the corresponding APDs), the BLM has calculated an average of 27 AF per lateral mile. Table 3-9 provides a summary of average number of stages dependent on length of well bore and the average water use to complete 1- to 3- mile laterals.

Table 3-9. Average Volume of Water Required to Complete 1-3 Mile Laterals Utilizing Slick Water Stimulation in the Mancos Shale and Gallup Sandstone Formations

Miles	Number of Stages	Acre Feet
1	26	27
1.5	39	40
2	52	53
2.5	65	67
3	78	80

Current technology allows operators to utilize water with TDS of 50,000 ppm for use in slick water stimulation activities, well above the NMOSE potable water threshold of 1,000 ppm. This allows for the use of currently non-traditional water sources, including the connate water, recycled flowback water, and produced water. Appendix C contains additional background information on slick water fracturing in the Farmington FO as well as information regarding the methodology for capturing information and calculating water use by stage.

3.1.4. Cumulative Water Use Estimates

Past and Present Actions

Past and present use is discussed above in Section 3.1.1, Existing Surface and Groundwater Use. As noted in that section, total water use in the counties comprising the New Mexico portion of the San Juan Basin (486,660 AF) accounted for 15 percent of total state withdrawals (3,249,667 AF) in 2015 (Dieter et al. 2018). Mining (which includes oil and gas development) comprised about 2 percent of San Juan Basin total water withdrawals. The largest user of water in the New Mexico portion of the San Juan Basin is irrigation (comprising 79 percent of all withdrawals in the New Mexico portion of the San Juan Basin).

The BLM also examined FracFocus data reported for the calendar years of 2014 to 2018 (FracFocus 2019) to ascertain actual water use by the oil and gas industry in the San Juan Basin. This information is presented in Table 3-9.

Consumptive water use by municipal, industrial, and agricultural activities (including oil and gas activities) represents a single element of a hypothetical water budget for the planning area. While a detailed water budget quantifying hydrologic inputs and outputs for the planning area is outside the scope of this document, it should be noted that various hydrologic inputs are occurring alongside the consumptive water use depicted in Figure 2-4 and Figure 2-5. Groundwater can be recharged through a variety of processes such as precipitation, irrigation return flow, and seepage from rivers and streams. Similarly, groundwater discharge in the planning area occurs not only through consumptive water use, but also through evapotranspiration and discharge from springs and seeps.

Table 3-9. Actual Water Use in the San Juan Basin for Calendar Years 2014-2018

Year	Federal Water Use (AF)	Non-Federal Water Use (AF)	Total WU (AF)	Federal Water Use (%)	Federal Cumulative Water Use (AF)	Total Cumulative Water Use (AF)	Average Water Use per Well (AF)	Total # of Wells Reported to FracFocus
2014	165	155	320	51	165	320	2.4	133
2015	87	255	343	25	252	662	3.8	90
2016	86	26	111	77	337	773	2.5	44
2017	229	50	279	82	566	1,052	4.4	63
2018	361	282	643	56	927	1,695	4.6	141
Total	**927**	**768**	**1,695**	**--**	**--**	**--**	**--**	**471**

Source: FracFocus 2019.

Note: San Juan Basin is comprised of Sandoval, Rio Arriba, and San Juan Counties.

Water use by oil and gas wells in the San Juan Basin has increased from 320 AF in 2014 to 643 AF in 2018, with a corresponding basin-wide average water use per well increase from 2.4 AF per well to 4.6 AF per well (FracFocus 2019). Total federal cumulative water use in the basin was 927 AF during the same period, a percentage of 55 percent of total water use. Cumulative water use is calculated by adding all previous water use to the water use for any given year. The total number of wells that were reported to FracFocus from 2014 to 2018 also increased from 133 wells to 141 wells. As noted in Section 3.1.3, 20 wells have been drilled to date using long laterals with slick-water stimulation within the Farmington FO. The average lateral well bore was 1.5 miles in length and associated water use was approximately 41 AF.

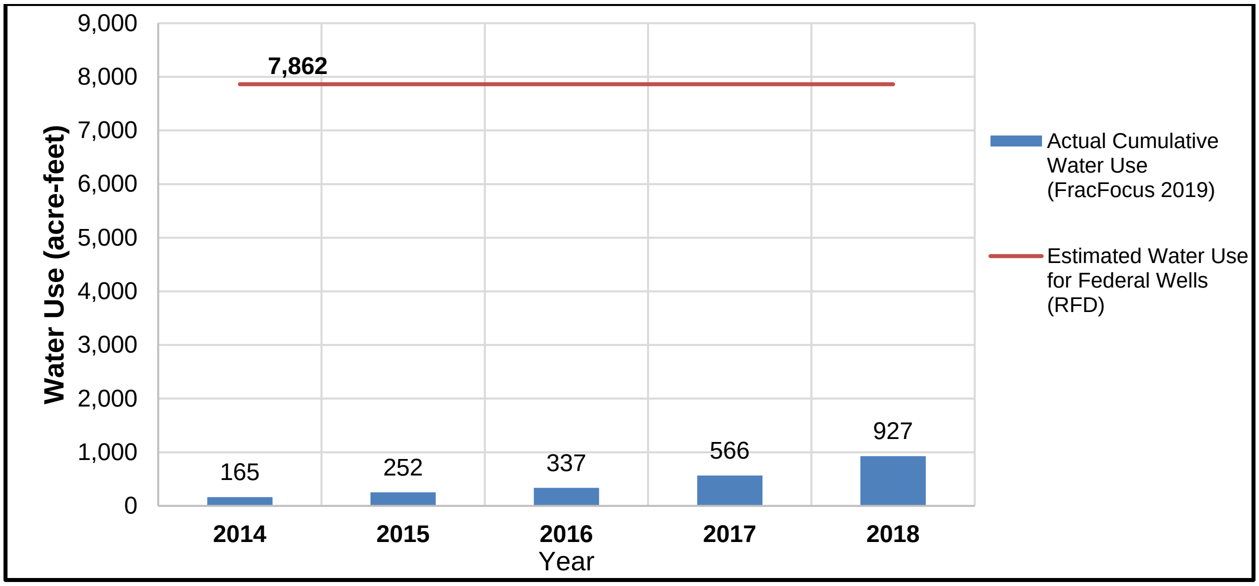
Reasonably Foreseeable Future Actions (RFFAs)

Oil and Gas Development RFFAs

As noted above in Section 3.1.2, Water Use Associated with Reasonably Foreseeable Oil and Gas Development, 3,200 wells are expected to be drilled in the planning area between 2018 and 2037, with a total of 1,980 wells being on federal land (1,580 horizontal and 400 vertical). Total water use for the RFD over the 20-year period is currently estimated at 11,615 AF, or about 580 AF in any given year. Well development projected as a result of ongoing BLM and state lease sales is already considered in the RFD. Well development associated with recent or reasonably foreseeable APDs or master development plans are also included in the RFD.

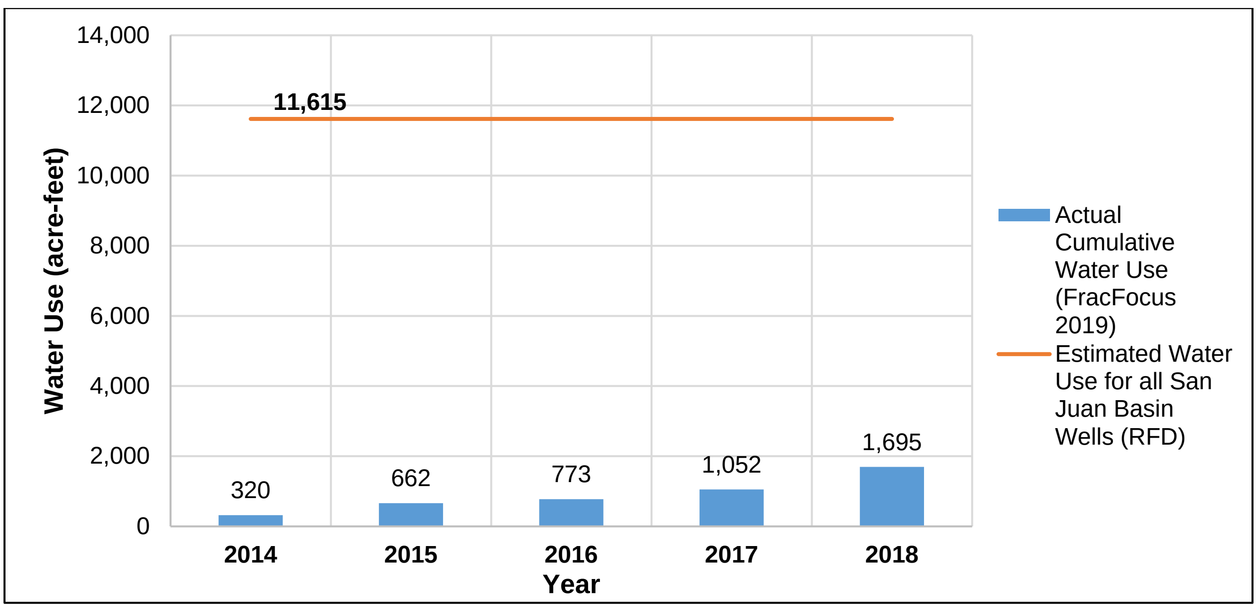
Figure 3.1 shows cumulative water use between 2014 and 2018 for federal wells in the San Juan Basin (FracFocus 2019) compared to water use estimates from the RFD scenario (Crocker and Glover 2018). A similar scenario is presented in Figure 3.2, which shows cumulative water use between 2014 and 2018 for all wells (both federal and non-federal) in the San Juan Basin (FracFocus 2019) compared to water use estimates from the RFD scenario (Crocker and Glover 2018). The total water use estimate for the RFD scenario is derived by assuming 2,300 wells would be drilled horizontally, and 900 wells would be drilled vertically.

For 2018 (the first year that is projected in the RFD), water use reported to Frac Focus was 643 AF. This is 5.5% of the total RFD water use estimate (11,615 AF), which is about 0.5 % (63 AF) higher than the RFD projection for any given year (580 AF).



Note: Actual water use from FracFocus 2019. Cumulative water use for each year (shown in blue) is calculated by adding the sum of all previous actual water use to the actual water use for any given year. The estimated water use for the federal wells in the San Juan Basin (shown in orange) is derived from the RFD scenario using the revised water use estimates discussed in Section 3.1.2 (4.84 AF per horizontal well). The RFD scenario estimates 1,980 federal wells (1,580 horizontal and 400 vertical).

Figure 3.1. Actual Water Use (2014-2018) Compared to Projected Water Use for Federal Wells in the San Juan Basin.



Note: Actual water use from FracFocus 2019. Cumulative water use for each year (shown in blue) is calculated by adding the sum of all previous actual water use to the actual water use for any given year. The estimated water use for all wells in the San Juan Basin (shown in orange) is derived from the RFD scenario using the revised water use estimates discussed in Section 3.1.2 (4.84 AF per horizontal well).

Figure 3.2 Actual Cumulative Use (2014-2018) Compared to Projected Water Use for All Wells in the San Juan Basin.

Beginning in 2015, the Farmington Field Office began receiving APDs that included new technologies that utilize greater quantities of water during the stimulation of the well under development. If operators implement the slickwater technology more frequently than occurred in 2018 and prior years, it is expected that total water use volumes on a per well basis will trend upward. To address this concern, the BLM analyzed data from FracFocus for 20 recent APDs utilizing slick water stimulation, and developed estimates of miles of lateral and associated water use for development of the RFD (2,300 horizontal wells over 20 years) using slick water stimulation techniques. Using an average of a 2-mile lateral (operator input gathered by the BLM suggests the horizontal lengths would range from 1-3 miles), the BLM estimates that development of 2,300 wells would result in 4,600 miles of laterals. The amount of water that would be required to completely develop 4,600 miles of horizontal wells in the Mancos Shale and Gallup Sandstone formations via slick water stimulation is estimated to be approximately 125,000 AF, or 6,250 AF in any given year (see Table 3-9 for water use factor by lateral length). This scenario was developed as a maximum reasonable estimate of future water use if existing slick water stimulation techniques (which currently comprise 3% of all well completions in the San Juan Basin) were to be applied to all 2,300 wells forecasted in the RFD over the next 20-years, versus the use of less water intensive stimulation technologies, such as nitrogen completions.

For 2018 (the first year that is projected in the RFD), water use reported to Frac Focus was 643 AF. This is 0.5% of the total slick water trend water use estimate (11,615 AF), which is about 4.5 % (5,607 AF) less than the slick water trend projection for any given year (6,250 AF).

<u>Other (non-RFD) RFFAs</u>

No other RFFAs with substantial use have been identified. Some water use would be required during construction and operation of reasonably foreseeable transmission lines and pipelines. These uses are minimal and are not quantified in this cumulative impact scenario analysis, but would be quantified at the site-specific EA level. Future water use for the other reported water use categories in the San Juan Basin is assumed to continue at current levels.

Cumulative Impacts

Development of the RFD using water use values of 0.537 AF/vertical well (Crocker and Glover 2018), and 4.84 AF/horizontal well (developed through a review 2018 FracFocus water use data) would result in the use of approximately 11,615 AF of water, or 580 AF of water in any given year (Table 3-11, column 1). This water use would occur over approximately 20 years and would cumulatively represent about 0.12 percent of San Juan Basin 2015 total water withdrawals (486,660 AF). As noted above, the agriculture would remain by far the largest water use within the San Juan Basin (currently 79 percent of all water use within the San Juan Basin).

If the slick water trends noted above are realized in the San Juan Basin and remain consistent over the 20- year development scenario timeframe, total cumulative water volumes would be closer to the totals disclosed in column 2 of Table 3-11 (approximately 125,000 AF, or 6,250 AF in any given year). This water use would occur over approximately 20 years and would cumulatively represent about 1.3 percent of San Juan Basin 2015 total water withdrawals (486,660 AF). As noted above, the agriculture would remain by far the largest water use within the San Juan Basin (currently 79 percent of all water use within the San Juan Basin).

Table 3-10. Cumulative RFD Water Use Volumes Based on 2019 Trend Projections

Well Orientation	2018 RFD	Slick Water Trend Projections	Quantity Increase
900 Vertical	483 AF	483 AF	0 AF
2,300 Horizontal	11,132 AF	124,515 AF	113,866 AF
Total 3200 Wells	**11,615AF**	**124,998 AF**	**113,866 AF**

Note: 2018 RFD water use is based on revised water use estimates (4.84 AF per horizontal well) documented above in Section 3.1.2. Updated Farmington FO 2019 Trend projection water use estimates are based on slick water fracturing planning factors (53 AF per 2 mile lateral) noted above and in Appendix C.

As noted in Section 3.1.3, slick water fracturing technology allows operators to utilize water with TDS of 50,000 ppm for use in slick water stimulation activities, which allows for the use of currently non-traditional water sources, including the connate water, recycled flowback water, and produced water (see Section 3.1.5). Appendix C contains additional background information on slick water fracturing in the Farmington FO as well as information regarding the methodology for capturing information and calculating water use by stage.

3.1.5. Potential Sources of Water for Project Development

Because most water used in mining activities in the counties that comprise the Farmington FO is currently from groundwater, it is reasonable to assume that a large portion of the water used for hydraulic fracturing under the RFD scenario would likely be groundwater. Groundwater is a more readily available source of water than surface water due to the ephemeral nature of many surface water features in the San Juan Basin. Generally, sources of groundwater can be found in nearly every area of the Farmington FO. Water yields in these areas vary, but most aquifers yield less than 20 gallons per minute (gpm) (BLM 2003). Aquifers that are known to yield sufficient quantities of water are usually found within the sandstone units of Jurassic, Cretaceous, and Tertiary age (BLM 2003). Aquifers that have the potential to yield 100 gpm include the Ojo Alamo Sandstone, the Nacimiento Formation, and the San Jose Formation, all of which are within the greater Unite-Animas aquifer (BLM 2003).

San Juan Basin oil and gas operators have included plans to use multiple hydraulic fracturing methods including slick water fracturing technology. The two general water types that may be used for slick water stimulation are categorized as “potable/fresh” and “non-potable”. Any water that has Total Dissolved Solids (TDS) greater than 1,000 ppm has been defined as “non-potable” by the State of New Mexico (72-12-25 NMSA 1978), the BLM has identified anything less than 10,000 ppm to be protected in the casing rule of the BLM’s Onshore Order #2 (BLM 1988). Non-potable water is outside the appropriative processes and is mainly diverted for mineral exploration purpose. The higher allowable TDS levels that are acceptable for slick water stimulation expand the possible water sources beyond those that are traditionally used (e.g., surface or ground water) into non-traditional sources of water (e.g. non-potable groundwater sources). Recently, the NMOSE has approved permits to drill wells within the San Juan Basin to withdraw non-potable connate water (groundwater) from the Entrada sandstone formation for use as a potential source of water for slick water stimulation operations (see Appendix C for more information). Water contained in the Entrada formation is highly saline (Kelley et al. 2014). As such, it is considered non-potable and has not been declared as an administrative aquifer by the NMOSE. Table 3-12 identifies four aquifers found within the Farmington FO, their associated rock types, and sources of recharge.

Table 3-11. Potential Sources of Groundwater in Farmington FO

Aquifer Name	Description	Sources of Recharge
Mesaverde	Sandstone, coal, siltstone and shale of the Mesaverde Group	Upland areas, mainly in areas of the Zuni Uplift, Chuska Mountains, and northern Sandoval County
Rio Grande	Unconsolidated sand and gravel basin-fill	Precipitation and snowmelt from the mountains and valleys that surround the basin. Most precipitation is lost to evaporation and transpiration, and very little percolates to a sufficient depth to recharge the aquifer.
Unite-Animas	Lower tertiary rocks; permeable, coarse, arkosic sandstone interlayered with mudstone; permeable conglomerate and medium to very coarse sandstone interlayered with relatively impermeable shale and mudstone	In higher elections that encircle the San Juan Basin
Entrada Sandstone	Sandstone; eolian sand dunes	Through surface exposures on the margins of the basin in the foothills of the Laramide uplifts.

Source: BLM 2003, Kelley et al 2014.

In order to further identify sources and quantity and quality of groundwater, the BLM is currently collaborating with Sandia National Laboratory on the development of a study that will identify counties that have high potential for oil and gas development within Farmington FO. The study will establish a water-level and chemistry baseline and develop a modeling tool to aid the BLM in understanding the regional water supply dynamics under different management, policy, and growth scenarios and to pre-emptively identify risks to water sustainability. Once this study is complete, this section will be updated to analyze and discuss the results.

Other sources of non-potable water that can be utilized in stimulation are “flowback fluid” and “produced water”. Flowback fluid is a mixture of water and small amounts of chemicals and other proppants that flow back through the well head directly after stimulation activities. Generally, 10-40% of the initial volume utilized for stimulation activities returns as flowback fluid, of this 10-40% is non-potable water that may be used in future stimulation activities. Produced water is naturally occurring water that exists in the formation that is being targeted for mineral extraction and is produced as a byproduct, therefore becoming “produced water”. Based on operator input, after the initial flowback recovery of 10-40%, remaining water used for stimulation does return to the surface through production activities at a slower rate of return.

Water used for oil and gas drilling and completion would generally be obtained through the following methods:

- leasing a valid water right through a State Engineer permit.
- buying/leasing water from a legal water provider (or, up to 3AF, a private well owner).
- purchasing water from a non-potable reclaimed water supplier.

It is speculative to predict the actual source of water that would be used for development of the RFD (or the development of any specific lease sales). In addition to utilizing surface or groundwater, operators may also bring water to a well site via truck from any number of sources. The transaction would be handled by the New Mexico Oil Conservation Division, as well as the New Mexico Office of the State Engineer. All water uses would be evaluated at the APD stage in site-specific NEPA analysis and subject to standard lease terms and conditions; however, it is important to note that sources of water for lease development are also not always known at the APD stage.

3.1.6. Water Use Mitigations

Overall, there have been calls to increase the use of alternative water sources such as brackish water or recycling produced water, minimizing the strain on local freshwater resources (Kondash et al. 2018). The BLM encourages the use of recycled water in hydraulic fracturing techniques. Moreover, recent studies indicate that the water used for hydraulic fracturing may be retained within the shale formation, with only a small fraction of the fresh water injected into the ground returning as flowback water; water returning to the surface is highly saline, difficult to treat, and is often disposed through deep-injection wells (Kondash et al. 2018). Thus, the ability to recycle water may be more limited than previously reported. Note that the water use calculations above do not assume the use of recycled water.

As noted above, water-intensive stimulation methods such as slick water fracturing can be accomplished using non-traditional water sources, including the connate water within the Entrada formation. NMOSE is the agency responsible for water withdrawal permitting actions. Their NOI process includes a model-based evaluation of the potential effects of proposed withdrawals and the identification of possible requirements for applicants to obtain water rights to offset any depletions identified in NMOSE's analyses prior to applicants commencing diversions.

3.2. Existing Water Quality

Sections 3.2.1 and 3.2.2 detail existing surface and ground water quality, and potential sources of surface and ground water contaminants associated with oil and gas development. In general, the analysis area for water sources for the Farmington FO is the San Juan Basin

3.2.1. Groundwater

Results of the hydrologic assessment of oil and gas development of the Mancos Shale in the San Juan Basin (Kelley et al. 2014) indicate that groundwater quality in the San Juan Basin is variable (ranging from fresh to brackish) due to the complex stratigraphy and varying rock formations within the Basin. Brackish and saline water is typically found in the center of the Basin, and fresh groundwater is typically found along the Basin margins. Deep saline water can migrate upward along cracks and fissures. Fresh water along the Basin margins at depths greater than 3,500 feet indicate fast recharge rates influenced by geologic structures (Kelley et al. 2014).

The geologic formation where groundwater resides also influences groundwater salinity. Figure 3.3 (Figure 15; Kelley et al. 2014) is an illustrated geologic cross section showing the distribution of saline aquifers within the San Juan Basin.

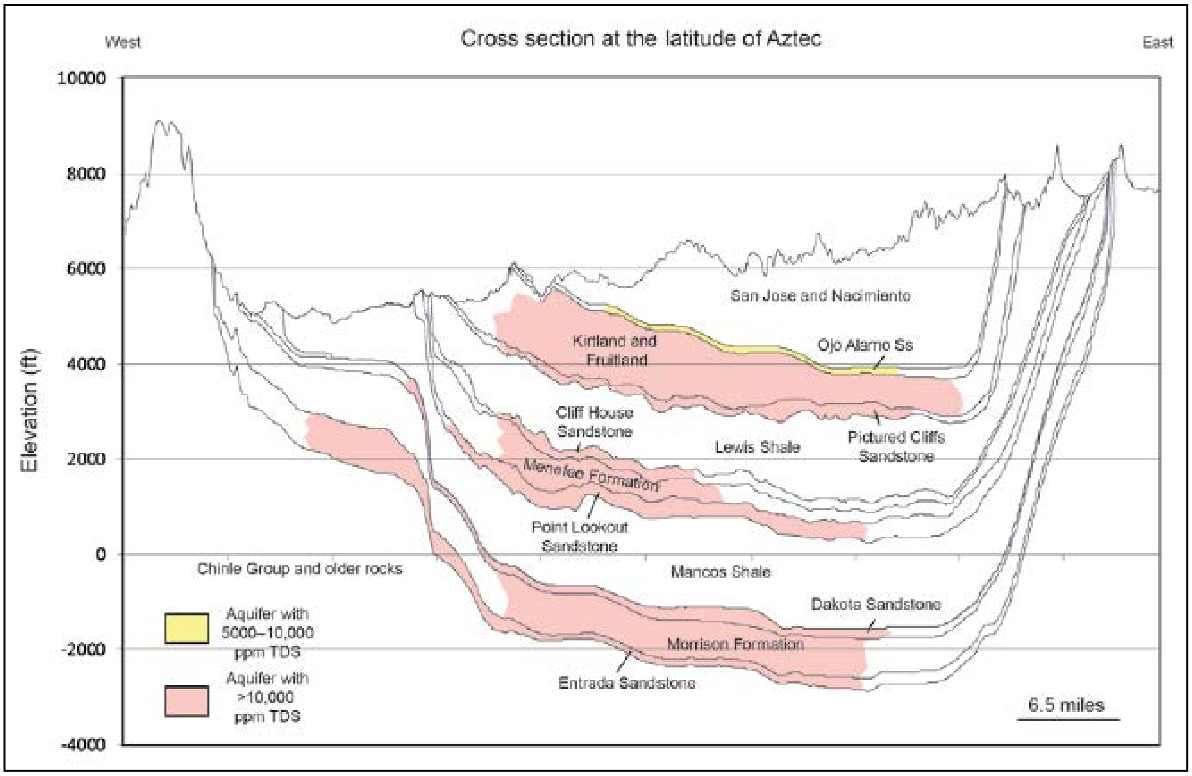


Figure 3.3. Geologic cross section showing the distribution of saline aquifers in the San Juan Basin.

Source: Figure 15 in Kelley et al. 2014.

Total dissolved solids (TDS) concentration is a measure of all the dissolved matter in a sample of water. TDS is the primary indicator of groundwater quality as higher TDS concentrations typically make water less suitable for drinking or for agricultural purposes like irrigation. In groundwater, TDS is influenced by the dissolution of natural materials such as rock, soil, and organic material. Anthropogenic activities also contribute to TDS concentrations in shallow unconfined aquifers.

TDS concentration in the San Juan Basin is dependent on the stratigraphic location and the geologic formation where the water resides. Fresh water (TDS < 1,000 milligrams per liter [mg/l]) is typically found at depths <2,500 feet (ft) below the ground surface, although exceptions to this generalization occur in deeper layers like the Gallup Sandstone and Morrison Formation. Saline and brackish water is dominant in the center of the Basin at deeper depths (Kelley et al. 2014).

As noted above in Section 3.1.2, the BLM is working with Sandia National Laboratory to prepare a report on water sustainability in the Farmington FO related to oil and gas development. Upon completion of that report, this section will be updated to discuss the results and further analyze groundwater quality.

3.2.2. Surface Water

Surface water quality streamflow data is limited to data gathered from perennial surface water drainages in the northern part of the Farmington FO planning area (BLM 2003) that are within various aquifers and watersheds. Surface water quality is dependent upon environmental related factors the water has encountered, such as upstream or downstream, types of rocks and soils, potential contaminants, and flow conditions. In general, surface water has relatively low concentrations of dissolved solids in its upper reaches, and high concentrations of magnesium, calcium, sodium, and sulfate in its middle and lower reaches; there are also higher concentrations of ions at low flow conditions (BLM 2003). To further asses surface water quality, data from the forthcoming Sandia National Laboratory report (as described above in Section 3.1.2) will be analyzed and discussed in this section once that report is available.

3.2.3. Potential Sources of Surface Water or Groundwater Contamination

Spills

Spills associated with oil and gas development may reach surface water directly during the spill event. Spills may also reach surface waters indirectly, when the spill has occurred and a rain event moves contaminants into nearby surface water bodies through surface water flow or even subsurface groundwater flow into springs that discharge into a surface water body.

The San Juan Basin has been a producing oil and natural gas field since the early to middle 1900s. According to available GIS data, approximately 37,000 wells have been drilled within the boundary of the Farmington FO (BLM 2018). In 2017 oil and gas development resulted in 5,979,536 barrels (bbls) of crude oil; 464,709,385 thousand cubic feet (mcf) of natural gas; and 17,068,297 bbls of produced water. As shown in Table 2-12, there were a total of 106 spills in the New Mexico portion of the San Juan Basin in 2018. The volume of spilled oil, natural gas, and produced water comprises approximately 2.0 percent, 0.0003 percent, and 0.01 percent, respectively, of 2017 oil, natural gas and produced water values. Appendix C contains a methodology for analyzing spill data.

The rate of recovery varied by spill type but, in general, about 55 percent of all spills were not recovered. Of the spills above, nine incidents were reported as having affected surface waterways: three incidents involving produced water (57 bbls, due to well equipment failure or pipeline corrosion), two incidents involving natural gas-methane (49 mcf, due to pipeline equipment failure or corrosion), one incident involving crude oil (8 bbls, due to tank or pit overflow), one incident involving condensate (3 bbls, due to flowline equipment failure), and two incidents involving other materials (240 bbls, during transport due to human error); NMOCD 2019). The BLM works with the NMOCD to remediate spills on public BLM lands. Per NMAC 19.15.29.11, the responsible person shall complete division-approved corrective action for releases that endanger public health or the environment in accordance with a remediation plan submitted to and approved by the division or with an abatement plan submitted in accordance with 19.15.30 NMAC. The remaining contaminates from unrecovered spills are remediated in accordance with federal and state standards. Some remediation consists of removing contaminated soil and replacing it with uncontaminated soil and corresponding chemical testing.

Table 3-12. Summary of 2018 Spills in San Juan Basin

Spilled Material Type	Number of Spills	Volume Spilled	Volume Lost	Units	% Volume Lost
Condensate	21	403	286	Barrels	71%
Crude Oil	12	1,174	273	Barrels	23%
Lube Oil	1	23	23	Barrels	100%
Motor Oil	1	0.07	0.07	Barrels	100%
Other (Specify)	12	605	412	Barrels	68%
Produced Water	34	873	402	Barrels	46%
Total	**81**	**3,078**	**1,396**	**Barrels**	**45%**
Natural Gas (Methane) and Natural Gas Liquids	25	117,325	112,502	MCF	96%
Total Number of Spills	**106**				

Source: NMOCD 2018.

Drilling and Completion Activities

The BLM and NMOCD's casing, cementing, and inspection requirements would limit the potential for groundwater reservoirs and shallow aquifers to be impacted by fracking or the migration of hydrocarbons on the nominated lease parcels. Prior to approving an APD, a BLM geologist would identify all potential subsurface formations that would be penetrated by the wellbore, including groundwater aquifers and any zones that would present potential safety or health risks that would need special protection measures during drilling, or that could require specific protective well construction measures. Casing programs and cement specifications would be submitted to the BLM and NMOCD for approval to ensure that well construction design would be adequate to protect the subsurface environment, including known or anticipated zones with potential risks or zones identified by the geologist. Surface casing would be set to an approved depth, and the well casing and cementing would stabilize the wellbore and provide protection to any overlying freshwater aquifers by isolating hydrocarbon zones from overlying freshwater aquifers. Before hydraulic fracturing takes place, all surface casings and intermediate zones would be required to be cemented from the bottom of the cased hole to the surface. The cemented well would be pressure tested to ensure there are no leaks, and a cement bond log would be run to confirm that the cement has bonded to the steel casing strings and to the surrounding formations.

The BLM requires operators to comply with the regulations at 43 CFR 3160. These regulations require oil and gas development to comply with directives in the Onshore Orders and the orders of the Authorized Officer. Onshore Order No. 2 and the regulations at 43 CFR 3162.3-3 provide regulatory requirements for hydraulic fracturing, including casing specifications, monitoring and recording, and management of recovered fluids. The State of New Mexico also has regulations for drilling, casing and cementing, completion, and plugging to protect freshwater zones (19.15.16 NMAC). Complying with the aforementioned regulations requires producers and regulators to verify the integrity of casing and cement jobs. Casing specifications are designed and submitted to the BLM together with an APD. The BLM petroleum engineer independently reviews the drilling plan and, based on site-specific geologic and hydrologic information, ensures that proper drilling, casing and cementing procedures are incorporated in the plan in order to protect usable groundwater. This isolates usable water zones from drilling, completion/hydraulic fracturing fluids, and fluids from other mineral bearing zones, including hydrocarbon bearing zones. Conditions of approval (COAs) are attached to the APD, if necessary, to ensure groundwater protection. Installation of the casing and cementing operations are witnessed by certified BLM Petroleum Engineering Technicians. At the end of the well's economic life, the operator must submit a plugging plan. The plugging plan ensures permanent isolation of usable groundwater from hydrocarbon bearing zones and is reviewed by the BLM petroleum engineer prior to well plugging. BLM inspectors ensure planned procedures are properly followed in the field.

Surface casing and cement would be extended beyond usable water zones. Production casing will be extended and adequately cemented within the surface casing to protect other mineral formations, in addition to usable water bearing zones. These requirements ensure that drilling fluids, hydraulic fracturing fluids, and produced water and hydrocarbons remain within the well bore and do not enter groundwater or any other formations. Since the advent of hydraulic fracturing, more than 1 million hydraulic fracturing treatments have been conducted, with perhaps only one documented case of direct groundwater pollution resulting from injection of hydraulic fracturing chemicals used for shale gas extraction (Gallegos and Varela 2015). Requirements of Onshore Order No. 2 (along with adherence to state regulations) make contamination of groundwater resources highly unlikely, and there have not been any documented past instances of groundwater contamination attributed to well drilling. This is an indication of how effective the use of casing and cement is at preventing leaks and contamination.

CHAPTER 4. RIO PUERCO FIELD OFFICE

The Rio Puerco Field Office (FO), located in central and western central New Mexico, is approximately 8,620,838 acres and includes all of Bernalillo, Cibola, Torrance, and Valencia Counties, most of Sandoval County, and small parts of McKinley and Santa Fe Counties (BLM 1986). Some of the land managed by the Rio Puerco FO is within the San Juan oil and gas basin, located in the four-corners area of the United States. To date, most of the drilling in the Rio Puerco FO has occurred in the portion of Sandoval County that is within the San Juan Basin.

Chapter 4 outlines existing and projected (reasonably foreseeable) water quantity and water quality for the Rio Puerco FO. The analysis is based on information gathered from the following sources: 1) the Reasonable Foreseeable Development Scenario for Oil and Gas Activities, Mancos-Gallup RMPA Planning Area, Farmington Field Office, northwestern New Mexico ("2018 RFD"; Crocker and Glover 2018), 2) 2015 consumptive water use data from a USGS report, Estimated Use of Water in the United States in 2015 (Dieter et. al. 2018), 3) FracFocus, a national hydraulic fracturing chemical registry managed by the Ground Water Protection Council and Interstate Oil and Gas Compact Commission (FracFocus 2018), and 4) hydrologic assessments from the New Mexico Bureau of Geology and Mineral Resources (Broadhead et al. 2018; Kelley et al. 2014).

4.1. Water Quantity

Section 4.1.1 documents the total 2015 water withdrawals for the seven counties that are within or partially within the Rio Puerco FO area boundary. Section 4.1.2 describes estimated water use associated with existing and projected (reasonably foreseeable) oil and gas activities within the Rio Puerco FO based on the e2018 RFD (Crocker and Glover 2018). This RFD scenario was originally developed for the Farmington FO, but the BLM has extended its applicability to the Rio Puerco FO because the same geologic formations are present in both Field Offices. The analysis area for examining reasonably foreseeable impacts to water quantity is restricted to the New Mexico portion of the San Juan Basin where most of the oil and gas development is expected to take place. However, existing water use data (Dieter et al. 2018) is provided for the seven counties that are within or partially within the Rio Puerco FO for use in future water quantity analysis.

4.1.1. Existing Surface and Groundwater Use

Rio Puerco FO (Sandoval, Bernalillo, McKinley, Torrance, Santa Fe, Cibola, and Valencia Counties)

Total 2015 consumptive water use data for the seven counties that intersect the Rio Puerco FO are summarized in Table 4-1 through Table 4-7.Water use data is provided for the eight categories within each county: public water supply, industrial, irrigation, livestock, aquaculture, mining (including oil and gas), thermoelectric power, and domestic. For each category, water use totals (in acre-feet per year [AF/yr]) are summarized for surface and groundwater. Surface and groundwater totals are further divided to show the amount of fresh water and saline water used for each category. The USGS data (Dieter et al. 2018) show that no surface water was used in any of the seven counties that comprise the Rio Puerco FO planning area in 2015.

In Sandoval County, where most of the drilling in the Rio Puerco FO is expected to take place, mining accounts for 2 percent (1,312 AF/yr) of the total water use in the county. All water used by mining activities in Sandoval County comes from groundwater. The largest water use categories in Sandoval County are irrigation (79percent), followed by public water supply (8 percent). Most drilling activities in the Rio Puerco FO are expected to take place in the northwest corner of Sandoval County which falls within the San Juan Basin where there is a much greater development potential for oil and gas than in other areas of the county. This determination is based on a 2018 report submitted to the Sandoval County Planning and Zone Commission about the oil and natural gas potential of Sandoval County, which included a discussion on the potential for aquifer contamination (Broadhead et al. 2018). According to this report, the oil and gas development in Sandoval County has thus far occurred in the northern part of the county that is within the San Juan Basin. This trend is likely to continue because "oil and gas potential decreases southward primarily because petroleum source rocks, including the Mancos Shale, become less mature in this direction" (Broadhead et al. 2018:8).

In Bernalillo County, consumptive water use from mining activities in 2015 was 135 AF/yr, which was less than 1 percent of the total water use in that county. The major water use category in Bernalillo County is public water supply, which accounts for 69 percent of the total water use in that county.

Consumptive water use from mining activities in McKinley County accounts for 17 percent of the total water use (Dieter et al. 2018). The 2015 USGS data show water use by county and not BLM field office boundary; therefore, it is not known if mining activities accounting for 17 percent of the total water use are within the Rio Puerco FO or within the neighboring Farmington FO.

In Valencia County, consumptive water use from mining activities in 2015 was 437 AF/yr (all from groundwater), which was less than 1 percent of the total water use in that county. In 2015, irrigation withdrawals accounted for 93 percent of the total water use.

Torrance County water use data is similar to Valencia County. Mining activities used 112.1 AF of water in 2015 (all from groundwater). Water used for mining accounted for 0.2 percent of the total 2015 water use. The dominant water use category in Torrance County was irrigation, which accounted for 94 percent of the total water withdrawal.

In Santa Fe County, located in the northeastern portion of the Rio Puerco FO, consumptive water use from mining activities accounted for 0.6 percent of the total 2015 water use. The largest water use category in Santa Fe County was irrigation at 62 percent, followed by public water supply (30 percent).

Consumptive water used in mining activities in Cibola County account for 13 percent of the 2015 total water use. Most of the groundwater used was saline.

San Juan Basin (Sandoval, Rio Arriba, McKinley, and San Juan Counties)

Table 4-8 summarizes the 2015 water withdrawals within the New Mexico portion of the San Juan Basin, which is comprised of Sandoval, Rio Arriba, McKinley, and San Juan Counties, because the New Mexico portion of the San Juan Basin presents the highest potential for oil and gas development in the Rio Puerco FO. The 2018 RFD scenario states that "unless significant new oil and gas discoveries are made in the area, future activity will be primarily horizontal drilling for oil in the Mancos-Gallup play, with minor development targeted at natural gas production" (Crocker and Glover 2018:4). In 2015 water withdrawals for the mining category accounted for 2 percent of the total water use in the New Mexico portion of the San Juan Basin. Most of the mining water was saline groundwater.

State of New Mexico Water Use

In 2015, withdrawals for all water use categories across the State of New Mexico totaled 3,249,666.9 AF (Dieter et al. 2018). Table 4-9 lists the water withdrawals for the major industries in New Mexico. As shown in the table, *Mining* water withdrawals totaled 163,901 AF, or about 5 percent of the total water withdrawals for the State of New Mexico. While the data presented in this table are for the state as a whole, most water use in this category is from the Permian Basin, with some water use from the New Mexico portion of the San Juan Basin.

Table 4-1. 2015 Sandoval County Water Use by Category (AF)

	Surface Water				Groundwater				Total Water			
Category	**Fresh**	**Saline**	**Total Surface Water**	**% of Total Water**	**Fresh**	**Saline**	**Total Groundwater**	**% of Total Water**	**Total Fresh Water**	**Total Saline Water**	**Total Water**	**% of Total Water**
Aquaculture	0	0	0	0%	1,087	0	1,087	100%	1,087	0	1,087	1%
Domestic	0	0	0	0%	3,128	0	3,128	100%	3,128	0	3,128	2%
Industrial	0	0	0	0%	2,578	0	2,578	100%	2,578	0	2,578	1%
Irrigation	48,326	0	48,326	99%	2,3201	0	2,321	1%	50,647	0	50,647	79%
Livestock	101	0	101	31%	123	0	123	69%	224	0	224	0%
Mining	0	0	0	23%	1,065	247	1,312	77%	1,065	246.6	1,312	2%
Public Water Supply	135	0	135	55%	12,466	0	12,466	45%	12,600	0	12,600	8%
Thermoelectric power	0	0	0	93%	0	0	0	7%	0	0	0	7%
County Totals	**48,562**	**0**	**48,562**	**90%**	**22,768**	**247**	**23,014**	**10%**	**71,329**	**246.6**	**71,576**	**100%**

Source: Dieter et al. 2018

Table 4-2. 2015 Bernalillo County Water Use by Category (AF)

	Surface Water				Groundwater				Total Water			
Category	**Fresh**	**Saline**	**Total Surface Water**	**% of Total Water**	**Fresh**	**Saline**	**Total Groundwater**	**% of Total Water**	**Total Fresh Water**	**Total Saline Water**	**Total Water**	**% of Total Water**
Aquaculture	0	0	0	0%	22	0	22	100%	22	0	22	0%
Domestic	0	0	0	0%	1,312	0	1,312	100%	1,312	0	1,317	1%
Industrial	0	0	0	0%	56	0	56	100%	56	0	56	0%
Irrigation	38,843	0	38,843	83%	7,701	0	7,701	17%	46,544	0	46,544	30%
Livestock	11	0	11	6%	191	0	191	094%	202	0	202	0%
Mining	0	0	0	0%	135	0	135	100%	135	0	135	0%
Public Water Supply	52,743	0	52,743	49%	54,077	0	54,077	50%	106,820	0	106,820	69%
Thermoelectric power	0	0	0	0%	292	0	292	100%	292	0	292	0%
County Totals	**91,597**	**0**	**91,597**	**59%**	**63,785**	**0**	**63,785**	**41%**	**155,382**	**0**	**155,3819**	**100%**

Source: Dieter et al. 2018

Table 4-3. 2015 McKinley County Water Use by Category (AF)

	Surface Water				Groundwater				Total Water			
Category	**Fresh**	**Saline**	**Total Surface Water**	**% of Total Water**	**Fresh**	**Saline**	**Total Groundwater**	**% of Total Water**	**Total Fresh Water**	**Total Saline Water**	**Total Water**	**% of Total Water**
Aquaculture	0	0	0	0%	0	0	0	0%	0	0	0	0%
Domestic	0	0	0	0%	3,195	0	3,195	100%	3,195	0	3,195	24%
Industrial	0	0	0	0%	34	0	34	100%	34	0	34	0%
Irrigation	1,099	0	1,099	100%	0	0	0	0%	1,099	0	1,099	8%
Livestock	101	0	101	21%	370	0	370	79%	471	0	471	4%
Mining	0	0	0	0%	1,626	684	2,309	100%	1,626	684	2,309	17%
Public Water Supply	0	0	0	0%	3,811	0	3,811	100%	3,811	0	3,811	29%
Thermoelectric power	0	0	0	0%	2,298	0	2,298	100%	2,298	0	2,298	17%
County Totals	**1,200**	**0**	**1,200**	**9%**	**11,333**	**684**	**12,017**	**91%**	**12,533**	**684**	**13,217**	**100%**

Source: Dieter et al. 2018

Table 4-4. 2015 Valencia County Water Use by Category (AF)

	Surface Water				Groundwater				Total Water			
Category	**Fresh**	**Saline**	**Total Surface Water**	**% of Total Water**	**Fresh**	**Saline**	**Total Groundwater**	**% of Total Water**	**Total Fresh Water**	**Total Saline Water**	**Total Water**	**% of Total Water**
Aquaculture	0	0	0	0%	0	0	0	0%	0	0	0	0%
Domestic	0	0	0	0%	3,554	0	3,554	100%	3,554	0	3,554	2%
Industrial	0	0	0	0%	0	0	0	0%	0	0	0	0%
Irrigation	136,157	0	136,157	93%	10,089	0	10,089	7%	146,246	0	146,246	93%
Livestock	34	0	34	3%	987	0	987	97%	1,020	0	1,020	1%
Mining	0	0	0	0%	437	0	437	100%	437	0	437	0%
Public Water Supply	0	0	0	0%	5,538	0	5,538	100%	5,538	0	5,538	4%
Thermoelectric power	0	0	0	0%	0	0	0	0%	0	0	0	0%
County Totals	**136,190**	**0**	**136,190**	**867%**	**20,604**	**0**	**20,604**	**13%**	**156,794**	**0**	**156,794**	**100%**

Source: Dieter et al. 2018

Table 4-5. 2015 Torrance County Water Use by Category (AF)

	Surface Water				Groundwater				Total Water			
Category	Fresh	Saline	Total Surface Water	% of Total Water	Fresh	Saline	Total Groundwater	% of Total Water	Total Fresh Water	Total Saline Water	Total Water	% of Total Water
Aquaculture	0	0	0	0%	0	0	0	0%	0	0	0	0%
Domestic	0	0	0	0%	437	0	437	100%	437	0	437	1%
Industrial	0	0	0	0%	0	0	0	0%	0	0	0	0%
Irrigation	0	0	0	0%	45,849	0	45,849	100%	45,849	0	45,849	94%
Livestock	45	0	45	7%	605	0	605	93%	650	0	650	1%
Mining	0	0	0	0%	112	0	112	100%	112	0	112	0%
Public Water Supply	0	0	0	0%	1,973	0	1,973	100%	1,973	0	1,973	4%
Thermoelectric power	0	0	0	0%	0	0	0	0%	0	0	0	0%
County Totals	**45**	**0**	**45**	**0.1%**	**48,977**	**0**	**48,977**	**100%**	**49,021**	**0**	**49,021**	**100%**

Source: Dieter et al. 2018

Table 4-6. 2015 Santa Fe County Water Use by Category (AF)

	Surface Water				Groundwater				Total Water			
Category	Fresh	Saline	Total Surface Water	% of Total Water	Fresh	Saline	Total Groundwater	% of Total Water	Total Fresh Water	Total Saline Water	Total Water	% of Total Water
Aquaculture	0	0	0	0%	0	0	0	0%	0	0	0	0%
Domestic	0	0	0	0%	2,522	0	2,522	100%	2,522	0	2,522	6%
Industrial	0	0	0	0%	0	0	0	0%	0	0	0	0%
Irrigation	11,378	0	11,378	47%	12,936	0	12,936	53%	24,315	0	24,315	62%
Livestock	56	0	56	45%	67	0	67	55%	123	0	123	0%
Mining	0	0	0	0%	224	0	224	100%	224	0	224	1%
Public Water Supply	4,663	0	4,663	39%	7,185	0	7,186	60%	11,849	0	11,849	30%
Thermoelectric power	0	0	0	0%	0	0	0	0%	0	0	0	0%
County Totals	**16,098**	**0**	**16,098**	**41%**	**22,936**	**0**	**22,936**	**59%**	**39,033**	**0**	**39,033**	**100%**

Source: Dieter et al. 2018

Table 4-7. 2015 Cibola County Water Use by Category (AF)

	Surface Water				Groundwater				Total Water			
Category	**Fresh**	**Saline**	**Total Surface Water**	**% of Total Water**	**Fresh**	**Saline**	**Total Groundwater**	**% of Total Water**	**Total Fresh Water**	**Total Saline Water**	**Total Water**	**% of Total Water**
Public Water Supply	0	0	0	0%	2,668.0	0	2,668.0	100%	2,668	0	2,668	25%
Industrial	0	0	0	0%	0	0	0	0%	0	0	0	0%
Irrigation	1,5912	0	1,592	29%	3,856.2	0	3,856.2	71%	5,448	0	5,448	50%
Livestock	34	0	34	20%	134.5	0	134.5	80%	168	0	168	2%
Aquaculture	0	0	0	0%	0	0	0	0%	0	0	0	0%
Mining	0	0	0	0%	67.3	1,356.4	1,423.7	100%	67	1,356	1,424	13%
Thermoelectric power	0	0	0	0%	0	0	0	0%	0	0	0	0%
Domestic	0	0	0	0%	1,143.4	0	1,143.4	100%	1,143	0	1,143	11%
County Totals	**1,626**	**0**	**1,626**	**15%**	**7,869.4**	**1,356.4**	**9,225.8**	**85%**	**9,495**	**1,356**	**10,851**	**100%**

Source: Dieter et al. 2018

Table 4-8. 2015 San Juan Basin Water Use by Category (AF)

	Surface Water				Groundwater				Total Water			
Category	**Fresh**	**Saline**	**Total Surface Water**	**% of Total Water**	**Fresh**	**Saline**	**Total Groundwater**	**% of Total Water**	**Total Fresh Water**	**Total Saline Water**	**Total Water**	**% Total Water**
Public Water Supply	21,612.9	0.0	21,612.9	4%	17,958.4	0.0	17,958.4	4%	39,571.3	0.0	39,571.3	8%
Industrial	0.0	0.0	0.0	0%	2,634.4	0.0	2,634.4	1%	2,634.4	0.0	2,634.4	1%
Irrigation	381,240.9	0.0	381,240.9	78%	3,576.0	0.0	3,576.0	1%	384,816.9	0.0	384,816.9	79%
Livestock	437.2	0.0	437.2	0%	986.5	0.0	986.5	0%	1,423.7	0.0	1,423.7	0%
Aquaculture	0.0	0.0	0.0	0%	4,640.9	0.0	4,640.9	1%	4,640.9	0.0	4,640.9	1%
Mining	2,724.0	0.0	2,724.0	0.6%	3,676.9	5,257.5	8,934.4	1.8%	6,400.9	5,257.5	11,658.4	2%
Thermoelectric power	30,636.9	0.0	30,636.9	6%	2,298.1	0.0	2,298.1	0%	32,935.0	0.0	32,935.0	7%
Domestic	0.0	0.0	0.0	0%	8,979.2	0.0	8,979.2	2%	8,979.2	0.0	8,979.2	2%
County Totals	436,651.9	0.0	436,651.9	89.7%	44,750.3	5,257.5	50,007.8	10.3%	481,402.2	5,257.5	486,659.7	100%

Table 4-9. 2015 Statewide Water Use in New Mexico by Category (AF)

	Surface Water				Groundwater				Total Water			
Category	Fresh	Saline	Total Surface Water	% of Total Water	Fresh	Saline	Total Groundwater	% of Total Water	Total Fresh Water	Total Saline Water	Total Water	% of Total Water
Public Water Supply	87,751.9	0	87,751.9	3%	205,714.7	0	205,714.7	6%	293,466.6	0	293,466.6	9%
Industrial	0	0	0	0%	3,811.4	0	3,811.4	0%	3,811.4	0	3,811.4	0%
Irrigation	1,485,112.0	0	1,485,112.0	46%	1,175,312.5	0	1,175,312.5	36%	2,660,424.5	0	2,660,424.5	82%
Livestock	2,522.3	0	2,522.3	0%	33,372.2	0	33,372.2	1%	35,894.4	0	35,894.4	1%
Aquaculture	6,109.5	0	6,109.5	0%	20,929.1	0	20,929.1	1%	27,038.5	0	27,038.5	1%
Mining	19,550.2†	0	19,550.2	1%	44,111.4	100,239.8	144,351.2	4%	63,661.6	100,239.8	163,901.4	5%
Thermoelectric power	30,636.9	0	30,636.9	1%	6,871.7	0	6,871.7	0%	37,508.7	0	37,508.7	1%
Domestic	0	0	0	0%	27,621.4	0	27,621.4	1%	27,621.4	0	27,621.4	1%
Totals	**1,631,682.8**	**0**	**1,631,682.8**	**50.2%**	**1,517,744.3**	**100,239.8**	**1,617,984.1**	**49.8%**	**3,149,427.1**	**100,239.8**	**3,249,666.9**	**100%**

Source: Source: Dieter et al. 2018; updated with additional information provided to the BLM from the NMOSE regarding water use of the Navajo Power Plant (BLM 2019a).

† Approximately 19,550 AF of the freshwater use within the Mining industry is from surface water; the remainder of all other water use is from groundwater. The Mining category includes the following self-supplied enterprises that extract minerals occurring naturally in the earth's crust: solids, such as potash, coal, and smelting ores; liquids, such as crude petroleum; and gases, such as natural gas. This category includes water used for oil and gas production (well drilling and secondary recovery of oil), quarrying, milling (crushing, screening, washing, flotation, etc.), and other processing done at the mine site or as part of a mining activity, as well as water removed from underground excavations (mine dewatering) and stored in—and evaporated from—tailings ponds. The Mining category also includes water used to irrigate new vegetative covers at former mine sites that have been reclaimed. It does not include the processing of raw materials, such as smelting ores, unless this activity occurs as an integral part of a mining operation and is included in an NMOSE permit.

4.1.2. Water Use Associated with Reasonably Foreseeable Oil and Gas Development

Estimates for the number of oil and gas wells that could reasonably occur in the San Juan Basin were derived from two RFD scenarios: Reasonable Foreseeable Development Scenario (RFD) for Fluid Mineral Development in the Rio Puerco Field Office (BLM 2010) and the 2018 RFD (Crocker and Glover 2018).

The BLM 2010 RFD forecasted development of approximately 5.5 wells per year in the Rio Puerco FO, of which three were anticipated to be in the San Juan Basin. The 2018 RFD (Crocker and Glover 2018) Scenario projected 3,200 wells to be drilled in the Mancos-Gallup planning area between 2018 and 2037. Of the 3,200 wells projected to be drilled between 2018 and 2037, 2,300 are expected to be horizontal and 900 are expected to be vertical.

The 2018 RFD (Crocker and Glover 2018) was used to forecast the potential quantity of oil and gas wells in the Mancos-Gallup Resource Management Plan Amendment (RMPA) Planning Area. The RFD was also used to forecast estimates the quantity of water that would be required for hydraulic fracturing of the forecasted wells. These water use estimates assume that 100% of wells will be hydraulically fractured, and do not account for re-use or recycling of hydraulic fracturing fluid. While the 2018 RFD was originally developed for the Farmington FO, it is applicable to the Rio Puerco FO because the Mancos-Gallup planning area examined in the 2018 RFD included the portion of the Rio Puerco office where oil and gas development has typically occurred and because the same geologic formations that underlie the Farmington FO also underlie parts of the Rio Puerco FO likely to be developed in the future. The 2018 RFD incorporates more recent data than the 2010 RFD and discusses surface disturbance associated with both horizontal and vertical development. As such, the 2018 RFD is a reasonable estimate of the development and consumptive water use associated with hydrocarbon production in the New Mexico portion of the San Juan Basin for the next 20 years (2018–2037).

Water use associated with hydraulic fracturing is dependent on many factors, including the drilling method (horizontal or vertical) and the geologic formation at the well site. The 2018 RFD scenario utilizes water use estimates from a 2014 RFD scenario from the New Mexico Bureau of Geology and Mineral Resources entitled *Hydrologic Assessment of Oil and Gas Resource Development of the Mancos Shale in the San Juan Basin* by Kelley et al. (2014). According to Kelley et al. (2014:4), "vertical wells drilled into the Mesaverde Group, Gallup Sandstone, and the Dakota Sandstone account for 83% of the hydraulically fractured completions [in the San Juan Basin] since 2005."

Water use per well is dependent on the geologic formation, but on average, the water use for vertical wells in the New Mexico portion of the San Juan Basin is 0.537 AF/well (Crocker and Glover 2018). Horizontal wells require more water than vertical wells. The 2018 RFD reported that horizontal wells in the New Mexico portion of the San Juan Basin require on average approximately 3.13 AF of water. More recent information on horizontal well development in the New Mexico portion of the San Juan Basin has indicated water use is higher. Because of this uncertainty, the BLM conducted studies using calendar year 2018 data from FracFocus, a national hydraulic fracturing chemical registry managed by the Ground Water Protection Council and Interstate Oil and Gas Compact Commission, to provide objective information on hydraulic fracturing. Operators are required by the State of New Mexico to disclose chemistry and water use information on FracFocus. Analysis of the FracFocus data for the New Mexico portion of the San Juan Basin (which included 126 records) resulted in a value of 4.8 AF of water per horizontal well. As a result of these studies, the BLM considers the estimate of 4.8 AF the most accurate current estimate of water use per horizontal well in the New Mexico portion of the San Juan Basin. Table 4-10 provides a comparison of the water use estimates used in the RFD and the BLM's revised water use estimates. Some factors have been modified based on best available information (for example, the projected water use associated with horizontal drilling methods discussed above) as well as best professional judgment of BLM engineering staff and resource specialists.

Table 4-10. Projected Water Use in San Juan Basin (Farmington FO and Rio Puerco FO)

Factor	Water Use in RFD (Crocker and Glover 2018)	Revised Water Use	Rationale for Change
Average Water Use per Horizontal Well during a hydraulic fracturing operation	3.13 AF	4.8 AF[1]	Reflects actual use as reported in FracFocus
Average Water Use per Vertical Well during a hydraulic fracturing operation	0.48 AF	0.537 AF[2]	NA
Total Water Use (2018-2037)	7,683 AF[3]	11,523 AF[3]	

[1] Source: FracFocus 2018

[2] Source: Crocker and Glover 2018. Estimated water use based on number of wells in each geologic formation.

[3] Total water use = (2,300 horizontal wells * horizontal well water use estimate) + (900 vertical wells * vertical well water use estimate)

Note: AF is acre-feet.

Water used for development of the estimated 3,200 wells in the RFD scenario (Crocker and Glover 2018) is assumed to come primarily from groundwater sources based on previous oil and gas development in the area and from county water use data summarized above in Tables 4-1 through 4-8 (Dieter et al. 2018). Drilling and completion of the 3,200 wells estimated to occur in the planning area would require approximately 7,683 AF using water use estimates contained in the Crocker and Glover RFD scenario, and 11,615 AF of water using the BLM's revised water use estimates (1.6 and 2.4 percent, respectively, of the 2015 total water withdrawal in the San Juan Basin, if the entire RFD were to be developed in one year).

The cumulative impact on water use in the San Juan Basin for any given year during the 20-year RFD scenario is estimated by assuming wells and corresponding water use would be developed at a constant rate over a 20-year period (RFD scenario). Using the Crocker and Glover RFD scenario, water use for development of oil and gas would be 7,683 AF, or 384 AF for any given year in the 20-year period of the RFD, which is approximately 0.08 percent of the total 2015 water withdrawals in the San Juan Basin.

Using the BLM's revised water use figures, water use for development of oil and gas for any given year in the 20-year period of the RFD would be about 580 AF, which is approximately 0.12 percent of the total 2015 water withdrawals in the San Juan Basin. If all wells in the RFD were developed in one year, the water use required (11,615 AF) would be approximately 2.4 percent of the total 2015 water use in the San Juan Basin (486,660 AF).

Water use could increase if more water-intensive stimulation methods (e.g., slick water fracturing) are implemented or if laterals become longer. Alternatively, water use estimates could be lower if produced water is reused or recycled for use in hydraulic fracturing.

4.1.3. Cumulative Water Use Estimates

Past and Present Actions

Past and present use is discussed in Section 4.1.1, Existing Surface and Groundwater Use. As noted in that section, total water use in the counties comprising the San Juan Basin (486,660 AF) accounted for 15 percent of total state withdrawals (3,249,667 AF) in 2015 (Dieter et al. 2018). Mining (which includes oil and gas development) comprised about 2 percent of San Juan Basin total water withdrawals. The largest user of water in the San Juan Basin is irrigation (comprising 79 percent of all withdrawals in the San Juan Basin).

The BLM also examined FracFocus data reported for the calendar years of 2014 to 2018 (FracFocus 2019) to ascertain actual water use by the oil and gas industry in the San Juan Basin. This information is presented in Table 4-11.

Consumptive water use by municipal, industrial, and agricultural activities (including oil and gas activities) represents a single element of a hypothetical water budget for the planning area. While a detailed water budget quantifying hydrologic inputs and outputs for the planning area is outside the scope of this document, it should be noted that various hydrologic inputs are occurring alongside the consumptive water use depicted in Figures 2-4 and Figures 2-5. Groundwater can be recharged through a variety of processes such as precipitation, irrigation return flow, and seepage from rivers and streams. Similarly, groundwater discharge in the planning area occurs not only through consumptive water use, but also through evapotranspiration and discharge from springs and seeps.

Table 4-11. Actual Water Use in the San Juan Basin for Calendar Years 2014-2018

Year	Federal Water Use (AF)	Non-Federal Water Use (AF)	Total WU (AF)	Federal Water Use (%)	Federal Cumulative Water Use (AF)	Total Cumulative Water Use (AF)	Average Water Use per Well (AF)	Total # of Wells Reported to FracFocus
2014	165	155	320	51	165	320	2.4	133
2015	87	255	343	25	252	662	3.8	90
2016	86	26	111	77	337	773	2.5	44
2017	229	50	279	82	566	1,052	4.4	63
2018	361	282	643	56	927	1,695	4.6	141
Total	**927**	**768**	**1,695**	**--**	**--**	**--**	**--**	**471**

Source: FracFocus 2019.

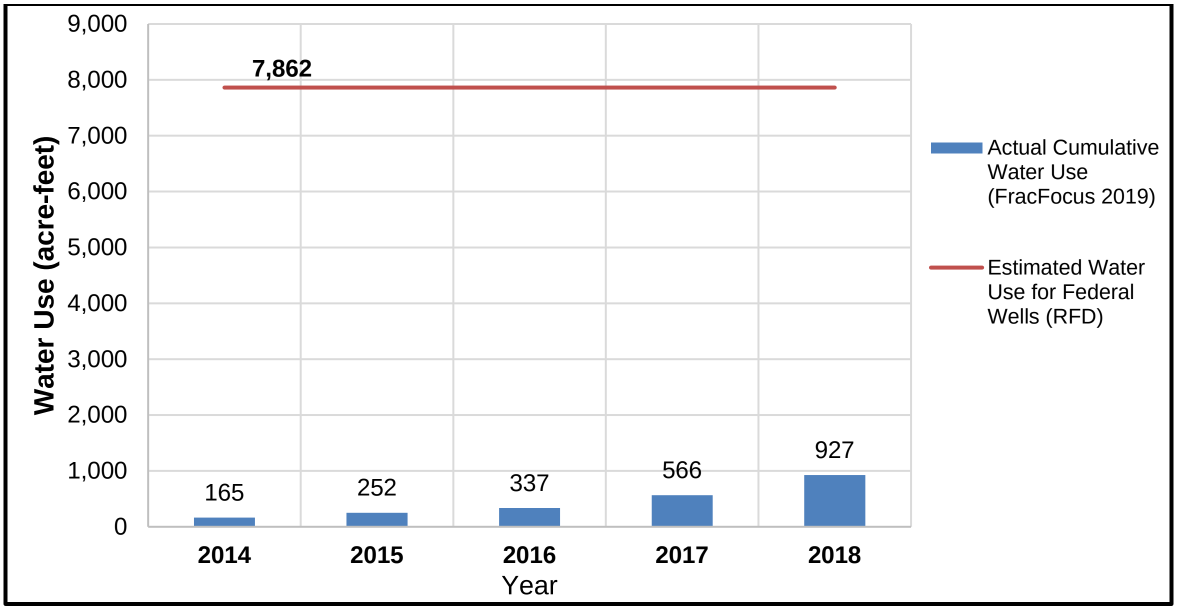
Note: San Juan Basin is comprised of Sandoval, Rio Arriba, and San Juan Counties.

Water use by oil and gas wells in the San Juan Basin has increased from 320 AF in 2014 to 643 AF in 2018, with a corresponding basin-wide average water use per well increase from 2.4 AF per well to 4.6 AF per well (FracFocus 2019). Total federal cumulative water use in the basin was 927 AF during the same period, a percentage of 55 percent of total water use. Cumulative water use is calculated by adding all previous water use to the water use for any given year. The total number of wells that were reported to FracFocus from 2014 to 2018 also increased from 133 wells to 141 wells.

Oil and Gas Development RFFAs

RFD

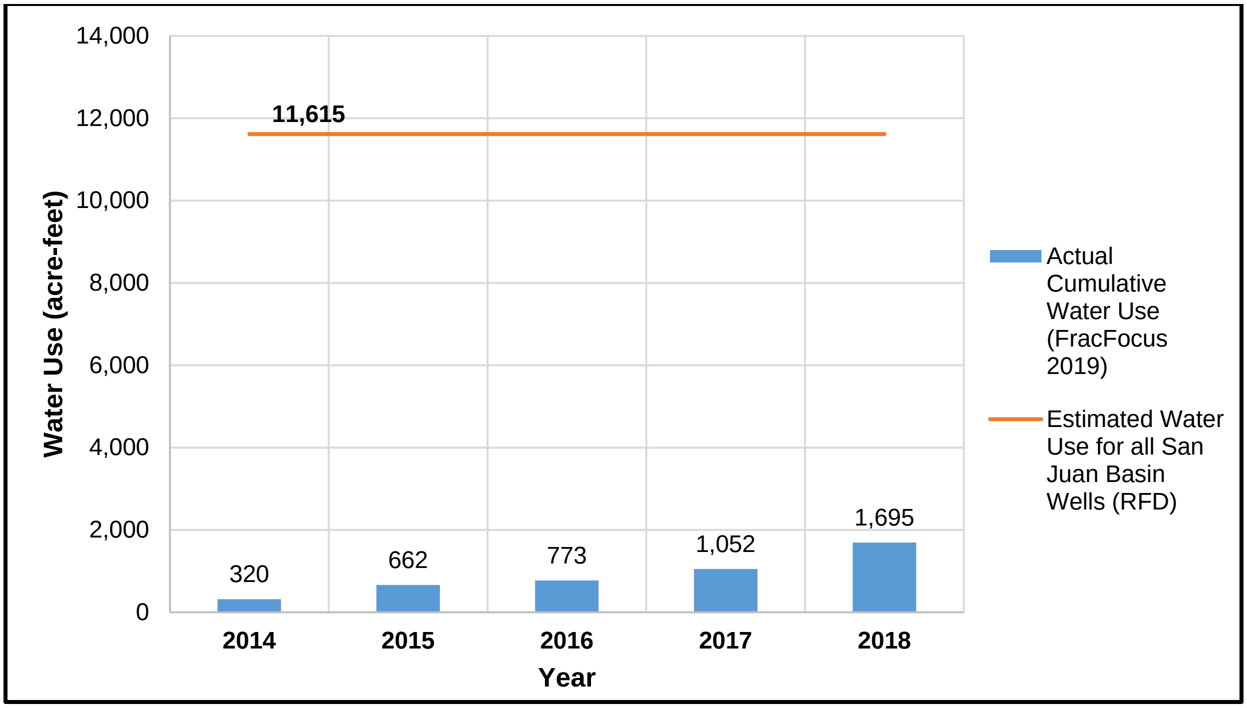
As noted in Section 4.1.2, Water Use Associated with Reasonably Foreseeable Oil and Gas Development, 3,200 wells are expected to be drilled in the San Juan Basin between 2018 and 2037, with a total of 1,980 wells on federal land (1,580 horizontal and 400 vertical). Total water use for the RFD over the 20-year period is currently estimated at 11,615 AF, or about 580 AF in any given year. Well development projected as a result of ongoing BLM and state lease sales is already considered in these RFDs. Well development associated with recent or reasonably foreseeable APDs or master development plans are also included in these RFDs. Figure 4-1 shows cumulative water use between 2014 and 2018 for federal wells in the San Juan Basin (FracFocus 2019) compared to water use estimates from the RFD scenario (Crocker and Glover 2018).



Note: Actual water use from FracFocus 2019. Cumulative water use for each year (shown in blue) is calculated by adding the sum of all previous actual water use to the actual water use for any given year. The estimated water use for federal wells in the San Juan Basin (shown in orange) is derived from the RFD scenario using the revised water use estimates discussed in Section 3.1.2 (4.84 AF per horizontal well). The RFD scenario estimates 1,980 federal wells (1,580 horizontal and 400 vertical).

Figure 4.1. Actual Water Use (2014-2018) Compared to Projected Water Use for Federal Wells in the San Juan Basin.

A similar scenario is presented in Figure 4-2, which shows cumulative water use between 2014 and 2018 for all wells (both federal and non-federal) in the San Juan Basin (FracFocus 2019) compared to water use estimates from the RFD scenario (Crocker and Glover 2018). As noted in Section 4.1.2, Water Use Associated with Reasonably Foreseeable Oil and Gas Development, 3,200 wells are expected to be drilled in the planning area between 2018 and 2037. Total consumptive water use for the RFD over the 20-year period is currently estimated at 11,615 AF, or about 580 AF in any given year.



Note: Actual water use from FracFocus 2019. Cumulative water use for each year (shown in blue) is calculated by adding the sum of all previous actual water use to the actual water use for any given year. The estimated water use for all wells in the San Juan Basin (shown in orange) is derived from the RFD scenario using the revised water use estimates discussed in Section 3.1.2 (4.84 AF per horizontal well).

Figure 4.2. Actual Cumulative Use (2014-2018) Compared to Projected Water Use for All Wells in the San Juan Basin.

2019 Oil and Gas Trends

In 2018, the Rio Puerco FO did not receive any APDs. The cumulative analysis herein is for the San Juan Basin as a whole and all APD authorizations noted for 2018 were processed through the Farmington FO. In 2019, by the publication date of this report, the Rio Puerco FO has received two APDs for wells located on Zia trust lands, with federal minerals. The two wells are vertical, and the water usage is expected to be consistent with that projected in the RFD for vertical wells.

Other RFFAs

No other RFFAs with substantial use have been identified. Some water use would be required during construction and operation of reasonably foreseeable transmission lines and pipelines; however, these uses are minimal and are not quantified in this analysis. Future water use for the other reported water use categories in the San Juan Basin is assumed to continue at current levels.

Cumulative Impacts

Development of the RFD using water use values of 0.537 AF/vertical well (Crocker and Glover 2018), and 4.84 AF/horizontal well (developed through a review 2018 FracFocus water use data) would result in the use of approximately 11,615 AF of water, or 580 AF of water in any given year. This water use would occur over approximately 20 years and would cumulatively represent about 0.12 percent of San Juan Basin 2015 total water withdrawals (486,660 AF). As noted above, agriculture would remain by far the largest water use within the San Juan Basin (currently 79 percent of all water use within the San Juan Basin).

4.1.4. Potential Sources of Water for Project Development

Water used for oil and gas drilling and completion would be purchased legally from those who hold water rights in or around the San Juan Basin. The transaction would be handled by the New Mexico Oil Conservation Division, as well as the New Mexico Office of the State Engineer. All water uses would be evaluated at the APD stage in site-specific NEPA analysis and subject to standard lease terms and conditions; however, it is important to note that sources of water for lease development are also not always known at the APD stage.

It is speculative to predict the actual source of water that would be used for development of the RFD (or the development of any specific lease sales). In addition to utilizing surface or groundwater, operators may also bring water to a well site via truck from any number of sources. Because most water used in mining activities in the counties that comprise the Rio Puerco FO is currently from groundwater, it is reasonable to assume that a large portion of the water used for hydraulic fracturing under the RFD scenario would likely be groundwater. Groundwater is a more readily available source of water than surface water due to the ephemeral nature of many surface water features in the San Juan Basin. Therefore, surface waters are discussed only briefly in this chapter.

The Rio Puerco FO contains many types of surface water bodies including springs, seeps, lakes, rivers, streams, and ephemeral drainages and draws. Waters from spring developments, reservoirs, streams, and stream diversions within the planning area are used primarily for irrigation, livestock, and wildlife. Diversions on BLM-managed lands support private land crop irrigation and stock water needs.

Information about the aquifers underlying the Rio Puerco FO comes primarily from the hydrologic assessment of oil and gas development in the San Juan Basin (Kelly et al. 2014), the Mancos-Gallup Resource Management Plan Amendment and EIS (BLM 2015), and from the Mancos-Gallup Resource Management Plan Amendment and Environmental Impact Statement (BLM 2015).

The geologic setting of the San Juan Basin is highly stratified and complex. Geologic processes have created both continuous and discontinuous sandstone aquifers. There are ten major confined aquifers in the San Juan Basin: Morrison Formation, Ojo Alamo Sandstone, Pictured Cliffs Sandstone, Cliff House Sandstone, Menefee Formation, Kirtland Shale/Fruitland Formation, Point Lookout Sandstone, Gallup Sandstone, Dakota Sandstone, and Entrada Sandstone" (Kelley et al. 2014). "Most of the groundwater in the San Juan Basin is developed in Cenozoic to Mesozoic sandstones that are separated by low-permeability shale to mudstone intervals" (Kelley et al. 2014:10). Table 4-11 lists the general description of the major rock units in the San Juan Basin.

Some formations within the San Juan Basin produce more water than others. Cenozoic (younger) aquifers in the San Juan Basin, such as the Ojo Alamo Sandstone, the Nacimiento Formation, and the San Juan Formation, have potential to produce water at a rate of 100 gallons per minute (gpm) (BLM 2015). Other aquifers in the San Juan Basin are known to yield water at rate of less than 20 gal/min (BLM 2015). According to Kelley et al. (2014:55), "Of the aquifers investigated in this study, the "true" Gallup Sandstone contains the least amount of water and the San Jose/Nacimiento aquifer contains the most."

In the southern portion of the San Juan Basin, water for hydraulic fracturing of oil wells comes from sources that tap the Nacimiento Formation and the Ojo Alamo Sandstone. Kelley et al. (2014:56) state that, "Water level monitoring by the U.S. Geological Survey during the 1980s reveals that long term use of a well drilled into these aquifers will cause water levels to drop, potentially affecting neighboring wells."

Table 4-12. General Description of the Major Rock Units in the San Juan Basin

Youngest	Formation	Rock Type (major rock listed first)	Resource
Cenozoic	San Jose Formation	Sandstone and shale	Water, gas
	Nacimiento Formation	Shale and sandstone	Water, gas
	Ojo Alamo Sandstone	Sandstone and shale	Water, gas
Cretaceous	Kirtland Shale	Interbedded shale, sandstone	Water, oil, gas
	Fruitland Shale	Interbedded shale, sandstone and coal	Coal, coalbed, methane
	Pictured Cliffs Sandstone	Sandstone	Oil, gas
	Lewis Shale	Shale, thin limestones	Gas
	Cliff House Sandstone	Sandstone	Oil, gas
	Menefee Formation	Interbedded shale, sandstone and coal	Coal, coalbed, methane, gas
	Point Lookout Sandstone	Sandstone	Oil, gas, water
	Crevasse Canyon Formation	Interbedded shale, sandstone and coal	Coal
	Gallup Sandstone	Sandstone, and a few shales and coals	Oil, gas, water
	Mancos Shale	Shale, thin sandstones	Oil, gas
	Dakota Sandstone	Sandstone, shale and coals	Oil, gas, water
Jurassic	Morrison Formation	Mudstones, sandstone	Uranium, oil, gas, water
	Wanakah/Summerville/Cow Springs/Bluff	Siltsone, sandstone	N/A
Oldest	Entrada Sandstone	Sandstone	Oil, gas, water

Source: Kelly et al. 2014. Table 15. Generalized description of the Cenozoic, Cretaceous, and Jurassic rock units in the San Juan Basin

4.1.5. Water Use Mitigations

Overall, there have been calls to increase the use of alternative water sources such as brackish water or recycling produced water, minimizing the strain on local freshwater resources (Kondash et al. 2018). The BLM encourages the use of recycled water in hydraulic fracturing techniques.

Moreover, recent studies indicate that the water used for hydraulic fracturing may be retained within the shale formation, with only a small fraction of the fresh water injected into the ground returning as flowback water; water returning to the surface is highly saline, is difficult to treat, and is often disposed through deep-injection wells (Kondash et al. 2018). Thus, the ability to recycle water may be more limited than previously reported. Note that water use calculations above do not assume the use of recycled water.

4.2. Water Quality

4.2.1. Groundwater

Results of the hydrologic assessment of oil and gas development of the Mancos Shale in the San Juan Basin (Kelley et al. 2014) indicate that groundwater quality in the San Juan Basin is variable (ranging from fresh to brackish) due to the complex stratigraphy and varying rock formations within the Basin. Brackish and saline water is typically found in the center of the Basin, and fresh groundwater is typically found along the Basin margins. Deep saline water can migrate upward along cracks and fissures. Fresh water along the Basin margins at depths greater than 3,500 feet indicate fast recharge rates influenced by geologic structures (Kelley et al. 2015).

The geologic formation where groundwater resides also influences groundwater salinity. Figure 4-1 (Figure 15; Kelley et al. 2014) is an illustrated geologic cross section showing the distribution of saline aquifers within the San Juan Basin.

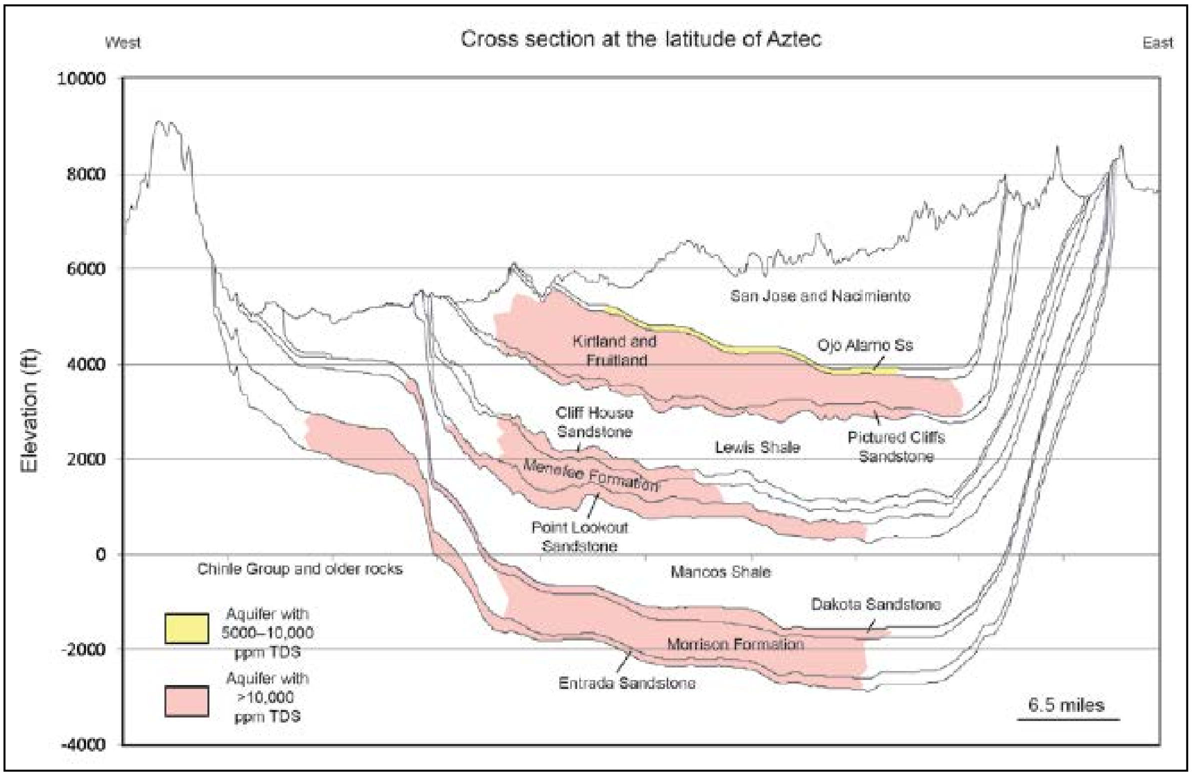


Figure 4.3. Geologic cross section showing the distribution of saline aquifers in the San Juan Basin.

Source: Figure 15 from Kelley et al. 2014.

Total dissolved solids (TDS) concentration is a measure of all the dissolved matter in a sample of water. TDS is the primary indicator of groundwater quality as higher TDS concentrations typically make water less suitable for drinking or for agricultural purposes like irrigation. In groundwater, TDS is influenced by the dissolution of natural materials such as rock, soil, and organic material. Anthropogenic activities also contribute to TDS concentrations in shallow unconfined aquifers.

TDS concentration in the San Juan Basin is dependent on the stratigraphic location and the geologic formation where the water resides. Fresh water (TDS < 1,000 milligrams per liter [mg/l]) is typically found at depths <2,500 feet (ft) below the ground surface, although exceptions to this generalization occur in deeper layers like the Gallup Sandstone and Morrison Formation. Saline and brackish water is dominant in the center of the Basin at deeper depths (Kelley et al. 2014).

4.2.2. Surface Water

Surface water quality data are limited to data gathered from perennial surface water drainages in the Rio Puerco FO. Water quality in streams flowing on BLM-managed land is influenced by both natural water quality with regard to salinity content and the intensity of human and industrial activity in the watershed. For example, water quality may be vastly different in a remote mountain spring creek than in waters with natural brine discharge, or where there are human impacts due to urban, farming, ranching, or industrial activity. Chemistry samples of surface water in the planning region are needed in order to establish a baseline chemistry data for the waters. Variances in baseline chemistry can indicate water quality changes attributable to land use development.

4.2.3. Potential Sources of Surface Water or Groundwater Contamination

Spills

Spills associated with oil and gas development may reach surface water directly during the spill event. Spills may also reach surface waters indirectly, when the spill has occurred, and a rain event moves contaminants into nearby surface water bodies through surface water flow or even subsurface groundwater flow into springs that discharge into a surface water body.

The San Juan Basin has been a producing oil and natural gas field since the early to middle 1900s. According to available GIS data, approximately 37,000 wells have been drilled within the boundary of the Farmington FO (BLM 2018). In 2017 oil and gas development resulted in 5,979,536 bbls of crude oil; 464,709,385 mcf of natural gas; and 17,068,297 bbls of produced water. As shown in Table 2-12, there were a total of 106 spills in the New Mexico portion of the San Juan Basin in 2018. The volume of spilled oil, natural gas, and produced water comprises approximately 2.0 percent, 0.0003 percent, and 0.01 percent, respectively, of 2017 oil, natural gas and produced water values. Appendix C contains a methodology for analyzing spill data.

The rate of recovery varied by spill type but in generally, about 55 percent of all spills were not recovered. Of the spills above, nine incidents were reported as having affected surface waterways: three incidents involving produced water (57 bbls, due to well equipment failure or pipeline corrosion), two incidents involving natural gas-methane (49 mcf, due to pipeline equipment failure or corrosion), one incident involving crude oil (8 bbls, due to tank or pit overflow), one incident involving condensate (3 bbls, due to flowline equipment failure), and two incidents involving other materials (240 bbls, during transport due to human error); NMOCD 2019). The BLM works with the NMOCD to remediates spills on public BLM lands. Per NMAC 19.15.29.11, the responsible person shall complete division-approved corrective action for releases that endanger public health or the environment in accordance with a remediation plan submitted to and approved by the division or with an abatement plan submitted in accordance with 19.15.30 NMAC. The remaining contaminates from unrecovered spills are remediated in accordance with federal and state standards. Some remediation consists of removing contaminated soil and replacing it uncontaminated soil and corresponding chemical testing.

Table 4-13. Summary of 2018 Spills in San Juan Basin

Spilled Material Type	Number of Spills	Volume Spilled	Volume Lost	Units	% Volume Lost
Condensate	21	403	286	Barrels	71%
Crude Oil	12	1,174	273	Barrels	23%
Lube Oil	1	23	23	Barrels	100%
Motor Oil	1	0.07	0.07	Barrels	100%
Other (Specify)	12	605	412	Barrels	68%
Produced Water	34	873	402	Barrels	46%
Total	**81**	**3,078**	**1,396**	**Barrels**	**45%**
Natural Gas (Methane) and Natural Gas Liquids	25	117,325	112,502	MCF	96%
Total Number of Spills	**106**				

Source: NMOCD 2018

Drilling and Completion Activities

The BLM and NMOCD's casing, cementing, and inspection requirements would limit the potential for groundwater reservoirs and shallow aquifers to be impacted by fracking or the migration of hydrocarbons on the nominated lease parcels. Prior to approving an APD, a BLM geologist would identify all potential subsurface formations that would be penetrated by the wellbore including groundwater aquifers and any zones that would present potential safety or health risks that would need special protection measures during drilling, or that could require specific protective well construction measures. Casing programs and cement specifications would be submitted to the BLM and NMOCD for approval to ensure that well construction design would be adequate to protect the subsurface environment, including known or anticipated zones with potential risks or zones identified by the geologist. Surface casing would be set to an approved depth, and the well casing and cementing would stabilize the wellbore and provide protection to any overlying freshwater aquifers by isolating hydrocarbon zones from overlying freshwater aquifers. Before hydraulic fracturing takes place, all surface casings and intermediate zones would be required to be cemented from the bottom of the cased hole to the surface. The cemented well would be pressure tested to ensure there are no leaks, and a cement bond log would be run to confirm that the cement has bonded to the steel casing strings and to the surrounding formations.

The BLM requires operators to comply with the regulations at 43 CFR 3160. These regulations require il and gas development to comply with directives in the Onshore Orders and the orders of the Authorized Officer. Onshore Order No. 2 and the regulations at 43 CFR 3162.3-3 provide regulatory requirements for hydraulic fracturing, including casing specifications, monitoring and recording, and management of recovered fluids. The State of New Mexico also has regulations for drilling, casing and cementing, completion, and plugging to protect freshwater zones (19.15.16 NMAC). Complying with the aforementioned regulations require producers and regulators to verify the integrity of casing and cement jobs. Casing specifications are designed and submitted to the BLM together with an APD. The BLM petroleum engineer independently reviews the drilling plan, and based on site-specific geologic and hydrologic information, ensures that proper drilling, casing and cementing procedures are incorporated in the plan in order to protect usable groundwater. This isolates usable water zones from drilling, completion/hydraulic fracturing fluids, and fluids from other mineral bearing zones, including hydrocarbon bearing zones. COAs are attached to the APD, if necessary, to ensure groundwater protection. Installation of the casing and cementing operations are witnessed by certified BLM Petroleum Engineering Technicians. At the end of the well's economic life, the operator must submit a plugging plan. The plugging plan ensures permanent isolation of usable groundwater from hydrocarbon bearing zones and is reviewed by the BLM petroleum engineer prior to well plugging. BLM inspectors ensure planned procedures are properly followed in the field.

Surface casing and cement would be extended beyond usable water zones. Production casing will be extended and adequately cemented within the surface casing to protect other mineral formations, in addition to usable water bearing zones. These requirements ensure that drilling fluids, hydraulic fracturing fluids, and produced water and hydrocarbons remain within the well bore and do not enter groundwater or any other formations. Since the advent of hydraulic fracturing, more than 1 million hydraulic fracturing treatments have been conducted, with perhaps only one documented case of direct groundwater pollution resulting from injection of hydraulic fracturing chemicals used for shale gas extraction (Gallegos and Varela 2015). Requirements of Onshore Order No. 2 (along with adherence to state regulations) make contamination of groundwater resources highly unlikely and there have not been any documented past instances of groundwater contamination attributed to well drilling. This is an indication of how effective the use of casing and cement is at preventing leaks and contamination.

CHAPTER 5. HOW TO USE THIS REPORT TO ANALYZE WATER USE ASSOCIATED WITH WELL OR LEASE DEVELOPMENT

A water use analysis for well or lease development estimates the projected water use associated with the proposed action and then compares that use to existing water use in the county or counties in which water is assumed to come from and the USGS to understand how water use would increase. This report provides existing water use for all counties within each Field Office, but the actual counties used in the analysis may vary depending on the location of the project or proposed lease sale. For the Pecos District, recent lease sale analyses have considered a three-county area (Chavez, Eddy and. Lea counties). For the Farmington FO, recent lease sale analyses have considered Rio Arriba County, San Juan Basin, and Sandoval County. For the Rio Puerco FO, recent lease analyses have considered Sandoval County or the San Juan Basin.

Two scenarios are examined for the water use analysis. The first, a maximum development scenario, examines the impacts if all wells were developed in a single year. This scenario that may not occur in all projects but provides an analysis of the largest possible impact to water quantity. The second, an RFD cenario, considers water use if the wells were to be developed over a 20-year period. This analysis is consistent with the Engler and Cather 2012, 2014 RFD, and Crocker and Glover 2018 which assumes that reasonably foreseeable future development would not all happen in the same year but would be spread over the next 20 years.

Maximum Development Scenario Calculations

Under the maximum development scenario, the calculation of water use for well development associated with an APD or lease sale is based on the number of wells and projected water use per well (which may vary by well type). The resulting water use (calculated as AF) is then compared to the existing water use in the chosen county or counties, and to the State of New Mexico to understand how water use would increase. Key reporting metrics for the maximum development scenario analysis are as follows:

1. percent contribution to total water use in the chosen county or counties (delineated in the formulas below as COUNTY/IES. This is calculated as follows:

   [(proposed action AF + total COUNTY/IES water AF) / total COUNTY/IES water AF]= x 100

2. percent contribution to groundwater use in the Pecos District. This is calculated as follows:

   [(proposed action AF + total COUNTY/IES groundwater AF) / total COUNTY/IES groundwater AF] x 100

3. percent contribution to total "Mining" water use in the Pecos District. This is calculated as follows:

   [(proposed action AF + total COUNTY/IES mining AF) / total COUNTY/IES mining AF] x 100*

4. percent contribution to Pecos District oil and gas water use. This is calculated as follows:

   [(proposed action AF + COUNTY/IES O&G AF) / COUNTY/IES AF] x 100

5. percent contribution to statewide oil and gas water use. This is calculated as follows:

   [(proposed action AF + statewide oil and gas AF) / statewide O&G AF] x 100

* This calculation could be further refined to be county-specific depending on the location and size of the project. Note also that O&G comprises a small element of Mining; see the additional calculations below to further put the impact into context.

6. percent contribution of increased Pecos District oil and gas development water use (revised as per above) to the total Pecos Mining water use. This is calculated as follows:

(new total COUNTY/IES AF as calculated above / COUNTY/IES Mining AF) x 100

7. percent contribution of increased statewide oil and gas development water use (revised as per above) to the total statewide mining water use. This is calculated as follows:

(new total statewide O&G AF as calculated above / Statewide mining AF) x 100

RFD Scenario Calculations

Under the RFD scenario, the calculation of water use for any given year is made by taking the total water use associated with the proposed action (as calculated under the maximum development scenario) and dividing by 20 (life of the RFD). Key reporting metrics for the RFD scenario analysis are as follows:

8. percent contribution to Pecos District oil and gas water use

[(per year proposed action AF + COUNTY/IES O&G AF) / COUNTY/IES O&G AF] x 100

9. percent contribution to statewide oil and gas water use

[(per year proposed action AF + statewide O&G AF) / statewide O&G AF] x 100

10. percent contribution of increased Pecos District oil and gas development water use (revised as per above) to the total Pecos Mining water use

[new total COUNTY/IES O&G AF calculated as above / COUNTY/IES mining use] x 100

11. percent contribution of increased statewide oil and gas development water use (revised as per above) to the total statewide mining water use

[new total statewide O&G AF calculated as above / statewide mining use] x 100

The following example analyzes water use in the Pecos District associated with the maximum development scenario and RFD Scenario for a proposed action of 30 horizontal wells, reporting the 10 metrics listed above.

EXAMPLE WATER USE ANALYSIS

Proposed action: 30 horizontal wells

Analysis area: Chavez, Lea and Eddy Counties

Maximum development scenario: Proposed action would require 810 AF of groundwater total

RFD Scenario: Proposed action would require 40.5 AF of groundwater in any given year

Reported Metrics:

If all wells were developed <u>in a single year</u> (a maximum development scenario), there would be:

<u>Metric #1</u>: an increase of 0.13% over 2015 Pecos District total water use

<u>Metric #2</u>: an increase of 0.15% over 2015 Pecos District total groundwater use

<u>Metric #3</u>: an increase of 0.9% over 2015 Mining water use for Pecos District

<u>Metric #4</u>: an increase of 20% over 2015 Pecos District oil and gas water use

<u>Metric #5</u>: an increase of 20% over 2015 statewide oil and gas water use

<u>Metric #6</u>: an increase in the percentage contribution of Pecos District water use associated with oil and gas development to total 2015 Pecos District mining water use, from 4.2% to 5.1%

Metric #7: an increase in the percentage contribution of statewide water use associated with oil and gas development to total 2015 statewide mining water use, from 2.4% to 2.9%

If all wells were developed over a period of 20 years (the RFD scenario), then for any given year, there would be:

Metric #8: an increase of 1% over 2015 Pecos District oil and gas water use

Metric: #9: an increase of 1% over 2015 statewide oil and gas water use

Metric #10: an increase in the percentage contribution of Pecos County water use associated with oil and gas development to total 2015 Pecos District mining water use, from 4.2% to increase to 4.3%

Metric #11: an increase of in the percentage contribution of statewide water use associated with oil and gas development to total 2015 statewide mining water use, from 2.4% to increase to 2.5%

CHAPTER 6. LITERATURE CITED

Broadhead, R. and A. J. Rinehart. 2018. The Oil and Natural Gas Potential of Sandoval county, New Mexico and its Relationship to Groundwater, with a Discussion of Modern Oil Drilling Methods and Possibilities for Aquifer Contamination. New Mexico Bureau of Geology and Mineral Resources. Available at: http://www.sandovalcountynm.gov/wp-content/uploads/2018/06/NMBGMR-SandovalAssessment-June2018.pdf. Accessed July 2019.

Bureau of Land Management (BLM). 1986. Rio Puerco Resource Management Plan and Record of Decision. Albuquerque, New Mexico.

———. 2003. *Farmington Resource Management Plan and Final Environmental Impact Statement*. U.S. Department of Interior, Bureau of Land Management., Farmington Field Office. Farmington, New Mexico.

———. 2010. Reasonable Foreseeable Development Scenario for the Fluid Mineral Development in the Rio Puerco Field Office. Rio Puerco BLM, Albuquerque, New Mexico.

———. 2015. Mancos-Gallup Resource Management Plan Amendment and Environmental Impact Statement. Assessment of the Management Situation. March 2015. Farmington Field Office. Farmington, New Mexico.

———. 2018. Internal BLM data reported to Dave Herrell, Soils and Water Specialist at New Mexico State Office.

———. 2019a. Personal communication between David Herrell, BLM and Julie Valdez, NMOSE regarding water use associated with the Navajo Power Plant.

———. 2019b. Development Planning Meeting between BLM Farmington FO and Operator at Farmington FO Office. May 24, 2019. Farmington, New Mexico.

Crocker, K., and J. F. Glover. 2018. *Reasonable Foreseeable Development Scenario for Oil and Gas Activities, Mancos-Gallup RMPA Planning Area, Farmington Field Office, northwestern New Mexico*. United States Department of Interior, Bureau of Land Management. Final Report.

Dieter, C. A., M. A. Maupin, R. R. Caldwell, M. A. Harris, T. I. Ivahnenko, J. K. Lovelace, N. L. Barber, and K. S. Linsey. 2018. Estimated use of water in the United States in 2015: U.S. Geological Survey Circular 1441, 65 p. Report and dataset available at. https://pubs.er.usgs.gov/publication/cir1441. Downloaded April 1. 2019.

Engler, T. 2013. Response to comments on the DEIS for the Ochoa Mine Project. Socorro, NM, USA. November 16.

Engler, T. W., and M. Cather. 2012. Reasonable Foreseeable Development (RFD) Scenario for the BLM. New Mexico Pecos District. Final Report. New Mexico Institute of Mining and Technology. Available at: https://eplanning.blm.gov/epl-front-office/projects/lup/64444/77502/86228/Final_Report-BLM-NMT-RFD.pdf. January 2019.

———. 2014. Update to the Reasonable Foreseeable Development (RFD) for the BLM Pecos District, SENM. Final Report. New Mexico Institute of Mining and Technology. Available at: https://eplanning.blm.gov/epl-front-office/projects/lup/64444/80056/93025/Final_Report-SENM-DEC2014_updated_RFD.pdf

FracFocus. 2017. Retrieved from FracFocus Data Download. Dataset available for download at the following: http://fracfocus.org/data-download. Downloaded December 13, 2018.

———. 2018. Retrieved from FracFocus Data Download. Dataset available for download at the following: http://fracfocus.org/data-download. Downloaded January 28, 2019.

———. 2019. Retrieved from FracFocus Data Download. Dataset available for download at the following: http://fracfocus.org/data-download. Downloaded May 2019.

Gallegos, T. J., and B. A. Varela. 2015. Trends in hydraulic fracturing distributions and treatment fluids, additives, proppants, and water volumes applied to wells drilled in the United States from 1947 through 2010—Data analysis and comparison to the literature: U.S. Geological Survey Scientific Investigations Report 2014–5131, 15 p., http://dx.doi.org/10.3133/sir20145131. Accessed February 2019.

Kelley, S., T. Engler, M. Cather, C. Pokorny, Cheng-Heng Yang, E. Mamer, G. Hoffman, J. Wilch, P. Johnson, and K. Zeigler.2014. *Hydrologic Assessment of Oil and Gas Resource Development of the Mancos Shale in the San Juan Basin*. New Mexico Bureau of Geology and Mineral Resources. Available at: https://geoinfo.nmt.edu/resources/water/projects/sjb/home.html. Accessed May 2019.

Kondash, A. J., N. E. Lauer, and A. Vengosh. 2018. The intensification of the water footprint of hydraulic fracturing. Science. Available at: https://advances.sciencemag.org/content/advances/4/8/eaar5982.full.pdf. Accessed April 1, 2019.

Lowry, Thomas S., Michael D. Schuhen, Owen W. Lofton, La Tonya N. Walker, Patricia B. Johnson, Dennis W. Powers, and Dale O. Bowman. 2018. Water Resource Assessment in the New Mexico Permian Basin. Prepared by Sandia National Laboratories. SAND2018-12018. October 2018. Available in BLM project files or by order at the following: https://classic.ntis.gov/help/order-methods/

New Mexico Office of the State Engineer (NMOSE). 2019. 2015 draft self-supplied oil and gas water withdrawal data. Available by contacting the BLM.

New Mexico Oil Conservation Division (NMOCD).2019. 2018 Spill Data. Available at: https://wwwapps.emnrd.state.nm.us/ocd/ocdpermitting/Data/Spills/Spills.aspx. Accessed April 2, 2019.

Summers, W. K., 1972, Geology and regional hydrology of the Pecos river basin, New Mexico, Open File Report #37, New Mexico Water Resources Institute, New Mexico State University, Las Cruces, New Mexico, 393 p.

Appendix A. FracFocus Data Analysis Methodology

Permian Basin

Data downloaded from FracFocus 1/28/19 for all calendar year 2018 for Chaves, Eddy, and Lea counties.

Duplicate records were eliminated (due to one record for each chemical species).

Summary stats are best estimators at this point. BLM used the mean (31.2 AF/horizontal well). Could use 95% confidence interval instead (or leave out) Could work this into narrative.

Data downloaded from FracFocus 5/29/19 for cumulative analysis.

San Juan Basin

Data downloaded from FracFocus 1/28/19 for all calendar year 2018 for San Juan, Rio Arriba, and Sandoval counties.

Duplicate records were eliminated (due to one record for each chemical species). Summary stats are best estimators at this point,

BLM used the mean (4.84 AF/horizontal well). Could use 95% CI. Could work into narrative.

Data downloaded from FracFocus 5/29/19 for cumulative analysis

Appendix B. Spill Data Analysis Methodology

<u>Assumptions:</u>

- We should reject duplicate spills records
- We should reject spills where the spill volume was 0 barrels
- We should keep the methane spills when looking at number of unique incidents (spills count), but not include them in the volume spilled because the units are MCF (not barrels).
- We should reject records where the spill type was natural gas liquid or methane but was reported in barrels (bad data)

<u>Methodology:</u>

Working entirely from the spills (1) tab of the San Juan Basin spills spreadsheet (starting with 1607 records):

1. Cleared all filters
2. Created a primary key for the data to identify and remove duplicates. *Primary key=Incident Number_Spilled Material*. In San Juan Basin, there were 3 duplicated spills. Removed one of each duplicated record from analysis. (***1604 records remain***)
3. Filtered on column W (County) to McKinley, Rio Arriba, San Juan, and Sandoval (***227 records remain***)
4. Removed spills where the volume spilled was 0 barrels (assumed to be bad data) Filtered on column P (Volume Spilled) to all values EXCEPT 0 (***111 records remain***)
5. Converted the one volume that was reported as GALLONS to BARRELS (***111 records remain***)
6. Rejected data where 'Spilled material' = Natural Gas (Methane) and Natural Gas Liquid, AND, 'Unit of Volume= BBL' (***106 records remain***)
7. Used Pivot Table tool to aggregate and summarize the data.

Working entirely from the spills (1) tab of the Permian Basin spills spreadsheet (starting with 1607 records):

1. Cleared all filters
2. Filtered on County column for Lea and Eddy counties (***1355 records remain***)
3. Created a primary key for the data to identify and remove duplicates. *Primary key=Incident Number_Spilled Material*. In Permian Basin, there were 14 duplicated spills. Removed one of each duplicated record from analysis. (***1341 records remain***)
4. Removed spills where the volume spilled was 0 barrels (assumed to be bad data). Filtered on 'Volume Spilled' to all values EXCEPT 0 (***1270 records remain***)
5. Converted the 8 volumes that was reported as GALLONS to BARRELS (***1270 records remain***)
6. Rejected data where 'Spilled material' = Natural Gas (Methane) and Natural Gas Liquid, AND, 'Unit of Volume= BBL' (9 records) (***1261 records remain***)
7. Entered 'BBL' as unit for spill with no units (Incident Number= nOY1812332827, Material spilled=Crude Oil) (***1261 records remain***)

On both sets of records

1. Using DATA worksheet, filtered on column AI (groundwater affected). (***0 records remain***)
2. Using DATA worksheet, filtered on column AH (waterway affected). (12 ***records remain***)
3. Removed spills where the volume spilled was 0 barrels (assumed to be bad data) (***9 records remain, all in San Juan Basin***)
4. Reviewed and summarized data (counties, volume of pill, cause and source)

Appendix C. 2019 Farmington Field Office Slick Water Stimulation Water Use Update

Purpose of the Update

Fluid mineral development in the San Juan Basin has experienced technological advances with the introduction of slick water stimulation beginning in 2015. Since the development of the Reasonable Foreseeable Development Scenario for Oil and Gas Activities, Mancos-Gallup RMPA Planning Area (Crocker and Glover 2018) additional information regarding the slick water stimulation technique has been gathered by the BLM Farmington FO . The 2018 Mancos-Gallup RFD presents the projected fluid mineral development potential for the Mancos-Gallup RMPA Planning Area, encompassing a total area of 4 million acres. Half of the total planning area (2 million acres) is located within one major horizontal oil and gas play, resulting in fluid mineral interest with" high" and "medium" development potential (Crocker and Glover 2018). The purpose of this update is to address the forecasted amount of water from the 2018 Mancos-Gallup RFD, which may be used during development of the Mancos Shale formation and Gallup Sandstone member utilizing slick water stimulation in the San Juan Basin.

Assumptions and Methodology

This update evaluates the potential water requirements for the development of the Mancos Shale and Gallup Sandstone within the San Juan Basin using the slick-water stimulation technique. Current industry trends in unconventional reservoir development have shifted to drilling of long (1- to 3- mile) horizontal laterals that are stimulated using large volumes of low-viscosity water-based fluids (slick-water stimulation). This development scenario evaluates the projected water demand of Mancos-Gallup development based on current industry expectations of lateral density. No evaluation of other factors (i.e. execution pace, reservoir recovery factor, economic results, alternative completion techniques) are made in this model.

Horizontal wells are currently stimulated during completion in short sections of laterals called stages. To date, 20 wells have been drilled using long laterals with slick-water stimulation within the Farmington FO. The water volume and stage length was averaged from the 20 wells using the APD and data from FracFocus. The equation for calculating estimated water volume is indicated below:

(Total water volume) = (stage water volume/stage length) x (number of stages/lateral length)

The total miles of lateral estimated to develop the Mancos Shale and Gallup Sandstone formations is based on the 2300 horizontal wells projected in the 2018 RFD. On average the wells would be stimulated in 2-mile laterals which would be approximately 4,600 miles, all of which are projected to be slick-water stimulated. For the 20 completed wells the Farmington FO calculated the average stage length to be 200 feet and the average water used per stage to stimulate the formation to be 334,000 gallons (~ 1 acre-foot). From the Farmington FO projected water use calculations, the Mancos Shale and Gallup Sandstone development within the high and medium potential areas would require approximately 125,000 acre-feet for the full development scenario using only slick-water stimulation techniques (see Table 1).

Context

The Colorado River Compact (The Compact) of 1922 determined how much water would be delivered downstream for use in the western states listed in The Compact. The remaining water is left to the individual states for allocation. It is the responsibility of the New Mexico Office of the State Engineer (NMOSE) to allocate remaining useable water within New Mexico and to ensure that all water is used according to state regulations and correctly reported. The authority and regulation of the NMOSE applies to water acquired for use in production and operation of oil and natural gas wells. Water use is published in a report every five years in the report titled "New Mexico Water Use By Categories", most recently published in 2015. See Chapter 3 of the Water Support document for information on the volume of water that was used specifically for hydraulic stimulation of oil and gas wells in the San Juan Basin using information from the NMOSE 2015 report.

The two general water types that may be used for slick water stimulation are categorized as "potable/fresh" and "non-potable". Any water that has Total Dissolved Solids (TDS) greater than 1,000 ppm has been defined as "non-potable" by the State of New Mexico (72-12-25 NMSA 1978), the BLM has identified anything less than 10,000 ppm to be protected in the casing rule of the BLM's Onshore Order #2 (BLM 1988). Non-potable water is outside the appropriative processes and is mainly diverted for mineral exploration purpose. Conversely, any water that is less than 1,000 ppm TDS is "potable/fresh". In general, potable water has a water right associated with it and is permitted and regulated by the NMOSE and may or may not be adjudicated.

During the process of gathering information regarding slick-water stimulation, the Farmington FO put together a questionnaire to conduct industry interviews. The questionnaire focused on estimated water use during drilling, completion, operation and production phases of oil and gas wells, with specific focus on water sources and water use associated with slick water stimulation. The questions were used to help the BLM determine how saline water is being utilized and to better understand the potential TDS levels within source water for the stimulation fluid. Onshore Order #1 (BLM 2017) requires operators to identify adequate water sources for stimulation plans as part of their APD.

Based on operator input the water used for slick-water stimulation can have high levels of TDS for the technology to be effective. The majority of operators within the San Juan Basin limit their TDS levels to 50,000 ppm for use in a slick water stimulation operation. The higher allowable TDS levels that are acceptable for slick water stimulation expand the possible water sources beyond those that are traditionally used (e.g., surface or ground water) into non-traditional sources of water (e.g. non-potable groundwater sources).

Recently, the NMOSE has received Notices of Intention (NOI) to Appropriate non-potable water from aquifers at depths 2,500 feet below ground level (BGL) or greater. The NMOSE has approved permits to drill wells within the San Juan Basin to withdraw non-potable connate water (groundwater) from the Entrada sandstone formation for use as a potential source of water for slick water stimulation operations. The Entrada sandstone formation maximum depth is approximately 9,500 feet deep. Water contained in the Entrada formation is highly saline (Kelley et al. 2014). As such, it is considered non-potable and has not been declared as an administrative aquifer by the NMOSE. NMOSE is the agency responsible for water withdrawal permitting actions. Their NOI process includes a model-based evaluation of the potential effects of proposed withdrawals and the identification of possible requirements for applicants to obtain water rights to offset any depletions identified in NMOSE's analyses prior to applicants commencing diversions.

Other sources of non-potable water that can be utilized in stimulation are "flowback fluid" and "produced water". Flowback fluid is a mixture of chemical proppant, water and sand that flows back through the well head directly after stimulation activities. Generally, 10-40% of the initial volume utilized for stimulation activities returns as flowback fluid, of this 10-40% is non-potable water that may be used in future stimulation activities. Produced water is naturally occurring water that exists in the formation that is being targeted for mineral extraction and is produced as a byproduct, therefore becoming "produced water". Based on operator input, after the initial flowback recovery of 10-40%, remaining water used for stimulation does return to the surface through production activities at a slower rate of return.

Projected Water Use Discussion

To gain the most current information, outreach was conducted with local operators actively drilling and producing mineral resources in the San Juan Basin to gather information regarding slick-water stimulation and reservoir development. According to the 20 APDs the average lateral well bore is one and a half miles (1.5) in length for a horizontal well (see Attachment 1). The estimated water use is approximately 41 acre feet (af) for slick water stimulation. Advances in horizontal drilling and completion techniques in the San Juan Basin in the past four to five (4-5) years has resulted in the ability to drill and complete horizontal laterals up to three (3) miles in length (according to operator input). Horizontal well bores are stimulated in intervals, each interval is called a stage. Refer to table 1 for number of stages dependent on length of well bore as well as the average water use of 1-3 mile laterals per completion.

Table C-1: Average volume of water required to complete 1-3 mile laterals utilizing slick water stimulation in the Mancos Shale and Gallup Sandstone formations

Miles	Number of Stages	Acre Feet
1	26	27
1.5	39	40
2	52	53
2.5	65	67
3	78	80

Conclusions

The amount of water that would be required to completely develop 4,600 miles of horizontal wells in the Mancos Shale and Gallup Sandstone formations via slick-water stimulation has been estimated to be approximately 125,000 af. The 2018 RFD estimates 2,300 horizontal wells that may be developed in 2018-2037, based on operator input the horizontal lengths will range from 1-3 miles. Current technology allows operators to utilize water with TDS of 50,000 ppm, well above the NMOSE potable water threshold of 1,000 ppm. This allows for the use of currently non-traditional potable water sources, including the connate water within the Entrada formation and recycled flowback water and produced water for use in slick water stimulation activities.

References

Bureau of Land Management (BLM). 1988. 43 CFR Part 3160 Onshore Oil and Gas Operations: Federal and Indian Oil and Gas Leases; Onshore Oil and Gas Order Number 2, Drilling Operations. Available at https://www.blm.gov/sites/blm.gov/files/energy_onshoreorder2.pdf. Accessed September 2019.

———. 2017. 43 CFR Part 3160 Onshore Oil and Gas Operations: Federal and Indian Oil and Gas Leases; Onshore Oil and Gas Order Number 1, Approval of Operations. Federal Register 82(6), Rules and Regulations. Available at: https://www.blm.gov/programs/energy-and-minerals/oil-and-gas/operations-and-production/onshore-orders. Accessed September 2019.

Crocker, K., and J. F. Glover. 2018. *Reasonable Foreseeable Development Scenario for Oil and Gas Activities, Mancos-Gallup RMPA Planning Area, Farmington Field Office, northwestern New Mexico*. United States Department of Interior, Bureau of Land Management. Final Report.

Kelley, S., T. Engler, M. Cather, C. Pokorny, Cheng-Heng Yang, E. Mamer, G. Hoffman, J. Wilch, P. Johnson, and K. Zeigler.2014. *Hydrologic Assessment of Oil and Gas Resource Development of the Mancos Shale in the San Juan Basin*. New Mexico Bureau of Geology and Mineral Resources. Available at: https://geoinfo.nmt.edu/resources/water/projects/sjb/home.html. Accessed August 2019.

New Mexico State Statutes. 2011. Chapter 72: Water Law. Available at: https://law.justia.com/codes/new-mexico/2011/chapter72/. Accessed August 2019.

Attachment C.1.

Table C.1-a. Water Use Averages from 20 APDs Using FracFocus Data

Well Name/Operator	Water Usage Per Stage	Stage Length
NEBU604_3H(BP)	517,171.19	201
NEBU602COM1H(BP)	444,653.34	149.6
NEBU604COM2H(BP)	535,124.92	200
NEBU604COM1H(BP)	526,524.65	200
NEBU605COM2H(BP)	551,075.29	205
NEBU605COM1H(BP)	427,903	165
SEscavdaUnit353H(Enduring)	160,437.94	176.64
EscavadaUnit302H(Enduring)	162,902.25	179.5
NEscavadaUnit316H(Enduring)	143,312.48	177.28
NEscavadaUnit330H(Enduring)	429,107.70	482.85
NEscavadaUnit317H(Enduring)	150,050.52	180
NEscavadaUnit318H(Enduring)	152,921.60	180
NEscavadaUnit331H(Enduring)	143,150.40	175.48
NEscavadaUnit315H(Enduring)	145,898.40	179.4
ROSAUnit641H(WPX)	468,363.91	207.3
ROSAUnit643H(WPX)	338,364.25	202.3
ROSAUnit640H(WPX)	389,188.64	200.3
ROSAUnit642H(WPX)	330,273.30	212.7
PallucheHZMC1H(Hilcorp)	207,003.06	201.25
SanJuan29-6UnitCom601_1H(Hilcorp)	458,228.90	194.9
Average	**334,082.79**	**203.525**

Table C.1-b. Projected Water Use by Lateral Length

Lateral Length (Feet)	Lateral Length (Miles)	Number of Stages	Water Used (Gallons)	Water Used (Acre Feet)
5280	1	25.94	8,667,029.18	26.60
7920	1.5	38.91	13,000,543.76	39.90
10,560	2	51.89	17,334,058	53.20
13,200	2.5	64.86	21,667,572.94	66.50
15,840	3	77.83	26,001,087.53	79.79