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# REVISED FINAL REPORT: 2028 FUTURE YEAR OIL AND GAS EMISSION INVENTORY FOR WESTAR-WRAP STATES - SCENARIO #1: CONTINUATION OF HISTORICAL TRENDS

RAMBOLL Bright ideas. Sustainable change.

# Revised Final Report: 2028 Future Year Oil and Gas Emission Inventory for WESTAR-WRAP States - Scenario #1: Continuation of Historical Trends

## CONTENTS

## Table of Figures



## Table of Tables



## List of Appendices

# EXECUTIVE SUMMARY

This study provides estimates of criteria air pollutant and greenhouse gas emissions for oil and gas (O&G) exploration and production operations in the Western States Air Resources Council-Western Regional Air Partnership (WESTAR-WRAP) region for a 2028 future year based on the baseline emission inventory documented in the "Revised Final Report: Circa-2014 Baseline Oil and Gas Emission Inventory for the WESTAR-WRAP Region"[1]. This analysis was sponsored by the Western Regional Air Partnership (WRAP) Oil and Gas Working Group (OGWG).

The WESTAR-WRAP region consists of 15 states in the Western US, a number of which have substantial O&G exploration and production activities. Future year O&G emission inventories are critical for air quality planning, including regional haze planning. O&G activity in the WESTAR-WRAP Region comprises 40% of US-wide crude oil production (2017[2]) and 26% of US-wide natural gas production (2018[3]). Over 70% of active wells in the WESTAR-WRAP region in 2014 were vertical wells and over 75% of spuds were horizontal or directional wells, indicating a shift from development of vertical to horizontal and directional wells that could have substantial effects on future O&G activity and emission estimates.

Ramboll developed Scenario 1 O&G activity forecasts (Continuation of Historical Trends scenario) for basins comprising a vast majority of O&G activity in the WESTAR-WRAP region, except for in California, Colorado, and New Mexico. California future year emissions are being developed by the California Air Resources Board (CARB) and are not included herein. Colorado statewide future year emissions included herein were developed by the Colorado Department of Public Health and Environment (CDPHE). New Mexico emissions for certain Title V sources were estimated on a facility-by-facility basis by the New Mexico Environment Department (NMED) with input from facility operators; all other New Mexico emissions were estimated based on forecast methodology described herein.

O&G activity forecasts were developed by well type (oil, gas, and coalbed methane [CBM]) and spud type (vertical, directional, horizontal) for the following activity parameters: spuds, active well count, oil production, and gas production. California forecasts are not included herein because Forecasts were based on historical O&G activity trends in each basin for each parameter by well type and spud type and are based on several key assumptions:

- Oil development and production continues to be prioritized over gas development and production.
- Development is primarily focused on horizontal wells in tight oil formations such as the Denver Basin (Niobrara Play), Permian Basin, and Williston Basin (Bakken Play). Limited exploration activity for vertical wells.
- Production from legacy vertical wells continues to decline and these wells are gradually taken offline.

There is substantial uncertainty associated with any forecast of O&G activity due to political, economic, and other factors. This study qualitatively discusses this uncertainty but does not quantify uncertainty in the activity forecasts.

[1] Grant et al. (2019), available on the WRAP OGWG website: https://www.wrapair2.org/OGWG.aspx
[2] https://www.eia.gov/dnav/pet/pet_crd_crpdn_adc_mbbl_a.htm
[3] https://www.eia.gov/dnav/ng/ng_prod_sum_a_EPG0_FGW_mmcf_a.htm

Emissions control resulting from regulatory programs such as Federal New Source Performance Standard (NSPS) Subpart OOOO and OOOOa, Federal NSPS Subpart JJJJ, Federal off-road diesel engine tier standards and state specific regulatory programs were incorporated into future year emission estimates, to the extent feasible and to the extent that these programs are expected to have substantial impacts on future year emissions. Emission control estimates are based on the suite of regulations that were "on-the-books" at the time that this future year emission inventory was developed. Emission control assumptions for fugitive components (LDAR), green completions at oil wells, and pneumatic pumps are based on NSPS OOOOa provisions. EPA is conducting ongoing activities that may lead to future changes to NSPS OOOOa.

On-the-books and on-the-way regulatory control program effects on emissions were estimated for the Denver Basin (Wyoming only), Permian Basin, Williston Basin, Uinta Basin, Green River Basin, and Powder River Basin. Control factors were developed for the Williston, Permian, and Denver Basin (Wyoming only) because substantial activity growth, subject to control by on-the-books regulations, under Scenario 1, is estimated to occur between the baseline inventory and the future year inventory. For the Uinta Basin, a controls analysis was performed because on-the-books Utah State regulations are expected to result in substantial reductions to emissions from existing Uinta Basin oil and gas wellsite sources. Control factors were developed for the Green River and Powder River basins to take advantage of detailed 2014 and 2017 emission inventory files provided by the Wyoming Department of Environmental Quality (WYDEQ). A controls analysis was not performed (i.e., emission rates are assumed unchanged between the baseline year and future year) for the following basins because substantial growth is not estimated between the baseline year and future year under Scenario 1: all Alaska basins, Big Horn Basin, Paradox Basin, Powder River Basin, San Juan Basin, Sweetgrass, Arch, and Wind River Basin.

State-level WESTAR-WRAP region O&G emissions are presented in Table ES-1.

**Table ES-1. Future year 2028 WESTAR-WRAP region O&G emissions by state.**

| Pollutant | AK | AZ | CO | ID | MT | ND | NM | NV | OR | SD | UT | WA | WY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Criteria Air Pollutant Emissions (tons/yr) and Greenhouse Gas Emissions (1000 tons/yr) | | | | | | | | | | | | |
| NOx | 37,663 | 1,960 | 43,550 | 889 | 5,133 | 73,359 | 94,250 | 156 | 454 | 763 | 10,551 | 444 | 24,333 |
| VOC | 23,880 | 280 | 77,336 | 34 | 29,265 | 319,667 | 228,333 | 269 | 73 | 4,786 | 67,878 | 36 | 109,590 |
| CO | 11,838 | 439 | 43,965 | 272 | 6,333 | 127,946 | 126,653 | 111 | 263 | 817 | 9,889 | 301 | 14,891 |
| SOx | 1,876 | 33 | 502 | 4 | 487 | 33,043 | 31,652 | 15 | 13 | 28 | 600 | 14 | 5,503 |
| PM10 | 1,014 | 51 | 1,172 | 10 | 105 | 3,851 | 2,800 | 11 | 20 | 77 | 539 | 14 | 1,123 |
| PM2.5 | 956 | 51 | 1,138 | 10 | 105 | 3,527 | 2,754 | 11 | 20 | 77 | 539 | 14 | 1,123 |
| CO2 | [1] | 1,183 | 714 | 245 | 1,232 | 44,527 | 12,184 | 99 | 210 | 693 | 4,594 | 201 | 9,561 |
| CH4 | [1] | 1 | 505 | 0 | 114 | 427 | 779 | 0 | 0 | 6 | 352 | 0 | 195 |
| N2O | [1] | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| CO2(e) | [1] | 1,209 | 3,986 | 248 | 4,089 | 54,568 | 30,550 | 108 | 216 | 856 | 13,405 | 203 | 14,490 |
| | Percent Change from circa-2014 Baseline Emissions | | | | | | | | | | | | |
| NOx | -13% | 0% | -1% | 0% | -29% | 9% | 16% | 0% | 0% | -17% | -36% | 0% | -47% |
| VOC | -13% | 0% | -44% | 0% | -21% | 5% | 23% | 0% | 0% | -49% | -40% | 0% | -59% |
| CO | -13% | 0% | 5% | 0% | -26% | 52% | 12% | 0% | 0% | -47% | -30% | 0% | -30% |
| SOx | -13% | 0% | -6% | 0% | -1% | 117% | 37% | 0% | 0% | -54% | 3% | 0% | -20% |
| PM10 | -13% | 0% | 11% | 0% | -33% | 71% | 14% | 0% | 0% | 0% | -24% | 0% | -12% |
| PM2.5 | -13% | 0% | 14% | 0% | -33% | 65% | 12% | 0% | 0% | 0% | -24% | 0% | -12% |
| CO2 | 0% | 0% | -10% | 0% | -31% | 55% | -40% | 0% | 0% | -25% | -20% | 0% | -14% |
| CH4 | 0% | 0% | -11% | 0% | -16% | 26% | 11% | 0% | 0% | -44% | -34% | 0% | -47% |
| N2O | 0% | 0% | -9% | 0% | -39% | 33% | -32% | 0% | 0% | -14% | -23% | 0% | -23% |
| CO2(e) | 0% | 0% | -13% | 0% | -21% | 46% | -19% | 0% | 0% | -30% | -30% | 0% | -29% |

[1] not available

This "Revised Final Report" incorporates revisions to New Mexico Title V point sources as described in Chapter 2.0 and a complete set of nonpoint source emissions for Colorado (drilling and hydraulic fracturing emissions from non-tribal lands were not available for incorporation into the previous report).

The contents of the report by Chapter are summarized as follows:

- Chapter 1.0 provides introductory information on study methodology, scope, and O&G activity in the WESTAR-WRAP region;
- Chapter 2.0 describes the steps taken to develop O&G activity forecasts;
- Chapter 3.0 describes the steps taken to develop the emission controls analysis per on-the-books and on-the-way regulations;
- Chapter 4.0 presents summaries of future year 2028 emissions.

# 1.0 INTRODUCTION

The WRAP OGWG is sponsoring the development of O&G emission inventories as part of efforts to support regional haze planning in the Western States Air Resources Council-Western Regional Air Partnership (WESTAR-WRAP) region. The O&G emission inventories developed under WRAP OGWG sponsorship will also facilitate other types of air quality planning (e.g., photochemical ozone modeling). More information about WRAP OGWG emission inventory development efforts may be found at the project webpage: https://www.wrapair2.org/ogwg.aspx.

This report describes the development of a criteria air pollutant and greenhouse gas (GHG) emissions inventory for O&G field operations in the WESTAR-WRAP region for a 2028 future year, including point (midstream) and nonpoint (wellsite) sources. The future year emissions inventory was compiled by forecasting the baseline emission inventory based on estimated changes to O&G activity and emission controls.

## 1.1 Scope

### 1.1.1 Sources

The emission inventory documented herein includes emissions from upstream and midstream O&G sources, consistent with the OGWG Road Map Scope of Work[4] and the OGWG Roadmap Phase I Report (Grant et al., 2018). Downstream O&G emissions are not included. Consistent with the baseline O&G emission inventory (Grant et al., 2019), the future year emission inventory includes wellsite, gathering, and processing subsectors (items 1, 5, and 6 in Figure 1-1). Item 1) On-shore Petroleum and Natural Gas Production is referred to as "wellsite" sources; emissions from wellsite sources are typically classified as nonpoint sources[5]. Items 5) Gathering and Boosting and 6) Gas Processing Plant are collectively referred to as "midstream" sources; emissions from midstream sources are typically classified as point sources. The classification of well-site emissions as nonpoint and midstream emissions as point sources is consistent with O&G emission inventory classifications used in the WRAP Phase III study[6], West-wide Jumpstart Air Quality Modeling Study (WestJUMP AQMS)[7], 2011 Western Air Quality Study[8], and 2014 NEI methodology[9].

[4] https://www.wrapair2.org/pdf/11162017_WRAPO&GWorkgroup_RoadMapSOW.pdf

[5] There are exceptions; for example, several wellsite sources in the Uinta Basin are available by facility and will be included in emission inventories as point source emissions.

[6] https://www.wrapair2.org/PhaseIII.aspx

[7] https://www.wrapair2.org/WestJumpAQMS.aspx

[8] http://vibe.cira.colostate.edu/wiki/wiki/1018/3saqs-2011a-modeling-platform

[9] https://www.epa.gov/air-emissions-inventories/2014-national-emissions-inventory-nei-technical-support-document-tsd

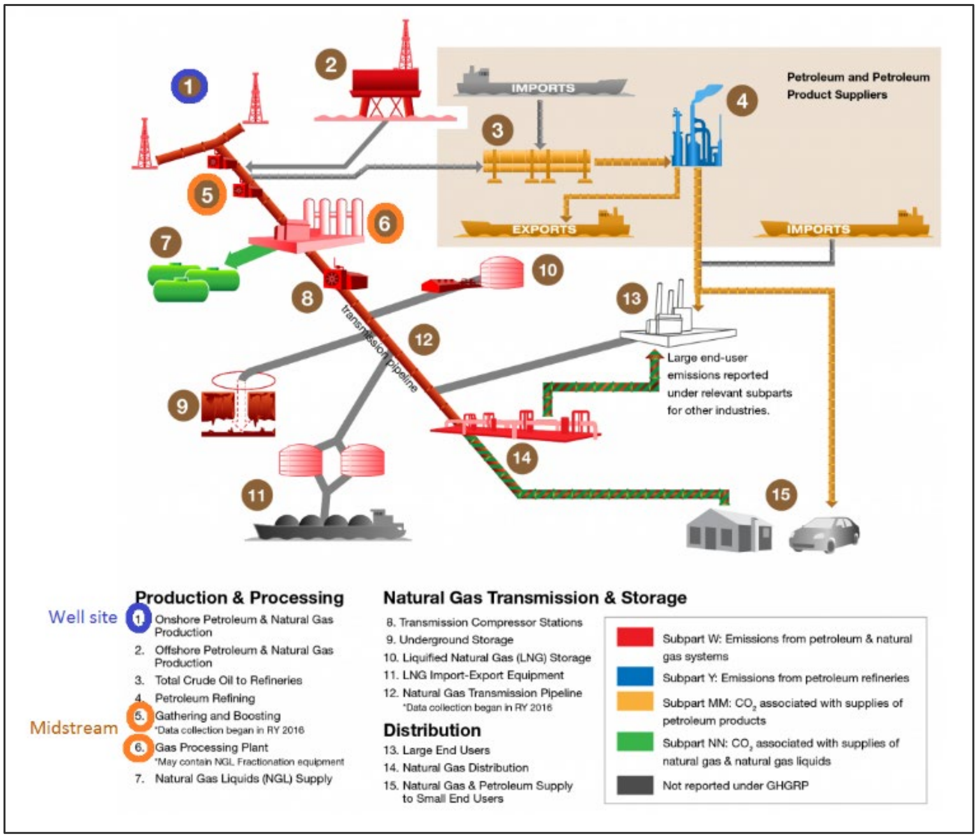


**Figure 1-1. Example Petroleum and Natural Gas Industry schematic[10,11].**

### 1.1.2 Geographical Scope

The WESTAR-WRAP region includes 15 states, a number of which have substantial O&G production and generate substantial O&G emissions. Figure 1-2 shows major basins in the WESTAR-WRAP region. California O&G emissions are estimated by the California Air Resources Board (CARB) and are not included herein. Several states have limited or zero O&G production and O&G sector emissions: Arizona, Hawaii, Idaho, Nevada, Oregon, South Dakota, and Washington. Emissions were estimated by county, distinguishing between tribal and non-tribal sources; emissions were not distinguished by mineral ownership.

[10] Source: https://www.epa.gov/ghgreporting/ghgrp-and-oil-and-gas-industry

[11] This figure shows O&G subsectors for which emissions have been developed in this study. It is important to consider that Petroleum and Natural Gas Industry equipment is typically tailored to meet field, basin, and/or region-specific infrastructure requirements.

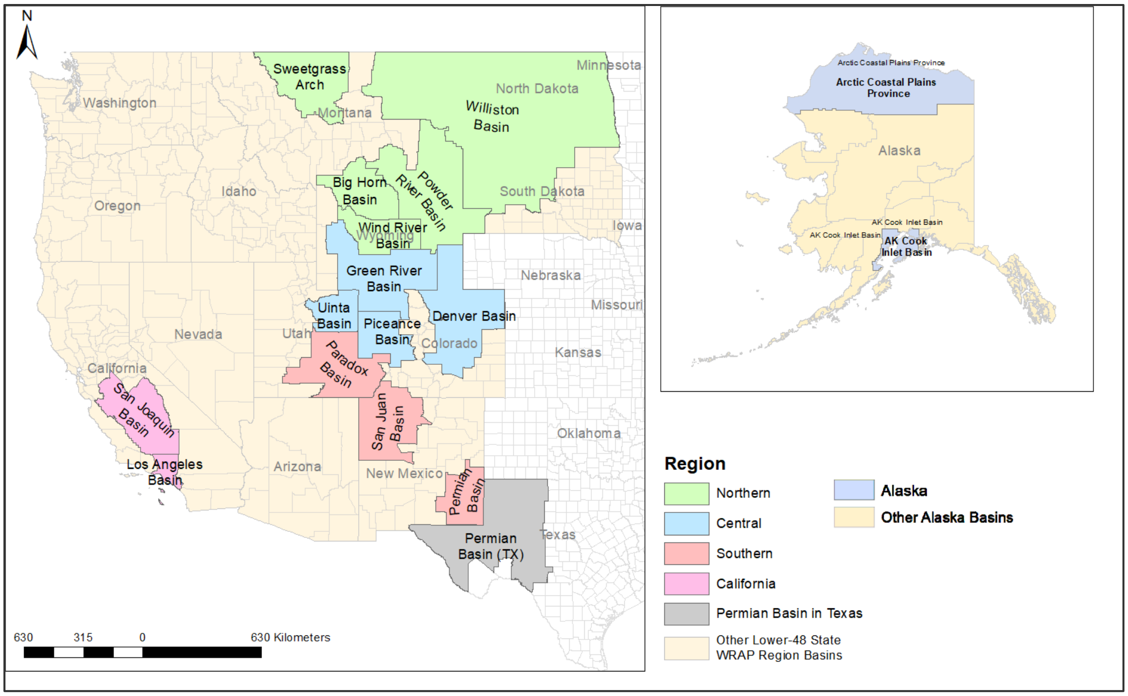


**Figure 1-2. WESTAR-WRAP region, including major O&G basins[12].**

### 1.1.3 Temporal Scope

The future year emission inventory was developed for future year 2028. The baseline 2014 emission inventory (Grant et al., 2019) is the basis of the future year emission inventory compilation. O&G activity forecasts were developed to forecast O&G activity changes from 2014 to 2023, under the assumption that – given high uncertainty in O&G activity forecasts – farther future year O&G activity forecasts to 2028 are not expected to be more predictive of 2028 O&G activity compared to 2023 O&G activity forecasts. O&G activity was held constant from 2023-2028 because of high uncertainty in forecasting farther than 9 years. O&G activity forecasts are described in Section 2.0.

### 1.1.4 Pollutants

Emissions were estimated for the following pollutants;

- Nitrogen oxide (NOx)
- Volatile organic compounds (VOC)
- Carbon monoxide (CO)
- Particular matter less than 10 microns ($PM_{10}$)
- Particulate matter less than 2.5 microns ($PM_{2.5}$)
- Sulfur oxides (SOx)
- Carbon dioxide ($CO_2$)
- Methane ($CH_4$)
- Nitrous oxide ($N_2O$)

[12] California O&G emissions are estimated by the California Air Resources Board (ARB) and are not included herein.

### 1.2 Well Count and Production Data

O&G related activity data were obtained from the IHS Enerdeq database[13] queried via online interface. The IHS Enerdeq database uses data from each state's Oil and Gas Conservation Commission (OGCC or equivalent) as sources of information for oil and gas activity. This data is also available directly through database querying tools maintained by the respective agencies. It was determined that the IHS database is more accurate and complete than the state databases. The IHS database was also used to develop emission inventories in the WRAP Phase III, WestJump AQMS, and IWDW studies. Therefore, the IHS database was chosen as the basis for O&G activity statistics for this analysis. Two types of data were queried from the Enerdeq database: production data and well data. Production data includes information relevant to producing wells and well data includes information relevant to drilling activity ("spuds") and completions.

Production data were obtained for all counties in the WESTAR-WRAP region as IHS "298" format data files. The "298" well data contain information regarding historical O&G production. The "298" well data were processed with a PERL script to develop a database by American Petroleum Institute (API)-number, well type (oil, gas, or coalbed methane; CBM), spud type (directional, horizontal, or vertical), annual gas production, oil production, and water production with latitude and longitude information.

The API number in the IHS database consists of 14 digits as follows:

- Digits 1 to 2: state identifier
- Digits 3 to 5: county identifier
- Digits 6 to 10: borehole identifier
- Digits 11 to 12: sidetracks
- Digits 13 to 14: event sequence code (recompletions)

Based on the expectation that the first 10 digits, which include geographic and borehole identifiers, would predict unique sets of well head equipment, the unique wells were identified by the first 10 digits of the API number.

Well data were also obtained from the IHS Enerdeq database for all WRAP region states as IHS "297" well data. The "297" well data contain information on spuds and completions. The "297" well data were processed with a PERL script to arrive at a database of by-API-number and spud type, spud and completion dates with latitude and longitude information. Drilling events in 2014 were identified by indication that the spud occurred within 2014. If the well API number indicated the well was a recompletion, it was not counted as a drilling event, but if the API number indicated the well was a sidetrack, it was counted as a drilling event.

O&G activity for the WRAP Region states is summarized in Grant et al. (2019); details by basin, spud type and well types are available in the 2014 O&G activity spreadsheet[14]. O&G activity forecasts for the future year emission inventory are described in Section 2.0.

[13] All data queried from IHS Enerdeq is subject to copyright protections

[14] https://www.wrapair2.org/pdf/WESTAR_OG_Activity_10Aug2018_distributed.xlsm

# 2.0 O&G ACTIVITY FORECASTS

Ramboll developed basin specific O&G activity forecasts for the following O&G activity parameters by well type (oil, gas, and coalbed methane [CBM]) and spud type (vertical, directional, horizontal):

- Spuds
- Active well count
- Oil production
- Gas production

Colorado emission inventory forecasts on state land were provided by CDPHE and incorporated into the Scenario 1 emission inventory as-is. The CDPHE inventory includes O&G activity forecasts per CDPHE estimates.

New Mexico emissions inventory forecasts for Title V point sources were provided by the NMED Air Quality Bureau[15]. NMED applied facility-by-facility growth factors accounting for changes in emissions from base year period to future year to certain Title V facilities based on facility operator input. Ramboll Scenario 1 growth factor estimates described below were applied to all other New Mexico point sources.

## 2.1 Scenario 1: Continuation of Historical Trends

Figure 1-2 shows the basins for which unique Scenario 1 forecasts were developed. These basins represent 98.6% of gas production, 99.6% of oil production, 99.5% of spuds, and 97.6% of active well count in the WRAP region in 2014. Note that, as mentioned previously, O&G activity forecasts were not developed for California herein because CARB is developing these forecasts. Outside of the basins identified in Figure 1-2; O&G activity was assumed unchanged from 2014. Future O&G production is difficult to forecast and forecasts to farther future years are more uncertain as a result of economic and political factors; therefore, O&G activity forecasts to 2023 are assumed for future year 2028. The basins were grouped into regions for organizational purposes. Four meetings[16] were held to present the draft forecasts to state agencies, one for each region identified in Figure 1-2. During the meetings, Ramboll presented the results for each basin in a given region and members provided feedback on the forecast estimates.

Per direction from the WRAP OGWG, forecasts were based on historical O&G activity trends in each basin for each parameter by well type and spud type and are meant to capture a scenario between a low development scenario that could result from factors such as substantial future decreases in O&G prices and high development scenario that could result from factors such as substantial future increases in O&G prices. The guiding assumptions for the forecast estimates were:

- Oil development and production continues to be prioritized over gas development and production.
- Development is primarily focused on horizontal wells in tight oil formations such as the Denver Basin (Niobrara Play), Permian Basin, and Williston Basin (Bakken Play). Limited exploration activity for vertical wells.

[15] Email from New Mexico Environment Department, Air Quality Bureau (Cember Hardison). February 5, 2020

[16] March 18, 2019 Northern Basins teleconference; March 19, 2019 Central Basins teleconference; March 20, 2019 Southern Basins teleconference; and March 21, 2019 Alaska Basins teleconference.

- Production from legacy vertical wells continues to decline and these wells are gradually taken offline.

Alaska-wide O&G activity change was not based on historical trends analysis. Per input from Alaska Department of Environmental Quality staff, Alaska forecasts were based on the February 2019 presentation, "Fall 2018 Production Forecast: House Finance Committee"[17]. In this presentation, 2023 oil production is estimated at approximately 475 Mbbl/day (slide 5). 2014 oil production is estimated at 546.6 Mbbl/day in the Alaska Department of Revenue-Tax Division 12/19/2017 "Production History and Forecast by Production Area from Fall 2017 RSB"[18]. The 2014 to 2023 oil production scalar (i.e., 13% Alaska-wide production decrease) was applied to forecast all emission source categories in Alaska.

**California** forecasts are not included herein because California forecasts are being developed by CARB.

**Uncertainty:** Forecasts are highly sensitive to factors that are difficult to predict (e.g., political, economic). Forecasts are also influenced by NEPA process (Projects and Regional Management Plans) and other regulatory factors (e.g., attainment status).

### 2.1.1 Scenario 1: O&G Activity Scaling Factor Development

The 2028 to 2014 ratio of each O&G activity metric by well type (summed over spud types) comprise the emission forecast scaling factors as shown in Equation 1.

$$f_{i,} = W_{i,2028} / W_{i,2014} \qquad \text{(Equation 1)}$$

where:

$f_i$ is the scaling factor for parameter *i* (oil production, gas production, active well count, and spud count)
$W_{i,2014}$ is the historical value of parameter *i* in 2014
$W_{i,2028}$ is the forecast value of parameter *i* in 2028

The O&G activity scaling factor associated with each emission source category is shown in Table 2-1[19]. The baseline inventory emissions were available for most wellsite categories by well type, but not by spud type. Therefore, factors by well type aggregated across spud type were used to scale the baseline inventory to the future year (see Table 2-1). Appendix A includes additional details on forecasts by spud type and well type that are the basis of the scaling factors presented in Table 2-2.

**Table 2-1. Scaling parameter by O&G source category.**

| Forecast O&G Activity Surrogate | Emission Source Category |
|---|---|
| **Active Well Count** | Refracing |
| | Water Pump Engines |
| | Well Venting |
| | Wellhead Engines (e.g., compressors, artificial lift) |

[17] http://www.akleg.gov/basis/get_documents.asp?session=31&docid=11246, accessed August 2019
[18] http://www.tax.alaska.gov/sourcesbook/AlaskaProduction.pdf, accessed August 2019
[19] 2014 base year activity estimates are summarized in the 2014 oil and gas activity spreadsheet at https://www.wrapair2.org/pdf/WESTAR_OG_Activity_10Aug2018_distributed.xlsm

| Forecast O&G Activity Surrogate | Emission Source Category |
|---|---|
| | Workover rigs |
| | Blowdowns |
| | Heaters |
| | Fugitive Leaks |
| | Pneumatic Devices |
| | Pneumatic Pumps |
| | Well Venting |
| | Recompletions |
| **Gas Production (i.e., total, primary, associated, CBM)** | Midstream Sources |
| | Produced Water Tanks |
| | Dehydrators |
| | Casinghead Gas |
| **Liquid Hydrocarbon Production (i.e., oil, condensate)** | Oil Tanks |
| | Condensate Tanks |
| | Tank Truck/Railcar Loading |
| **Spud Count** | Completions |
| | Drill Rigs |
| | Hydraulic Fracturing Engines |
| | Mud Degassing |

## Table 2-2. Summary of 2028 to 2014 scaling ratio by O&G activity metric and Basin.

| Activity Metric | Well Type | | | |
|---|---|---|---|---|
| | All | CBM | Gas | Oil |
| **Alaska (All Basins)** | | | | |
| Oil Production | 0.87 | | | |
| **Big Horn Basin** | | | | |
| Gas Production | 0.82 | -- | 0.49 | 0.99 |
| Oil Production | 0.71 | -- | 0.78 | 0.71 |
| Spud Count | 0.66 | -- | -- | -- |
| Well Count | 0.72 | -- | 0.80 | 0.71 |
| **Denver Basin (WY Only)** | | | | |
| Gas Production | 5.15 | -- | -- | 5.15 |
| Oil Production | 3.98 | -- | -- | 3.98 |
| Spud Count | 0.66 | -- | -- | -- |
| Well Count | 2.26 | -- | -- | 2.26 |
| **Green River Basin** | | | | |
| Gas Production | 0.96 | 0.64 | 0.96 | 0.99 |
| Oil Production | 1.00 | -- | 1.01 | 0.98 |
| Spud Count | 0.69 | -- | -- | -- |
| Well Count | 1.12 | 0.64 | 1.15 | 0.88 |
| **Paradox Basin** | | | | |
| Gas Production | 1.07 | 1.48 | 0.92 | 0.97 |
| Oil Production | 0.61 | -- | 0.24 | 0.61 |
| Spud Count | 0.18 | -- | -- | -- |

| Activity Metric | Well Type | | | |
|---|---|---|---|---|
| | All | CBM | Gas | Oil |
| Well Count | 0.81 | 0.99 | 0.97 | 0.65 |
| **Permian Basin** | | | | |
| Gas Production | 2.34 | -- | 2.94 | 2.15 |
| Oil Production | 2.33 | -- | 17.19[a] | 1.96 |
| Spud Count | 0.55 | -- | -- | -- |
| Well Count | 0.95 | -- | 0.91 | 0.97 |
| **Powder River Basin** | | | | |
| Gas Production | 0.62 | 0.25 | 0.53 | 1.87 |
| Oil Production | 0.87 | -- | 0.78 | 0.88 |
| Spud Count | 0.26 | -- | -- | -- |
| Well Count | 0.60 | 0.40 | 0.74 | 0.90 |
| **San Juan Basin** | | | | |
| Gas Production | 0.59 | 0.53 | 0.63 | 1.38 |
| Oil Production | 1.12 | -- | 0.80 | 1.23 |
| Spud Count | 0.44 | -- | -- | -- |
| Well Count | 0.90 | 0.91 | 0.91 | 0.78 |
| **Sweetgrass Arch** | | | | |
| Gas Production | 0.75 | -- | 0.74 | 0.93 |
| Oil Production | 0.55 | -- | 0.78 | 0.54 |
| Spud Count | 0.44 | -- | -- | -- |
| Well Count | 0.94 | -- | 0.87 | 1.00 |
| **Uinta Basin** | | | | |
| Gas Production | 0.40 | 0.51 | 0.33 | 0.70 |
| Oil Production | 0.67 | -- | 0.50 | 0.68 |
| Spud Count | 0.20 | -- | -- | -- |
| Well Count | 0.93 | 0.99 | 0.94 | 0.92 |
| **Williston Basin (ND Only)[b]** | | | | |
| Gas Production | 3.06 | -- | 0.79 | 3.11 |
| Oil Production | 1.57 | -- | 0.73 | 1.58 |
| Spud Count | 1.03 | -- | -- | -- |
| Well Count | 2.20 | -- | 0.96 | 2.23 |
| **Wind River Basin** | | | | |
| Gas Production | 0.86 | 0.00 | 0.72 | 2.01 |
| Oil Production | 0.90 | -- | 0.72 | 0.91 |
| Spud Count | 0.63 | -- | -- | -- |
| Well Count | 0.97 | 0.11 | 1.00 | 0.97 |

[a] Permian Basin condensate production from horizontal wells increased from 2.3 million barrels per year (MMbbl/yr) in 2015 to 13.8 MMbbl/yr in 2017. The substantial rate of increase from 2015 to 2017 was extended to 2023.
[b] Williston Basin activity in Montana and South Dakota was assumed unchanged from the base year based on limited recent drilling and recent activity declines. The exception is Williston Basin spudding activity in Montana which was estimated to remain at 2017 levels (18 spuds) which were substantially lower than the activity in base year 2014 (134 spuds).

# 3.0 SCENARIO 1 EMISSION CONTROL ESTIMATES

Emissions control resulting from regulatory programs such as NSPS Subpart OOOO and OOOOa, NSPS JJJJ standards, Federal off-road diesel engine tier standards and state specific regulatory programs were incorporated into future year emission estimates, to the extent feasible and to the extent that these programs are expected to make substantial impacts to future year emissions. Emission control estimates are based on the suite of regulations that were "on-the-books" at the time that this future year emission inventory was developed. Emission control assumptions for fugitive components (LDAR), green completions at oil wells, and pneumatic pumps are based on NSPS Subpart OOOOa provisions. EPA is conducting ongoing activities that may lead to future changes to NSPS Subpart OOOOa.

A controls analysis was performed and the effects of applicable regulations were applied, to the extent feasible, for the basins listed below.

- Denver Basin (Wyoming only)
- Permian Basin
- Williston Basin
- Uinta Basin
- Green River Basin
- Powder River Basin

Colorado emission inventory forecasts on state land were provided by CDPHE and incorporated into the Scenario 1 emission inventory as-is. The CDPHE inventory includes emission controls per CDPHE estimates.

Control factors were developed for Williston, Permian, and Denver (Wyoming only) basins because substantial activity growth, subject to control by on-the-books regulations, under Scenario 1 is estimated to occur between the baseline inventory and the future year inventory. For Uinta Basin, a controls analysis was performed because on-the-books Utah State regulations are expected to result in substantial reductions to emissions from existing oil and gas wells. Control factors were developed for the Green River and Powder River basins to take advantage of detailed 2014 and 2017 emission inventory files provided by the Wyoming Department of Environmental Quality (WYDEQ).

A controls analysis was not performed (i.e., emission rates per unit production or per well or spud were assumed unchanged between the baseline year and future year) because substantial growth is not estimated in the basins listed below between the baseline year and future year under Scenario 1.

- Alaska (All Basins)
- Big Horn Basin
- Paradox Basin
- Powder River Basin
- San Juan Basin
- Sweetgrass Arch
- Wind River Basin

The methodology used to estimate regulation effects on wellsite O&G emissions is described below. Point source O&G emissions may also be subject to additional control per requirements such as NSPS Subpart OOOO, and NSPS Subpart OOOOa; however, information was not readily available from point source emission inventory databases upon which to estimate the effect on emissions of such controls. Point source O&G emission forecasts do not include additional control resulting from regulatory control programs. Additional controls per the 2018 Final November 2018 BLM Methane Rule[20] were assumed negligible. Table 3-1 below summarizes "on-the-books" federal regulations that affect wellsite emissions source categories. A detailed table summarizing all state and federal regulations is available in Appendix A[21] of Grant et al. (2018).

State specific requirements applicable to the control factors analysis for Utah are provided in Section 3.1. The effects of state specific programs for Wyoming basins is incorporated implicitly in the WYDEQ 2014 and 2017 data submissions which are the basis of the Wyoming basins control analysis. State specific regulatory effects on control factors in the Williston and Permian Basins are not expected to result in substantial effects on emissions beyond Federal standards effects.

**Table 3-1. Summary of federal "on-the-books" regulations affecting O&G source categories considered in this inventory.**

| Source Category | Regulation | Enforcing Agency | Applicability | Effective Date |
|---|---|---|---|---|
| Drill Rigs, Fracturing Engines | **Nonroad engine Tier standards (1-4)**: Limits emission rates for compression ignition engines. | US EPA | All applicable off-road mobile engine categories | Phase-in from 1996 - 2014 |
| Pneumatic Controllers | **NSPS Subpart OOOO**: Six standard cubic-feet per hour (scfh) at well sites (i.e. low bleed gas-driven pneumatic controllers). | US EPA | New and modified[1] sources only (NSPS OOOO and OOOOa) | NSPS OOOO: August 2011 |
| Compressor Engines, Artificial Lift Engines | **NSPS Subpart JJJJ**: Limits emission rates for spark ignition engines. | US EPA | New and modified spark-ignition engines | Phase-in from 2005 to 2011 |
| Well Completions | **NSPS Subpart OOOO and OOOOa**: Green completions required at gas and oil well sites except for specific well types (wildcat, delineation, oil wells with a gas-oil ratio of less than 300 standard cubic-feet of gas per barrel, and oil wells for which a gas pipeline is not available). | US EPA | All applicable completions | NSPS OOOO and OOOOa: Phase-in from 2015 |
| Storage Tanks | **NSPS Subpart OOOO and OOOOa**: Storage vessels with VOC emissions equal to or greater than 6 tpy must reduce emissions by at least 95 percent. This can be accomplished by routing emissions to a combustion device. | US EPA | New and modified[1] sources only (NSPS OOOO and OOOOa) | NSPS OOOO and OOOOa: August 2011 |

[20] 43 CFR 3100,43 CFR 3160,43 CFR 3170
[21] https://www.wrapair2.org/pdf/Item4_OGWG_WP_AppendixA.xlsx

| Source Category | Regulation | Enforcing Agency | Applicability | Effective Date |
|---|---|---|---|---|
| Fugitives | **NSPS Subpart OOOOa**: LDAR programs are required at applicable well sites. | US EPA | New and modified sources (NSPS OOOOa) | NSPS OOOOa: Phase in from 2015 |
| Pneumatic Pumps | **NSPS Subpart OOOOa**: Route emissions from pneumatic diaphragm pumps to existing onsite control device, if available. | US EPA | New and modified sources (NSPS OOOOa) | NSPS OOOOa: Phase in from 2015 |

[1] The fraction of sources that would be classified as "modified" under NSPS OOOO and/or NSPS OOOOa is unavailable. Controls were applied to new sources only.

### 3.1 Utah State Oil and Gas Registration Requirements

As mentioned above, application of controls to the Uinta Basin focused on emission source categories with substantial emissions for which state specific programs are expected to result in substantial emission reductions. Facility-level throughput and emissions information available from the Utah Air Agencies Uinta Basin emission inventory was used to estimate facility-level emission reductions for Uintah and Duchesne counties. Table 3-2 describes controls application for the Uinta Basin. Uintah and Duchesne counties accounted for a vast majority of baseline emissions from pneumatic controllers, tanks, and fugitive components in the Uinta Basin; emission reductions for these categories were not estimated for other Uinta Basin counties. Facility-level dehydrator emissions necessary to estimate control effects were not available outside of Uintah and Duchesne counties, therefore, dehydrator emission reductions were not applied for other Uinta Basin counties.

**Table 3-2. Uinta Basin future year controls implementation.**

| Source | State Regulation | Future Years Control Assumption |
|---|---|---|
| Oil and Condensate Tanks | R307-506: A tank or a tank battery at existing oil and gas well sites are required to control VOC emissions at 95% if throughput of crude oil at 8,000 barrels or greater or 2,000 barrels of condensate or greater per year on a rolling 12 month basis. Sources can demonstrate less than 4 tpy with site specific sample and calculations based upon AP-42. A tank or tank battery at an oil and gas site that begins operations after January 1, 2018 are required to control VOC emissions at 95% for one year and can remove if throughput less than the 8,000 barrels of crude oil or 2,000 barrels of condensate or demonstrate emissions less than 4 tpy. Emergency tanks are exempt from R307-509 if not used as an active storage tank, emptied 15 days after receiving fluids and equipped with a liquid level gauge. | Facilities with 2014 tank throughput greater than 8,000 barrels of oil or 2,000 barrels of condensate which were uncontrolled in the baseline inventory were reduced by 95% in the future year inventory. |

| Source | State Regulation | Future Years Control Assumption |
|---|---|---|
| Fugitive Components (LDAR) | Oil and gas well sites that require controls in accordance with R307-506 (tanks) or R307-507 (dehydrators) are required to perform LDAR in accordance with OOOOa | LDAR implementation was assumed to result in 50% reductions to fugitive component emissions at all (existing and new) wells based on average reductions from annual and quarterly inspections assumed in CDPHE (2014). |
| Pneumatic devices | As of April 2017 all existing pneumatic controllers shall meet OOOO standards. | Assume all devices are low or no bleed devices. |
| Dehydrators | Dehydrators with VOC emissions of 4 tpy or greater, either alone or combined with emissions from tanks, require controls at 95% | Facilities with 2014 dehydrator VOC emissions of 4 tpy or greater were reduced by 95% in the future year inventory. |

### 3.2 Nonroad Diesel Engine Standards and Fuel Sulfur Standards

Williston and Permian basins include substantial emissions contributions from source categories expected to be affected by Federal Nonroad Diesel Engine and Fuel Sulfur Standards (drilling rigs and hydraulic fracturing engines). EPA MOVES 2014b[22] was run with default inputs for base year 2014 and future year 2028. Model outputs were used to develop basin-wide emissions per unit population for "other oil field equipment" (SCC 2270010010) for base year 2014 and future year 2028 for Montana, North Dakota and New Mexico. Emissions per unit population reflect the predicted fleet mix of engines – for various tier standards from baseline uncontrolled engines through Tier IV engines – and are used as a representation of fleet turnover for drilling rigs and fracing engines. The ratios of 2028 to 2014 per unit emissions are the control factors estimates which account for federal non-road tier standards and diesel fuel sulfur standards. Permian Basin emission rates implemented in the baseline inventory for drill rigs and hydraulic fracturing engines include substantial use of Tier 4 engines and were already at or below MOVES 2014b estimates, therefore no emission reduction was estimated for the Permian Basin.

### 3.3 New Source Performance Standards for Pneumatic Devices

Pneumatic device control factors were developed for the Williston and Permian basins according to NSPS Subpart OOOO and OOOOa. Pneumatic devices at all (existing and new) wells were assumed to be low-bleed (i.e. less than 6 standard cubic-feet per hour bleed rate).

### 3.4 New Source Performance Standards for Completions

NSPS Subpart OOOO and OOOOa require control of emissions from (i) hydraulically fractured gas well completions by flare from August 23, 2011 to December 31, 2014 and with green completion technology from January 1, 2015 and (ii) hydraulically fractured oil well completions by green completion technology from September18, 2015. Completions represent approximately 2% of Permian Basin and 4% of Williston Basin baseline VOC emissions. In 2014, oil wells completed in the Williston and Permian Basin were not subject to NSPS Subpart OOOOa requirements and included a mix of

[22] https://www.epa.gov/moves/latest-version-motor-vehicle-emission-simulator-moves

venting, flaring, and green completion technology. Given uncertainty in the feasibility of routing completion gas to pipeline in these basins, NSPS Subpart OOOOa requirements were assumed to be fulfilled by a mix of flaring and green completion technology; completion venting activity was assumed negligible and the relative split between the flaring and green completion volume per completion in the baseline inventory was assumed for the future year inventory.

### 3.5 New Source Performance Standards for Crude Oil and Condensate Tanks

Crude oil and condensate tank control factors were developed according to NSPS Subpart OOOO and OOOOa requirements. NSPS Subpart OOOO requires control of condensate and oil tank VOC emissions for tanks that emit over 6 tons per year VOC if the source was constructed or modified after August 23, 2011; NSPS OOOOa extends the requirements to control of methane emissions. The compliance deadline was April 15, 2014 for tanks constructed after April 12, 2013 and April 15, 2015 for tanks constructed between August 23, 2011 and April 12, 2013.

Close to 100% of Williston Basin tanks were controlled in the base year, therefore, Williston Basin tank emission rates were assumed unchanged in the future year inventory. Ramboll estimated control scalars for Permian Basin tanks. Permian Basin control factors were based on application of control to tanks with the potential to emit 6 tons per year VOC, but not to tanks with the potential to emit less than 6 tons per year VOC. For Permian Basin tank emissions added after base year 2014, 95% of oil and condensate tank and emissions were assumed to be controlled by flare (56%), vapor recovery unit (2%), or other device types (typically an enclosed combustor; 38%).

Similar to the baseline inventory, capture efficiency was assumed to be 100%.

### 3.6 New Source Performance Standards for Wellsite Natural-Gas Fired Engines

NSPS Subpart JJJJ requirements are applicable to natural gas-fueled wellsite engines. In the Permian and Williston basins, a vast majority of natural gas-fueled wellsite engines are artificial lift engines. Permian Basin artificial lift engine emission rates were not changed from the base year to the future year because 99% of natural gas-fueled artificial lift engines in the baseline inventory were assumed to meet NSPS JJJJ standards based on operator survey data (Grant et al., 2019). Williston Basin artificial lift engines fleetwide emission factors were estimated for the future year assuming that engines are added between the baseline and future year, with similar wellsite prevalence and configuration as in the baseline inventory, and that these engines meet NSPS Subpart JJJJ standards and have an average useful life of 40 years.

### 3.7 Associated Gas Venting and Flaring

The baseline inventory includes substantial casinghead gas flaring emissions for the Williston Basin. For the future year emission inventory, the percentage of associated gas that is not sent to pipeline in the Williston Basin was estimated to be 86% (14% not sent to pipeline)[23]. This is based on the NDIC Order 24665 (Policy/Guidance, Version 112018) post-November 1, 2020 gas capture goal of 91%. NDIC quantifies ‘capture rate’ as any casinghead gas not sent to the flare. The flared gas target of 9% is directly related to the 91% capture goal, and not equal to the amount of gas sent to pipeline (sales gas estimated at 86%). Based on historical trends, the amount of gas used onsite (referred to as lease use) was assumed to be 5%.

### 3.8 New Source Performance Standards for Fugitive Devices

NSPS Subpart OOOOa requires routine fugitive leak monitoring for well sites and compressor stations constructed or modified after September 18, 2015. LDAR program requirements specify that LDAR

[23] Email from North Dakota Department of Environmental Quality (NDDEQ; David Stroh), October 1, 2019.

surveys are conducted twice annually after the initial survey. LDAR implementation for the Williston and Permian basins is assumed to result in 50% reductions to fugitive component emissions at new wells based on average reductions from annual and quarterly inspections reductions assumed in CDPHE (2014).

### 3.9 New Source Performance Standards for Pneumatic Pumps

Emission control factors for pneumatic pumps resulting from NSPS Subpart OOOOa were not estimated. NSPS Subpart OOOOa requirements apply only to diaphragm pumps but not lean glycol circulation pumps or piston-driven chemical injection pumps. The base year inventory was based on generic pneumatic pump configurations which did not distinguish pump type. Not including additional control of pneumatic pumps per on-the-books regulations is a conservative assumption, consistent with Grant et al. (2018).

### 3.10 Wyoming Basins Control Factor Estimates

Controls were estimated for Denver, Green River, and Powder River basins in Wyoming based on detailed 2014 and 2017 emission inventory data provided by WYDEQ. Denver Basin controls were estimated to account for differences in emissions for wells that are expected to be added in the Denver Basin in the Niobrara formation which have a different equipment setup and emissions regime than the legacy wells in that basin. Green River and Powder River basin O&G activity is estimated to decline under Scenario 1 for most parameters. An analysis of emission rate differences between the baseline and future year inventories based on detailed emission inventory data provided by WYDEQ was used to estimate control factors for source categories with substantial NOx and VOC emissions.

#### 3.10.1 Denver Basin

Baseline emissions per O&G activity surrogate were estimated for each nonpoint source category; these emissions are representative of the active wells in the baseline inventory which are dominated by legacy vertical wells. Wells that are being added in the Denver Basin between the baseline and future year are expected to be primarily horizontal wells drilled in the Niobrara formation. The new horizontal wells are expected to have equipment configurations and emissions that differ substantially from the legacy vertical wells. WYDEQ 2017 annual emission inventory estimates for a substantial number of new Denver Basin horizontal wells were used to develop horizontal well emission rates. The control factors developed for the Denver Basin represent the change in emissions from legacy vertical wells in the base year inventory to new horizontal wells.

#### 3.10.2 Green River and Powder River Basins

Control factors were developed for specific Green River and Powder River basin source categories with substantial emission contributions and emission rate changes based on analysis of WYDEQ provided 2014 and 2017 annual emission inventory estimates for several operators. Emission rates were assumed unchanged from the base year for source categories that either (1) did not have substantial emission contributions or (2) for which emission changes were small. Circa-2014 baseline and 2017 emission rates were used to develop control factors for condensate tanks and wellhead engines in the Green River Basin and wellhead engines in the Powder River Basin.

### 3.11 Controls Summary

Scenario 1 future year 2028 changes in emissions by basins and source category resulting from control factors application is presented in Table 3-3.

### Table 3-3. Scenario 1 control effects summary.

| Description | Applicability[1] | Percent Change in Emissions from Baseline Inventory from Controls | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | NOx | VOC | CO | SOx | $PM_{10}$ | $PM_{2.5}$ | $CO_2$ | $CH_4$ | $N_2O$ |
| **Williston, MT** | | | | | | | | | | |
| Associated Gas Venting | all | -69% | -69% | -69% | -69% | 0% | 0% | -69% | -69% | -69% |
| **Williston, ND** | | | | | | | | | | |
| Artificial Lift Engines | all | -33% | 15% | -14% | 0% | 0% | 0% | 0% | 15% | 0% |
| Associated Gas Venting | all | -69% | -69% | -69% | -69% | 0% | 0% | -69% | -69% | -69% |
| Drill Rigs | all | -42% | -38% | 101% | 0% | -78% | -78% | 0% | -38% | 0% |
| Hydraulic Fracturing Engines | all | -53% | -53% | 99% | 0% | -81% | -81% | 0% | -53% | 0% |
| Nonpoint Fugitives | added | 0% | -50% | 0% | 0% | 0% | 0% | -50% | -50% | -50% |
| Pneumatic Devices | added | 0% | -89% | 0% | 0% | 0% | 0% | -89% | -89% | -89% |
| Completions | all | 8% | -78% | 8% | 0% | 0% | 0% | 8% | -78% | 8% |
| **Williston, SD** | | | | | | | | | | |
| Associated Gas Venting | all | -69% | -69% | -69% | -69% | 0% | 0% | -69% | -69% | -69% |
| **Permian, NM** | | | | | | | | | | |
| Condensate tank | added | 0% | -95% | 0% | 0% | 0% | 0% | -95% | -95% | -95% |
| Nonpoint Fugitives | added | 0% | -50% | 0% | 0% | 0% | 0% | -50% | -50% | -50% |
| Oil Tank | added | 0% | -95% | 0% | 0% | 0% | 0% | -95% | -95% | -95% |
| Pneumatic Devices | added | 0% | Gas wells: -90%<br>Oil wells: -85% | 0% | 0% | 0% | 0% | Gas wells: -90%<br>Oil wells: -85% | Gas wells: -90%<br>Oil wells: -85% | 0% |
| Venting - initial completions | all | 56% | -96% | 56% | 0% | 0% | 0% | 56% | -96% | 56% |
| **Green River, WY** | | | | | | | | | | |
| Condensate Tanks | all | -21% | -61% | -21% | 0% | 0% | 0% | -21% | -21% | -21% |
| Well-head Engines | all | -25% | -11% | 11% | -65% | -33% | -33% | 0% | -11% | 0% |
| Pneumatic Pumps | all | -55% | -66% | -55% | 0% | 0% | 0% | -66% | -66% | -66% |
| Nonpoint Fugitives | all | 0% | -78% | 0% | 0% | 0% | 0% | -78% | -78% | -78% |
| **Powder River, WY** | | | | | | | | | | |
| Well-head Engines | all | -37% | -45% | -52% | 32% | 486% | 486% | 0% | -45% | 0% |
| Pneumatic Pumps | all | 28% | 26% | 28% | 0% | 0% | 0% | 26% | 26% | 26% |
| Nonpoint Fugitives | all | 0% | -47% | 0% | 0% | 0% | 0% | -47% | -47% | -47% |
| **Denver Basin, WY** | | | | | | | | | | |
| Artificial Lift | added | -71% | -25% | -90% | -100% | -100% | -100% | 0% | -25% | 0% |
| Drill Rigs | all | -99% | -100% | -99% | -97% | -100% | -100% | 0% | -100% | 0% |
| Fugitives | added | 0% | 43% | 0% | 0% | 0% | 0% | 43% | 43% | 43% |
| Completion | all | -100% | 162% | -100% | -100% | -100% | -100% | 162% | 162% | 162% |
| Gas Well Venting - Blowdowns | added | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Heaters | added | -92% | -92% | -92% | -92% | -92% | -92% | -92% | -92% | -92% |

| Description | Applicability[1] | Percent Change in Emissions from Baseline Inventory from Controls | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | NOx | VOC | CO | SOx | $PM_{10}$ | $PM_{2.5}$ | $CO_2$ | $CH_4$ | $N_2O$ |
| Hydraulic Fracturing Engines | all | 305% | 46% | 400% | 1845% | 3% | -14% | 0% | 46% | 0% |
| Miscellaneous Engines | added | -71% | -25% | -90% | -100% | -100% | -100% | 0% | -25% | 0% |
| Oil Well Pneumatic Devices | added | 0% | -85% | 0% | 0% | 0% | 0% | -85% | -85% | -85% |
| Oil Well Pneumatic Pumps | added | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Oil Well Tanks - Flashing & Standing/Working/Breathing | added | -53% | -79% | -53% | 0% | 0% | 0% | -79% | -79% | -79% |
| Storage Tanks: Crude Oil | added | -53% | -79% | -53% | 0% | 0% | 0% | -79% | -79% | -79% |
| Tank Truck/Railcar Loading: Condensate | added | -50% | -7% | -58% | 0% | 0% | 0% | -7% | -7% | -7% |
| Tank Truck/Railcar Loading: Crude Oil | added | -50% | -7% | -58% | 0% | 0% | 0% | -7% | -7% | -7% |

[1] "Added" refers to O&G activity added between the baseline and future year. "All" refers to all O&G activity in future year 2028.

[2] Emission changes for the Denver Basin represent the change in emissions from legacy vertical wells in the base year inventory to new horizontal wells

[3] Emission changes for the Green River and Powder River basins represent emission rate changes from the baseline inventory based on WYDEQ provided detailed wellsite emissions data for 2014 and 2017.

# 4.0 RESULTS SUMMARY

O&G emissions results for the future year 2028 O&G emission inventory for the WESTAR-WRAP region are presented below as a series of tables and charts. Additional summaries and fully detailed emission inventory data are available in spreadsheets that accompany this report which are posted on the WRAP OGWG website (https://www.wrapair2.org/OGWG.aspx).

## 4.1 Future Year 2028 WRAP OGWG v2 emission inventory

Future Year 2028 WRAP OGWG NOx and VOC emissions for all WRAP region basins are summarized in Table 4-1 and Table 4-2, respectively. Across the WESTAR-WRAP region, most nonpoint O&G emissions are emitted from wellsite sources and most point O&G emission are emitted from midstream sources. Approximately 54% of 2028 NOx emissions and 86% of 2028 VOC emissions were from nonpoint sources. Basin specific nonpoint and point source contributions result from basin specific equipment and operational characteristics and infrastructure, and in some cases basin specific accounting. For example, the Uinta Basin includes several wellsite source categories in the point source emission inventory. The top-seven emitting basins account for approximately 83% of NOx emissions and the top-six basin and state combinations account for over 86% of VOC emissions.

**Table 4-1. Summary of nonpoint and point NOx emissions (tons/yr) by basin.**

| Basin and State | NOx Emissions (tons/yr) | | |
|---|---|---|---|
| | Nonpoint | Point | Total |
| Williston, ND | 57,500 | 15,859 | 73,359 |
| Permian, NM | 19,989 | 34,054 | 54,043 |
| San Juan, NM | 30,167 | 8,715 | 38,882 |
| Arctic Coastal Plains Province, AK | 1,204 | 29,883 | 31,087 |
| Denver, CO | 15,090 | 5,592 | 20,682 |
| San Juan, CO | 11,050 | 3,920 | 14,970 |
| Powder River, WY | 7,236 | 3,098 | 10,335 |
| Green River, WY | 4,663 | 5,189 | 9,852 |
| Uinta, UT | 728 | 8,695 | 9,423 |
| Piceance, CO | 2,475 | 4,175 | 6,650 |
| AK Cook Inlet Basin, AK | 1,612 | 4,058 | 5,670 |
| Sweetgrass, MT | 1,820 | 233 | 2,053 |
| Big Horn, WY | 683 | 1,223 | 1,906 |
| Williston, MT | 1,303 | 482 | 1,785 |
| Plateau Sedimentary Prov, AZ | - | 1,468 | 1,468 |
| Wind River, WY | 216 | 1,142 | 1,359 |
| Paradox, UT | 699 | 321 | 1,020 |
| Central Montana Uplift, MT | 411 | 560 | 971 |
| Denver Basin, WY | 711 | 171 | 882 |
| Williston, SD | 324 | 369 | 692 |
| Other WRAP Basins | 536 | 5,881 | 6,416 |
| **Total** | **158,418** | **135,087** | **293,505** |

**Table 4-2. Summary of nonpoint and point VOC emissions (tons/yr) by Basin.**

| Basin and State | VOC Emissions (tons/yr) | | |
|---|---|---|---|
| | Nonpoint | Point | Total |
| Williston, ND | 314,080 | 5,587 | 319,667 |
| Permian, NM | 124,129 | 27,332 | 151,461 |
| San Juan, NM | 70,590 | 5,549 | 76,139 |
| Powder River, WY | 53,047 | 2,877 | 55,923 |
| Uinta, UT | 3,994 | 51,285 | 55,279 |
| Denver, CO | 37,750 | 6,075 | 43,825 |
| Green River, WY | 28,789 | 10,848 | 39,637 |
| Piceance, CO | 23,036 | 3,230 | 26,266 |
| Williston, MT | 21,503 | 705 | 22,209 |
| Arctic Coastal Plains Province, AK | 18,512 | 584 | 19,096 |
| Paradox, UT | 11,823 | 52 | 11,874 |
| Wind River, WY | 5,613 | 1,220 | 6,833 |
| Williston, SD | 4,761 | 11 | 4,772 |
| AK Cook Inlet Basin, AK | 4,100 | 566 | 4,665 |
| Sweetgrass, MT | 4,501 | 77 | 4,578 |
| Denver Basin, WY | 3,212 | 1,008 | 4,220 |
| Other WRAP Basins | 11,172 | 3,810 | 14,982 |
| **Total** | **740,611** | **120,815** | **861,426** |

## 4.2 Future Year 2028 Comparison to circa-2014 Baseline Emission Inventories

Changes from the circa-2014 baseline WRAP OGWG v2 to the 2028 future year inventory are shown below for NOx (Figure 4-1) and VOC (Figure 4-2).

Changes from the circa-2014 baseline to the future year emission inventory are based on estimated change in O&G activity and emission control effects from the baseline to future year. WESTAR-WRAP region-wide NOx emissions decreased by 6% and VOC emissions decreased by 20%; emission changes vary substantially by state and basin.

NOx emission decreases for Montana, Wyoming, Utah, and Alaska are due primarily to declines in O&G activity from the baseline year to the future year. Permian Basin and North Dakota NOx emission increases result from increases to O&G activity from the baseline to future year.

VOC emission decreases for Alaska are based on decreases to O&G activity from the baseline to the future year. New Mexico and North Dakota VOC emission increases result from increases to O&G activity from the baseline to future year in the Permian Basin and Williston Basin, respectively. VOC emission decreases in Montana, and South Dakota result from the assumption that a higher percentage of associated gas is sent to pipeline compared to the baseline (i.e., lower percentage of associated gas is flared or vented) and NSPS Subpart OOOO and OOOOa control program requirements for pneumatic controls and completions. VOC emission decreases for Utah result from control effects of Utah O&G wellsite permitting programs which affect new and existing sources as well as O&G activity declines.

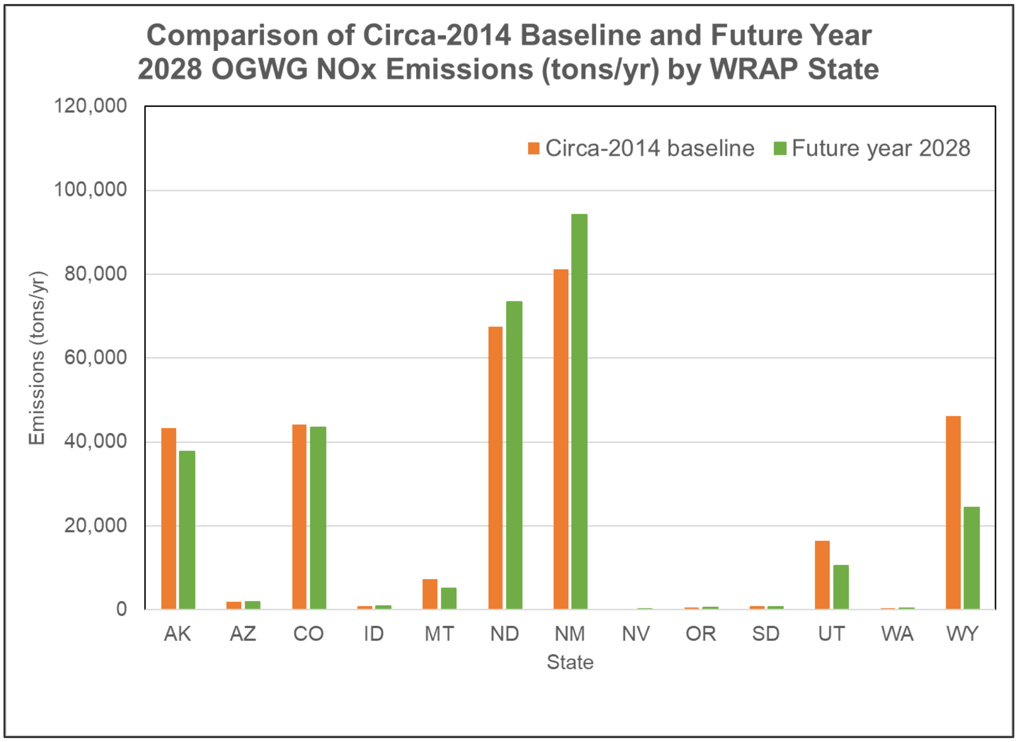


**Figure 4-1. Comparison of 2014 OGWG V2 and Future Year 2028 NOx emissions by WRAP region State.**

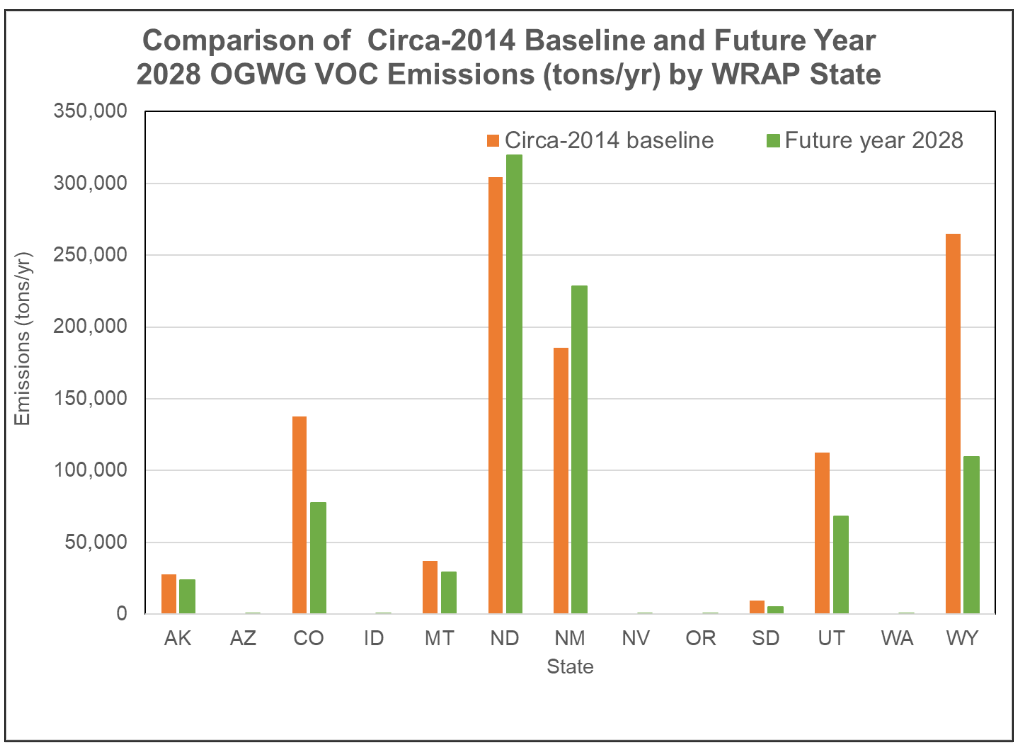


**Figure 4-2. Comparison of 2014 OGWG V2 and Future Year 2028 VOC emissions by WRAP region State.**

# 5.0 REFERENCES

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# APPENDIX A

## Scenario 1: Continuation of Historical Trends O&G Activity Forecast Details

O&G activity forecasts were developed for Scenario 1 for select WRAP O&G basins by extending recent historical oil and gas activity trends to future year 2023. O&G activity forecasts were developed for well count, gas production, and oil production by basin, spud type (vertical, horizontal, or directional) and well type (oil, gas, coalbed methane [CBM]); spud count forecasts were developed by basin and spud type. Trends in O&G activity for recent historical years (typically within the most recent 5 year period 2013-2017) were extended to future year 2023. Forecast methodology for each parameter, basin, spud type, and well type was chosen based on a review of recent trends and application of engineering judgement to estimate the historical year period to extend and the forecast method to assume. State agencies reviewed the methodology and forecasts during and subsequent to a series of late-March 2019 teleconferences[24] in which the forecasts were presented. A description of forecast methods is shown in Table 1. Tables 2 and 3 show forecasting methodologies that were applied for each parameter in each basin.

**Table 1. Summary of Forecasting Methods**

| Methodology | Indicator | Description |
|---|---|---|
| Default | d | Forecast based on average of the previous 5 years |
| Truncated Default | #d | Forecast based on average of previous # years |
| Linear Forecast | #L | Linear forecast based on previous # years |
| Last | Last | Forecast same as most recent year of production available |
| Percent Differential | #% | Forecast assumes annual % decline at a rate equal to the percent decline in previous # years |
| Percent Reduction | #r | Forecast assumes % decline over future period (2018-2023) is equal to % decline over # year time period |

**Table 2. Summary of Applied Production Forecast Methods by Basin**

| Basin (State) | Vertical | | | Horizontal | | | Directional | | |
|---|---|---|---|---|---|---|---|---|---|
| | Well Count | Oil Prod-uction | Gas Prod-uction | Well Count | Oil Prod-uction | Gas Prod-uction | Well Count | Oil Prod-uction | Gas Prod-uction |
| **Oil Wells** | | | | | | | | | |
| Denver Basin (WY) | Last | Last | Last | 5L | 5L | 5L | d | Last | Last |
| Sweetgrass Basin (MT) | d | 5% | Last | d | d | d | d | 3d | d |
| Williston Basin (MT,ND,SD) | a | a | a | a | a | a | a | a | a |
| Permian Basin (NM) | 5L | Last | Last | 5L | 4L | 5L | d | d | d |
| San Juan Basin (NM,CO) | 5L | Last | 5% | 5L | 4d | 4d | d | Last | d |
| Paradox Basin (CO,UT) | 5% | 3% | d | d | Last | d | Last | 5% | Last |
| Uinta Basin (UT) | 5r | 1% | 5% | Last | 3% | 3% | d | d | Last |
| Big Horn Basin (WY) | 5L | 5% | d | d | d | d | 4L | 5L | d |
| Green River Basin (WY) | Last | Last | d | d | d | d | d | 3d | d |
| Powder River Basin (WY) | 2% | 5% | 2% | 5L | Last | d | d | d | d |
| Wind River Basin (WY) | Last | Last | d | d | 4d | Last | d | d | 4L |

[24] March 18, 2019 Northern Basins teleconference; March 19, 2019 Central Basins teleconference; March 20, 2019 Southern Basins teleconference; and March 21, 2019 Alaska Basins teleconference.

| Basin (State) | Vertical | | | Horizontal | | | Directional | | |
|---|---|---|---|---|---|---|---|---|---|
| | Well Count | Oil Prod-uction | Gas Prod-uction | Well Count | Oil Prod-uction | Gas Prod-uction | Well Count | Oil Prod-uction | Gas Prod-uction |
| **Gas Wells** | | | | | | | | | |
| Denver Basin (WY) | - | - | - | - | - | - | - | - | - |
| Sweetgrass Basin (MT) | 5L | Last | Last | d | Last | Last | d | Last | 5% |
| Williston Basin (MT,ND,SD) | a | a | a | a | a | a | a | a | a |
| Permian Basin (NM) | 5L | 3% | Last | 5L | 3L | 3L | d | d | Last |
| San Juan Basin (NM,CO) | 5L | 5% | 5L | d | Last | Last | d | 2% | 5% |
| Paradox Basin (CO,UT) | d | 5% | d | d | d | Last | d | 5% | 5% |
| Uinta Basin (UT) | 5L | 5r | 5% | d | d | d | Last | 4% | 5% |
| Big Horn Basin (WY) | 5L | d | 5% | d | 3L | 3L | d | 5% | 5% |
| Green River Basin (WY) | 5L | 3% | Last | 3% | Last | Last | 3% | d | d |
| Powder River Basin (WY) | 5L | 5% | 5% | Last | Last | d | d | 4d | 3% |
| Wind River Basin (WY) | d | 4d | 5% | d | Last | Last | d | Last | Last |
| **CBM Wells** | | | | | | | | | |
| Denver Basin (WY) | - | - | - | - | - | - | - | - | - |
| Sweetgrass Basin (MT) | d | - | d | d | - | d | d | - | d |
| Williston Basin (MT,ND,SD) | a | a | a | a | a | a | a | a | a |
| Permian Basin (NM) | - | - | - | - | - | - | - | - | - |
| San Juan Basin (NM,CO) | 5L | - | 5% | 5L | - | d | 5L | - | 5% |
| Paradox Basin (CO,UT) | d | - | Last | d | - | Last | d | - | 5L |
| Uinta Basin (UT) | d | - | 5% | d | - | d | d | - | 3% |
| Big Horn Basin (WY) | - | - | - | - | - | - | - | - | - |
| Green River Basin (WY) | 3% | - | Last | d | - | d | d | - | Last |
| Powder River Basin (WY) | 3% | - | 1% | d | - | Last | d | - | Last |
| Wind River Basin (WY) | Last | - | d | d | - | d | d | - | Last |

[a] Williston Basin activity in North Dakota was based on North Dakota Industrial Commission forecasts (https://www.dmr.nd.gov/oilgas/presentations/HouseEnergyNaturalResources011019_25.pdf, https://www.dmr.nd.gov/oilgas/presentations/APIWilliston040219.pdf). Williston Basin O&G activity in Montana and South Dakota was assumed unchanged from the base year based on limited recent drilling and recent activity declines.

**Table 3. Summary of Spud Count Forecast Methods by Basin**

| Basin (State) | Vertical | Horizontal | Directional |
|---|---|---|---|
| **Spud Count** | | | |
| Denver Basin (WY) | - | d | - |
| Sweetgrass Basin (MT) | d | d | d |
| Williston Basin (MT,ND,SD) | [a] | | |
| Permian Basin (NM) | Last | d | 3d |
| San Juan Basin (NM,CO) | 3d | Last | Last |
| Paradox Basin (CO,UT) | Last | Last | d |
| Uinta Basin (UT) | Last | Last | Last |
| Big Horn Basin (WY) | d | d | d |
| Green River Basin (WY) | Last | Last | 3d |
| Powder River Basin (WY) | Last | 3d | Last |
| Wind River Basin (WY) | 3d | d | d |

[a] Williston Basin activity in North Dakota was based on North Dakota Industrial Commission forecasts (https://www.dmr.nd.gov/oilgas/presentations/APIWilliston040219.pdf). Williston Basin O&G activity in Montana and South Dakota was assumed unchanged from the base year based on limited recent drilling and recent activity declines with the exception of Williston Basin spudding activity in Montana which was estimated to remain at 2017 levels which were substantially lower than the spudding activity in base year 2014.

To illustrate the forecast methodology, Permian Basin methods and charts are included below with descriptions of forecasts by parameter, spud type, and well type for the most important parameters (forecast methods for all parameters may be found in Tables 2 and 3 above).

- **Spud Count (Figure 1):** Horizontal spud count was estimated as the average spudding activity over the five-year 2013-2017 period (5d).
- **Primary Gas Production (Figure 2):** Primary gas production from vertical wells was assumed to remain at 2017 levels. Primary gas production from horizontal wells was assumed to increase based on the linear trend over the three-year 2015-2017 period.
- **Associated Gas Production (Figure 3):** Continued increase in associated gas production from horizontal wells was estimated based on a five-year 2013-2017 linear forecast (5L).
- **Condensate Production (Figure 4):** Continued steady increase in condensate production from horizontal wells based on application of a 2015-2017 three-year linear forecast (3L).
- **Oil Production (Figure 5):** Continued steady increase in oil production from horizontal wells based on application of a 2014-2017 four-year linear forecast (4L).
- **Gas Well Count (Figure 6):** Continued steady decline in vertical gas well counts based on application of a five-year 2013-2017 linear forecast (5L). Continued steady increase in horizontal gas well counts based on application of five-year 2013-2017 linear forecast (5L).
- **Oil Well Count (Figure 7):** Continued increases in horizontal oil well counts based on a five-year 2013-2017 linear forecast (5L). Continued steady decline in vertical oil well counts based on application of a five-year 2013-2017 linear forecast (5L).

Figures 8 through 51 below show historical trends and forecast O&G activity for each basin and parameter (spud count, well count, gas production, and oil production) by spud type (vertical, horizontal, and directional).

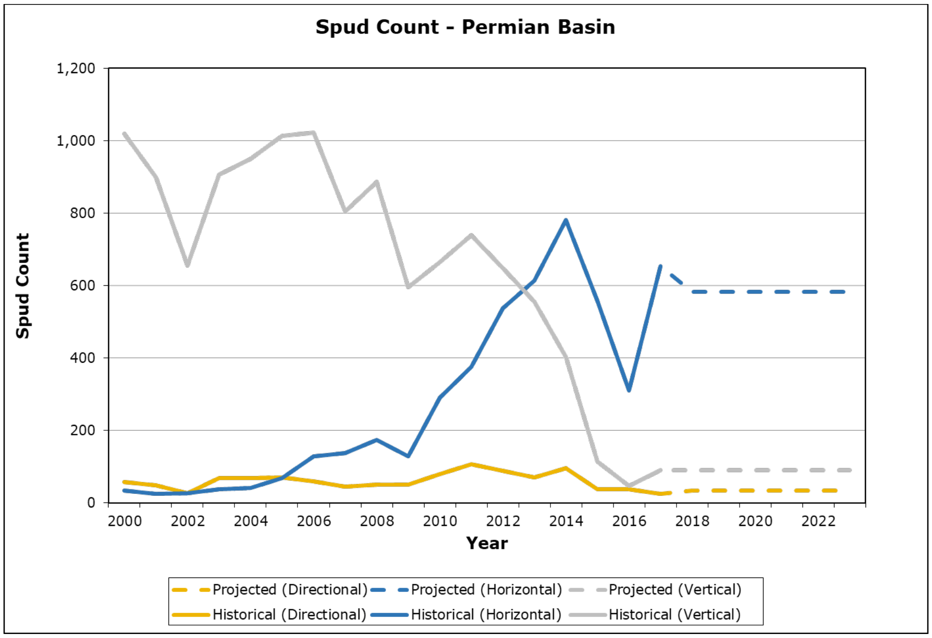


**Figure 1. Permian Basin - Spud Count**

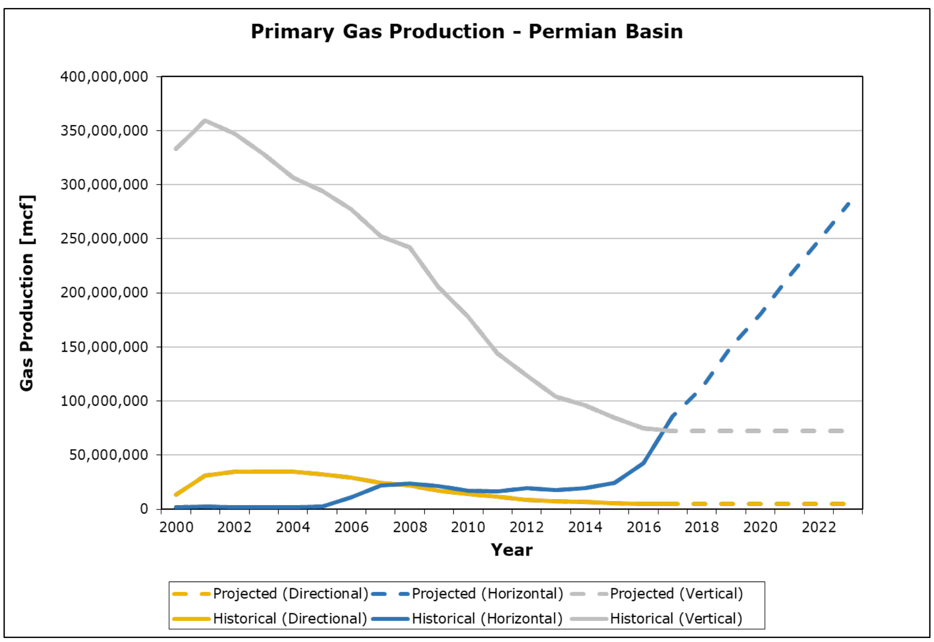


**Figure 2. Permian Basin - Primary Gas Production**

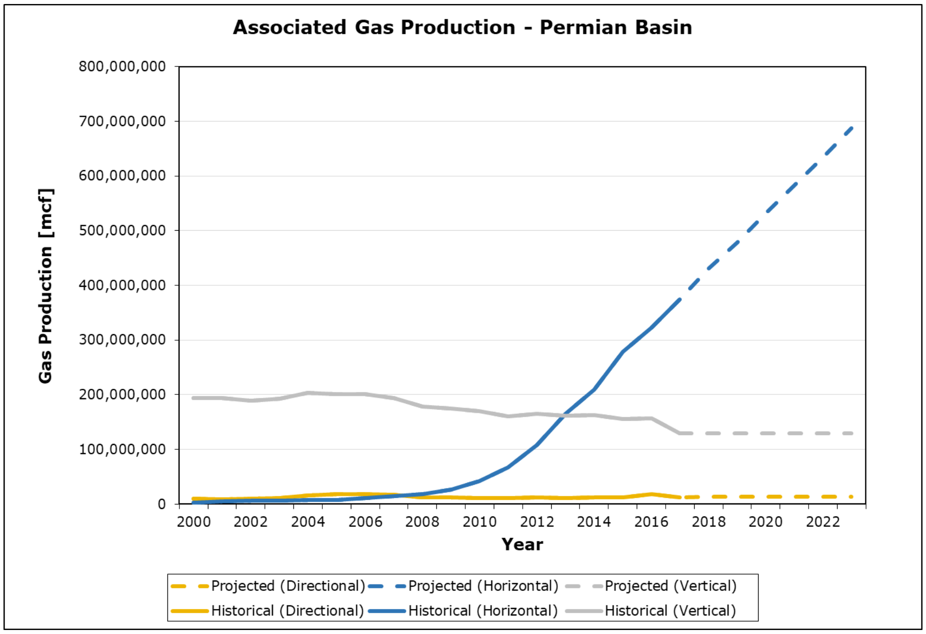


**Figure 3. Permian Basin - Associated Gas Production**

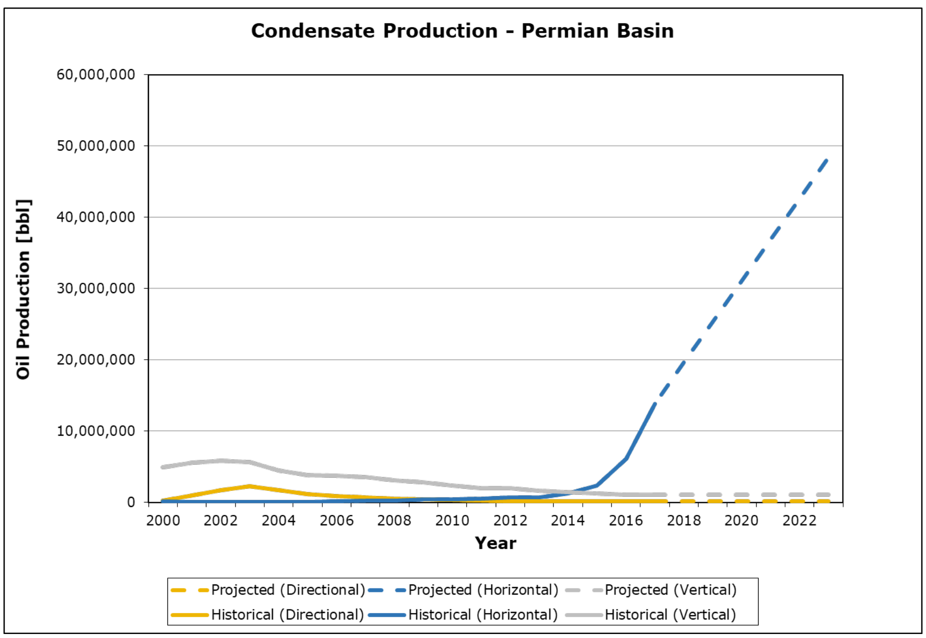


**Figure 4. Permian Basin – Condensate Production**

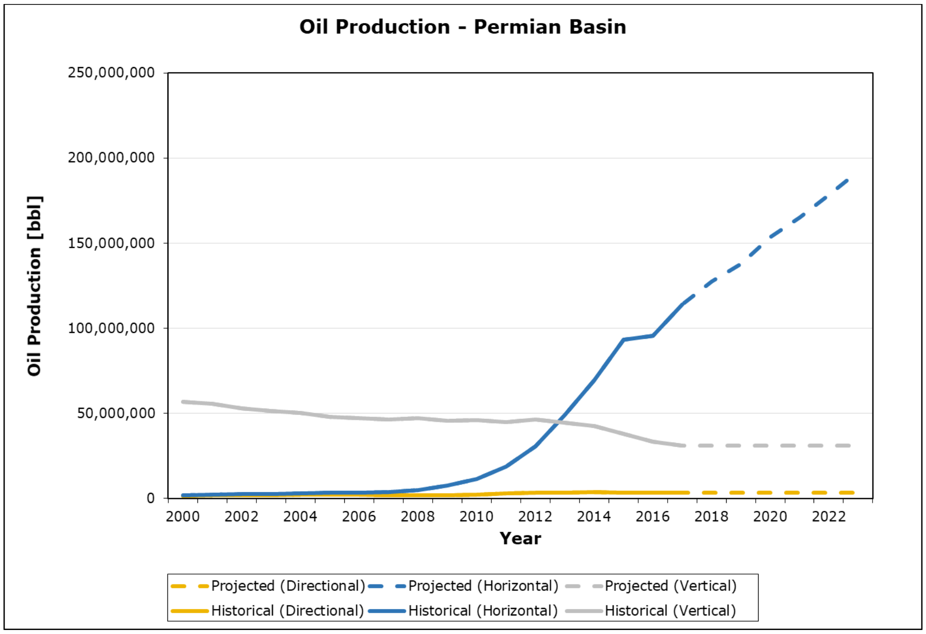


**Figure 5. Permian Basin – Oil Production**

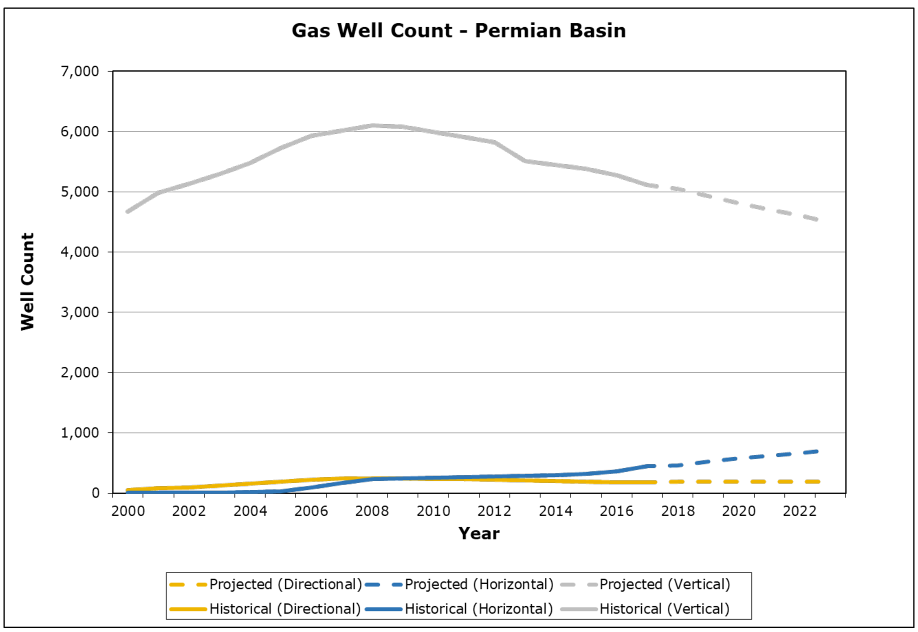


**Figure 6. Permian Basin – Gas Well Count**

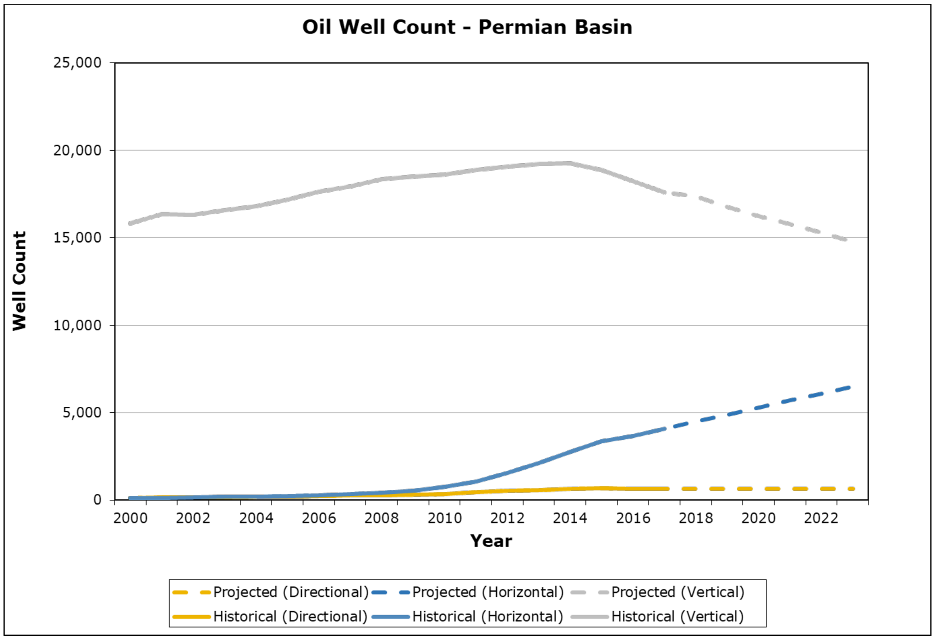


**Figure 7. Permian Basin – Oil Well Count**

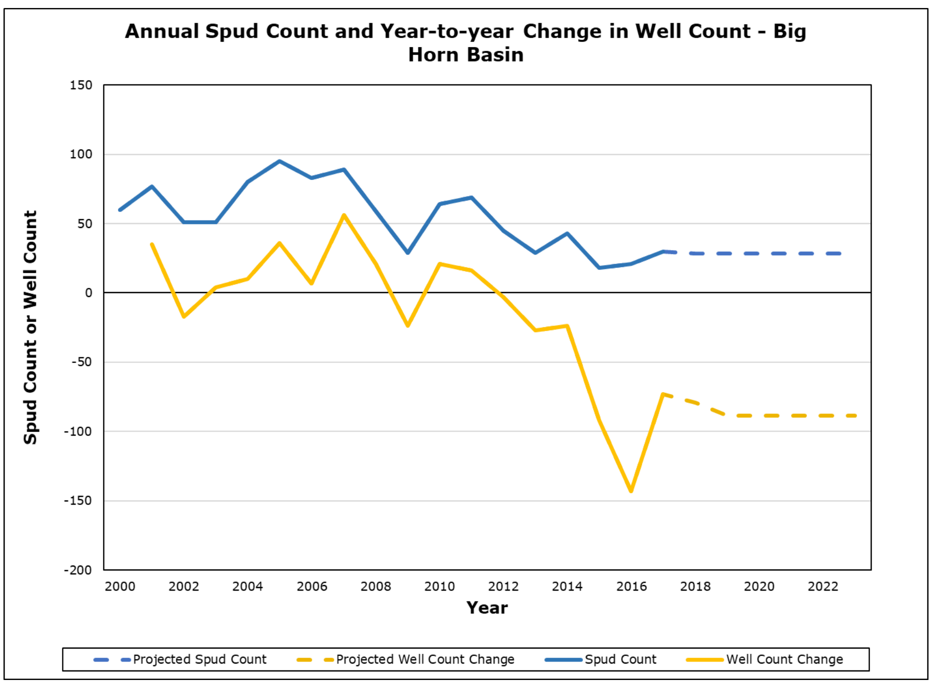


**Figure 8. Big Horn Basin - Annual Spud Count and Year-Over-Year Change in Well Count**

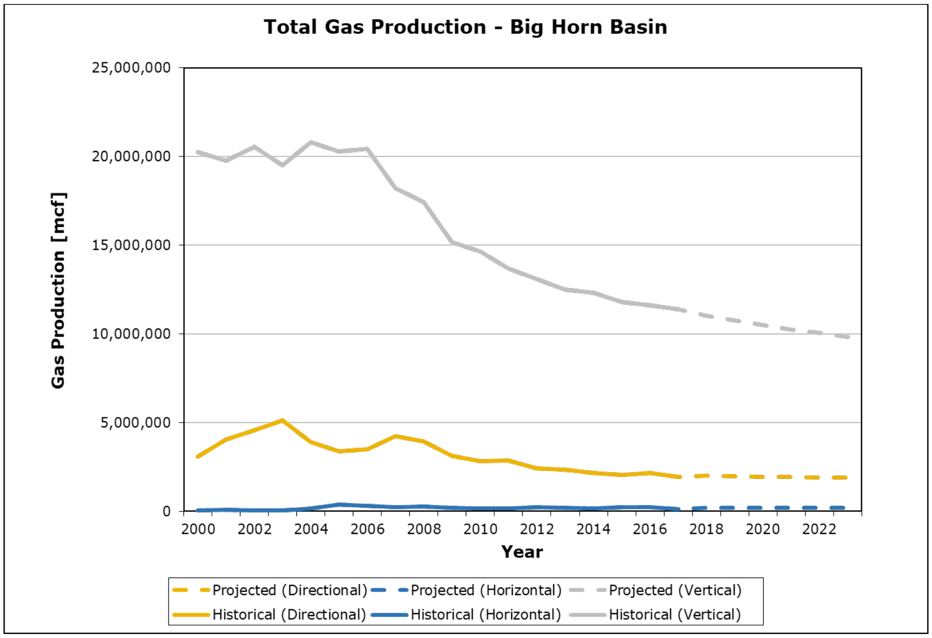


**Figure 9. Big Horn Basin - Total Gas Production**

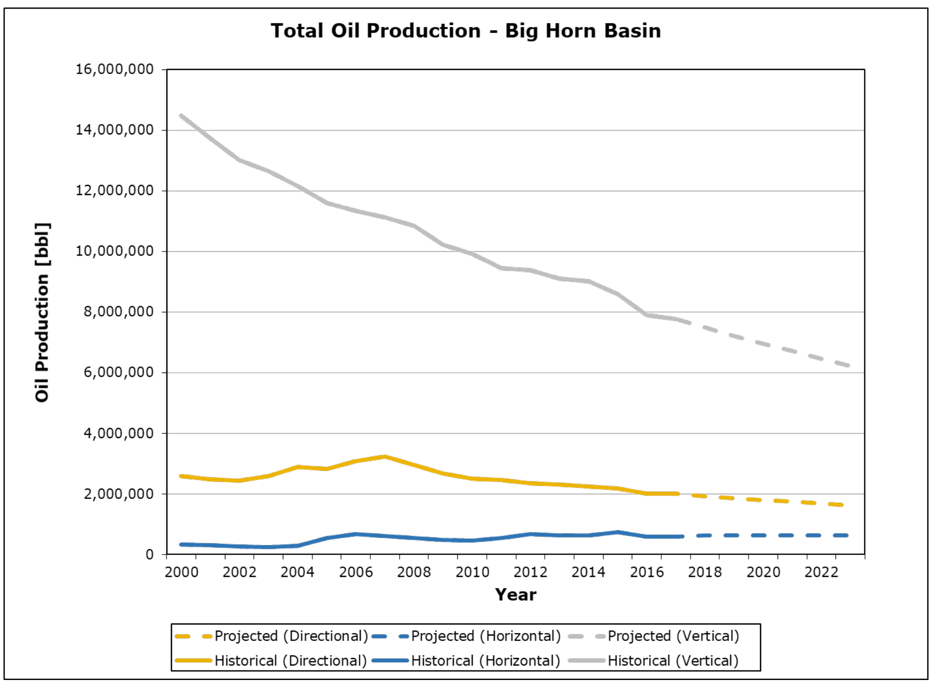


**Figure 10. Big Horn Basin - Total Oil Production**

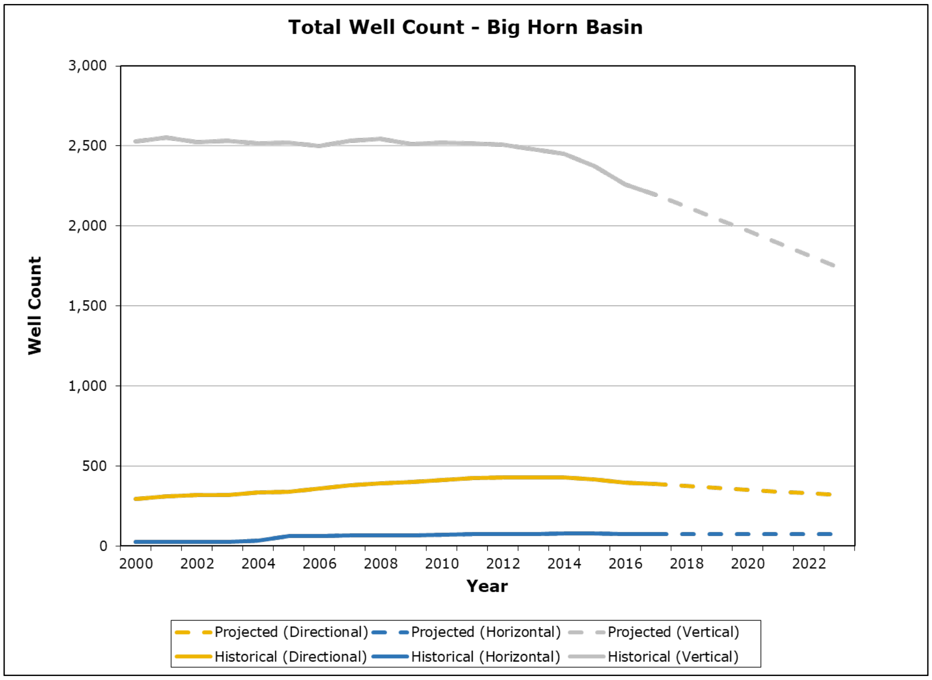


**Figure 11. Big Horn Basin - Total Well Count**

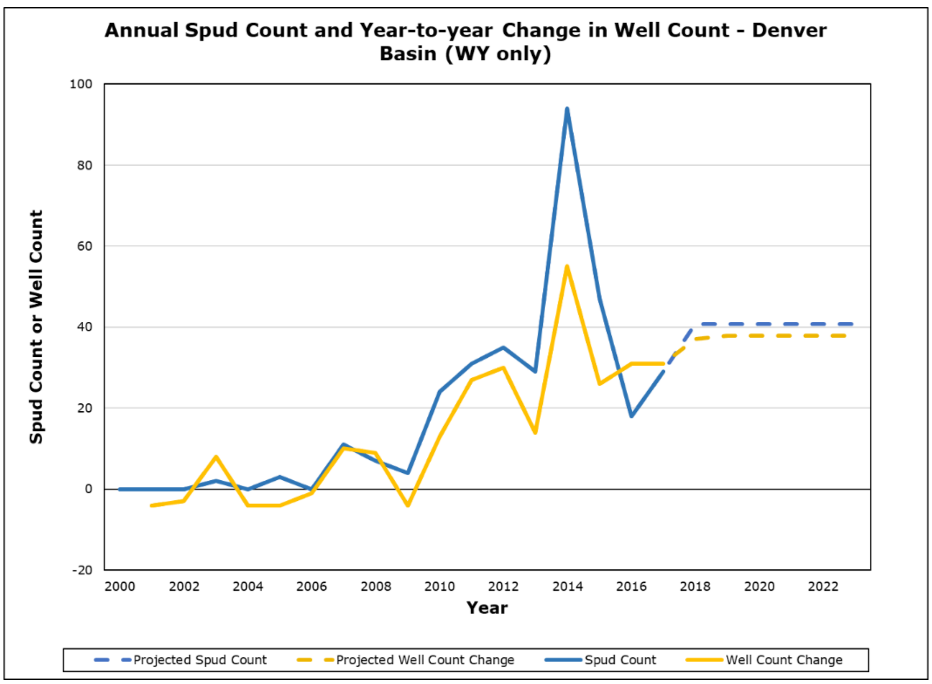


**Figure 12. Denver Basin (Wyoming only) - Annual Spud Count and Year-Over-Year Change in Well Count**

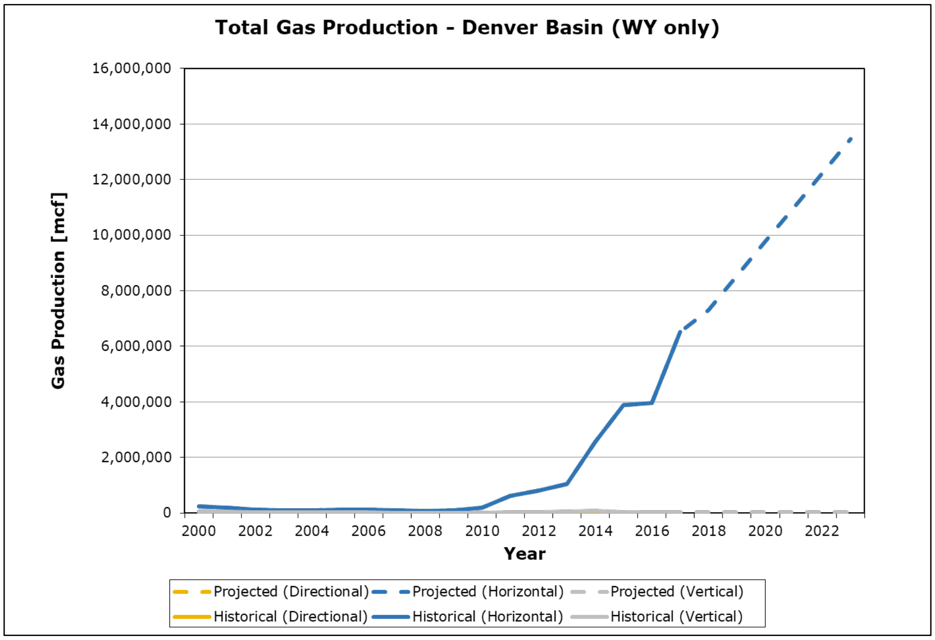


**Figure 13. Denver Basin (Wyoming only) - Total Gas Production**

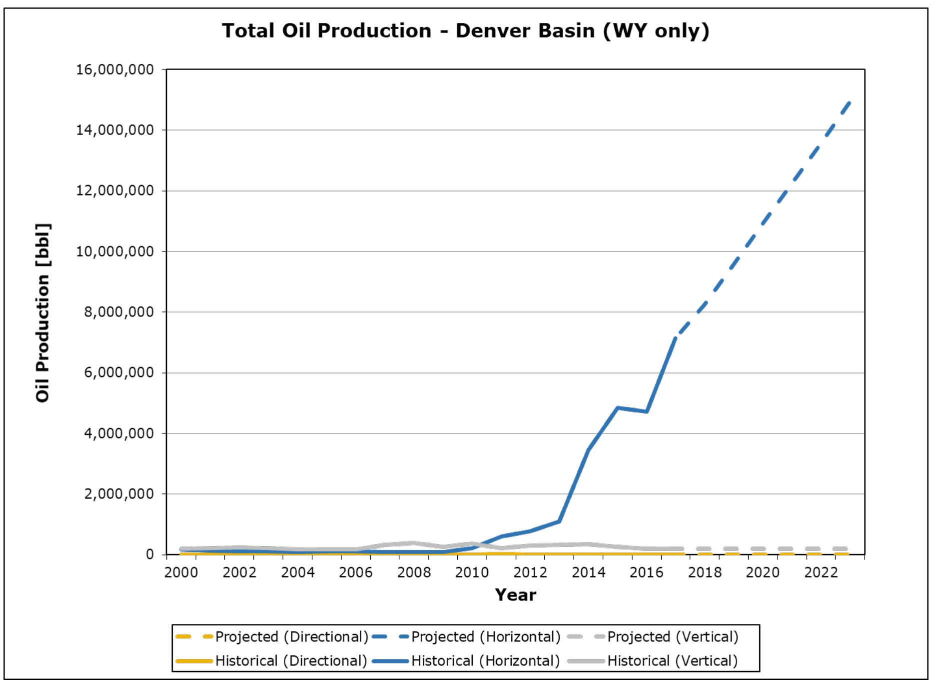


**Figure 14. Denver Basin (Wyoming only) - Total Oil Production**

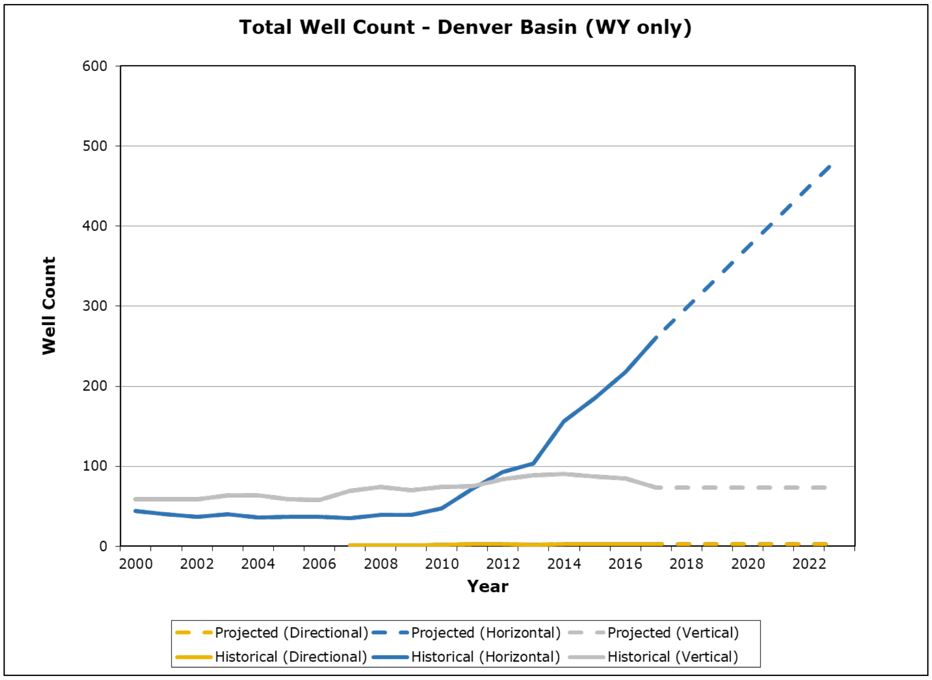


**Figure 15. Denver Basin (Wyoming only) - Total Well Count**

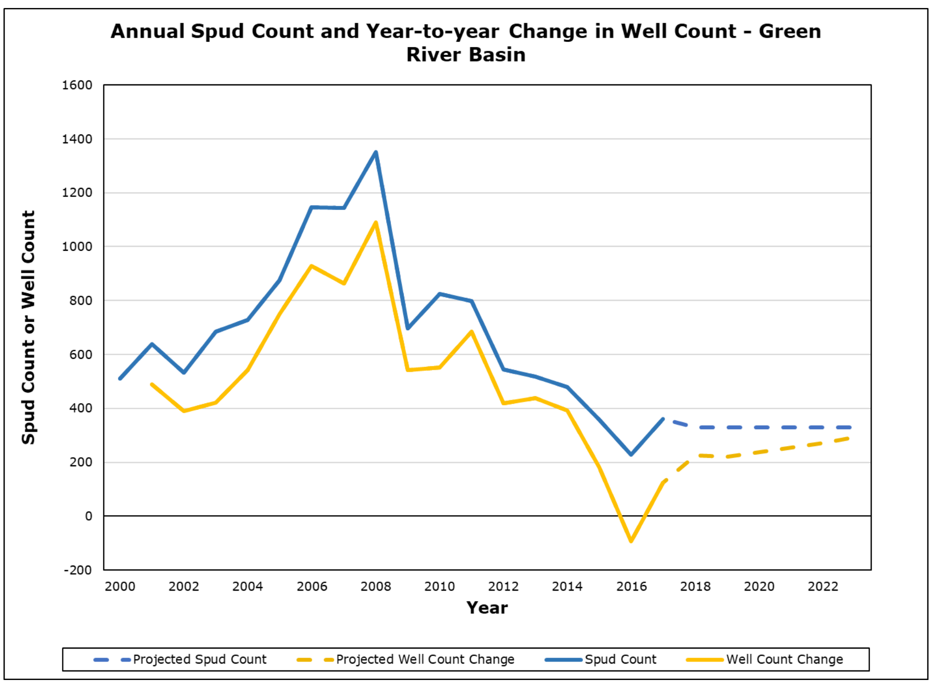


**Figure 16. Green River Basin - Annual Spud Count and Year-Over-Year Change in Well Count**

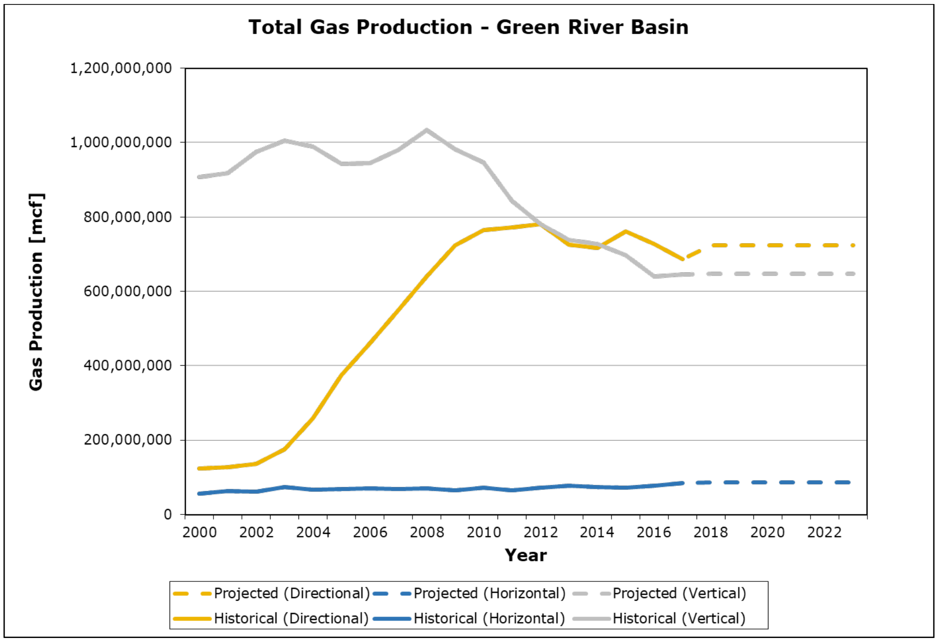


**Figure 17. Green River Basin - Total Gas Production**

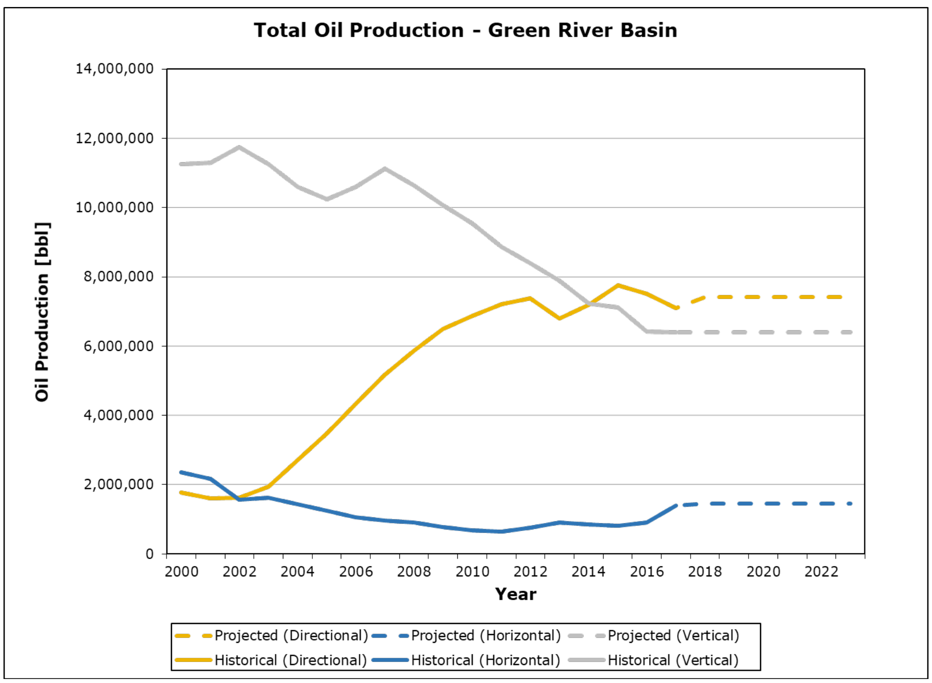


**Figure 18. Green River Basin - Total Oil Production**

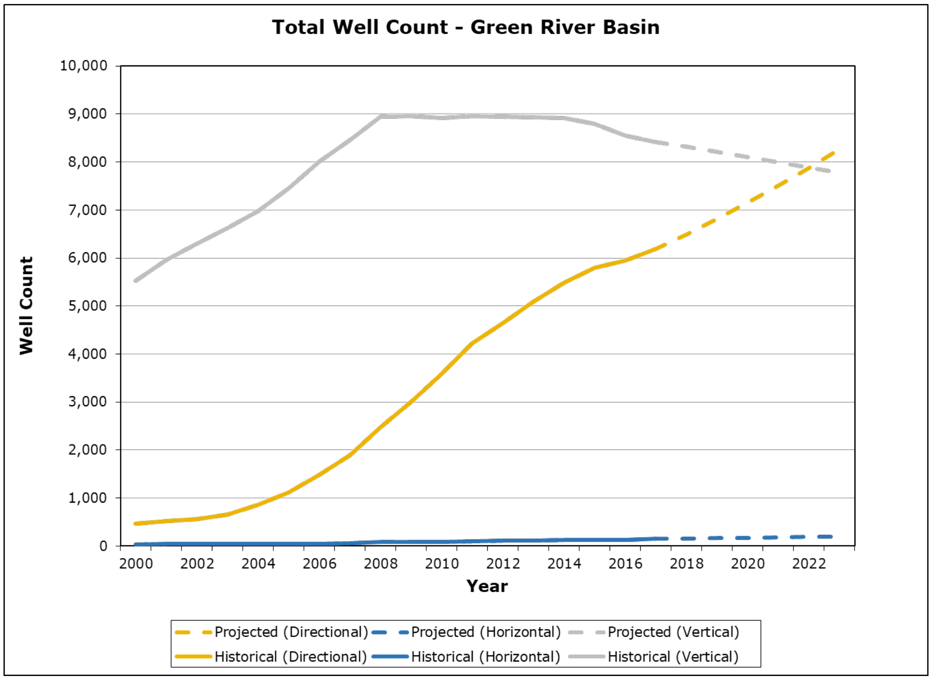


**Figure 19. Green River Basin - Total Well Count**

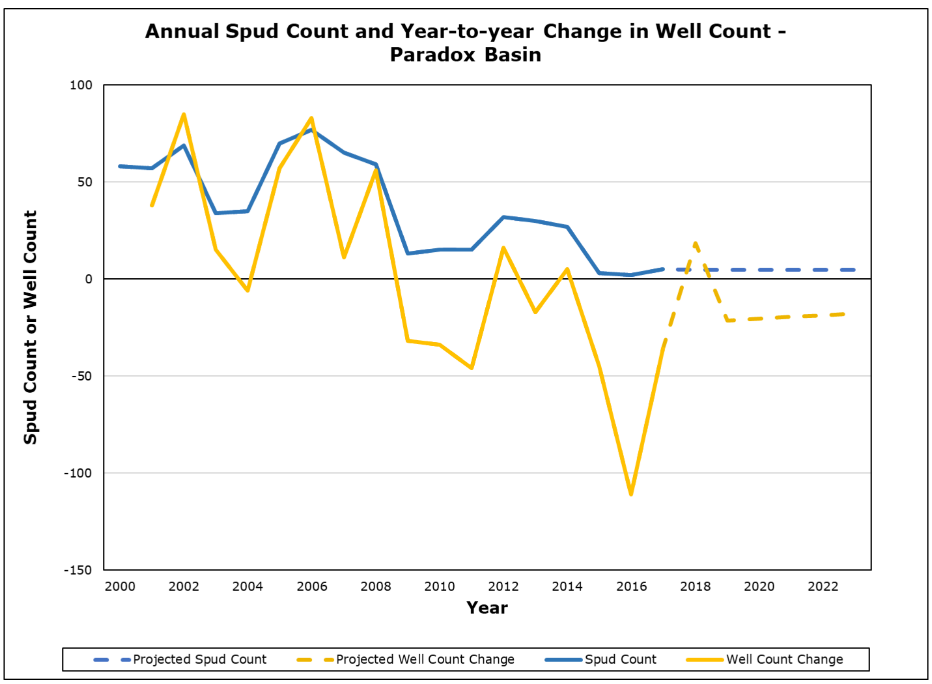


**Figure 20. Paradox Basin - Annual Spud Count and Year-Over-Year Change in Well Count**

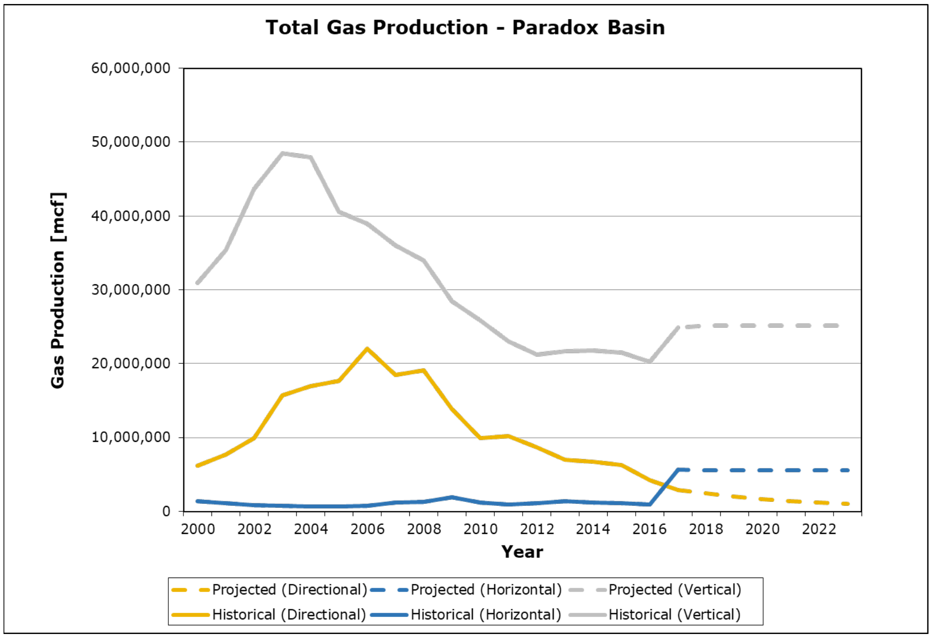


**Figure 21. Paradox Basin - Total Gas Production**

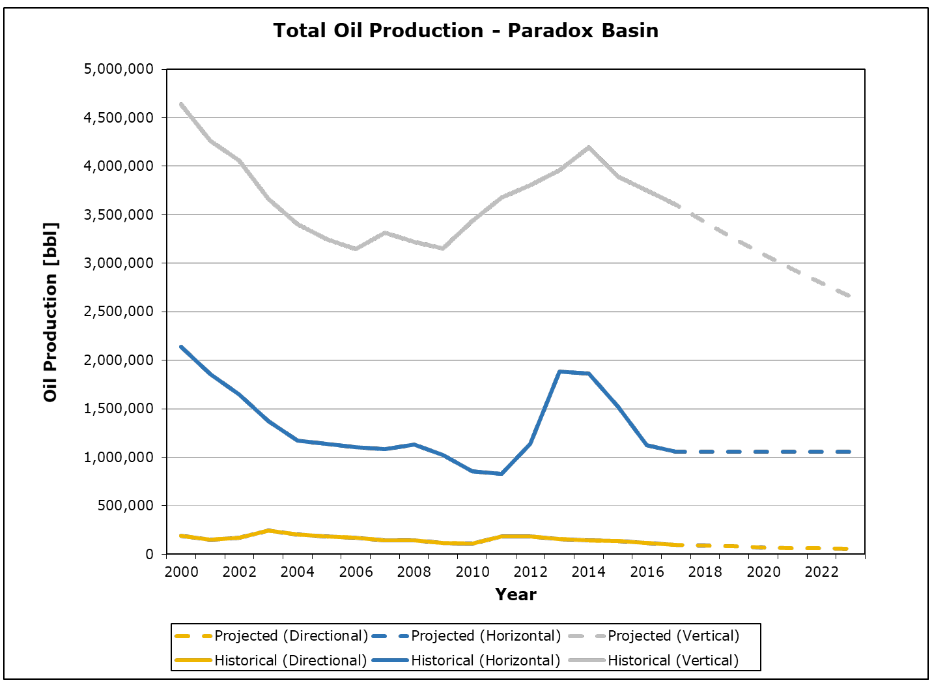


**Figure 22. Paradox Basin - Total Oil Production**

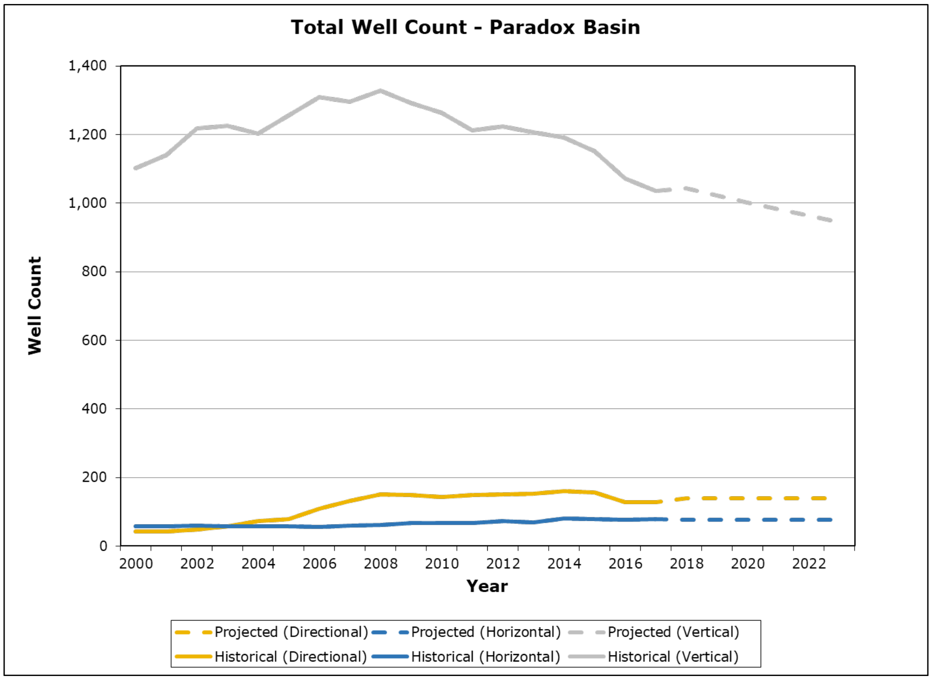


**Figure 23. Paradox Basin - Total Well Count**

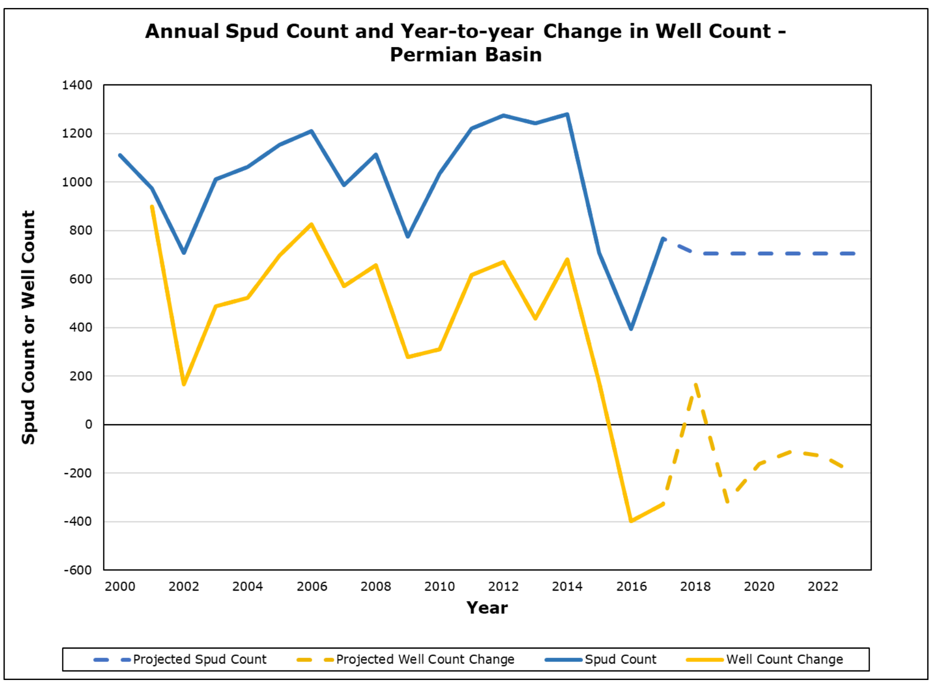


**Figure 24. Permian Basin - Annual Spud Count and Year-Over-Year Change in Well Count**

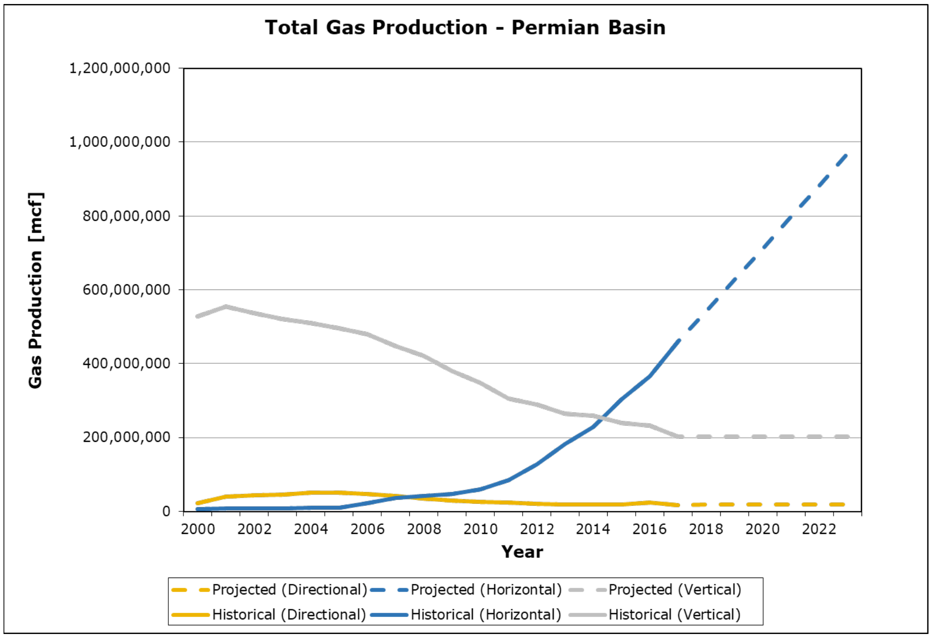


**Figure 25. Permian Basin - Total Gas Production**

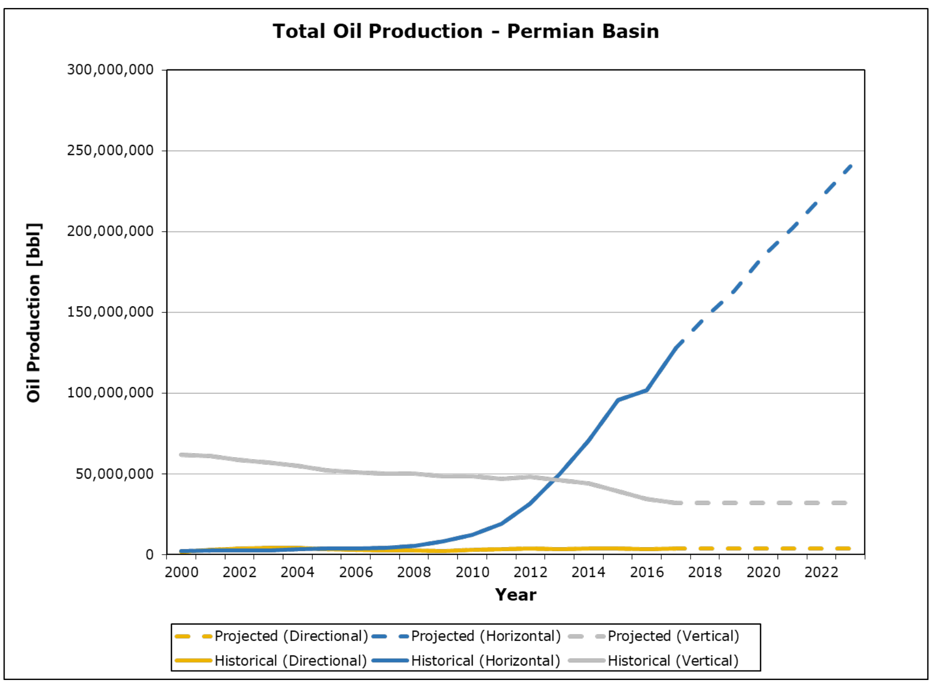


**Figure 26. Permian Basin - Total Oil Production**

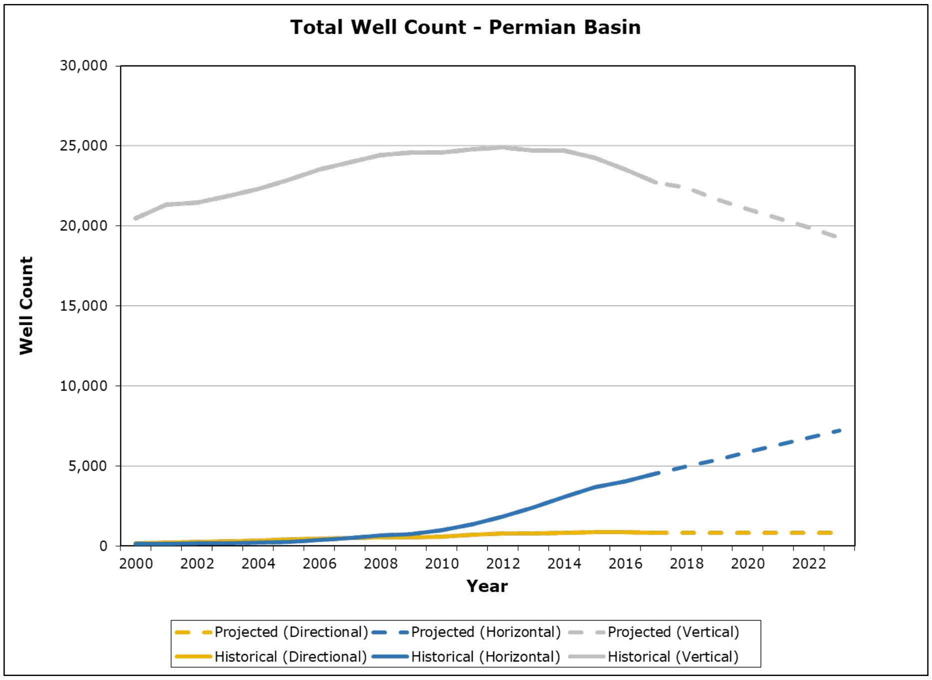


**Figure 27. Permian Basin - Total Well Count**

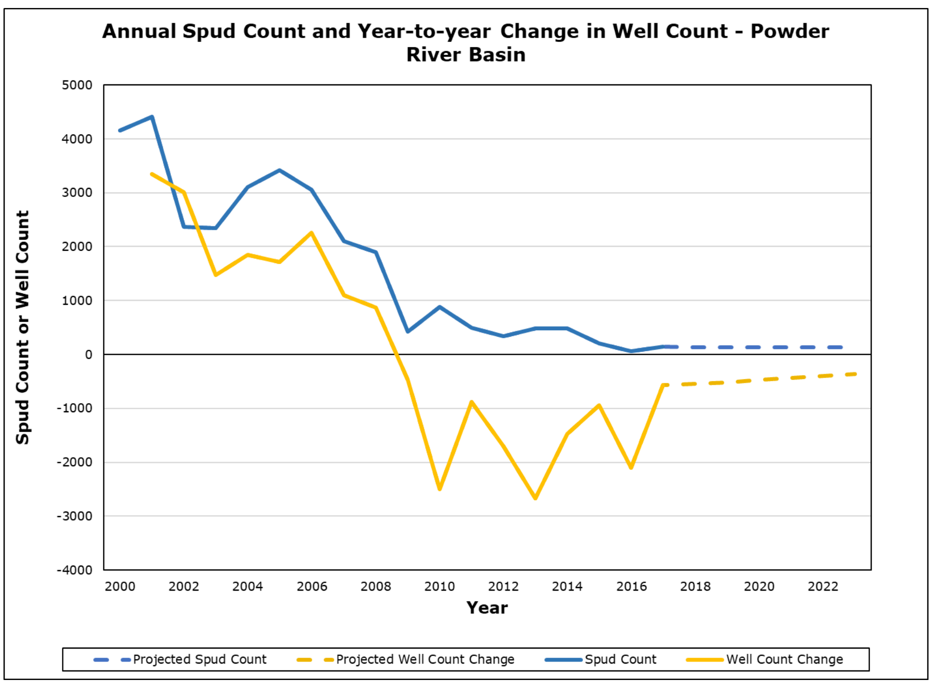


**Figure 28. Powder River Basin - Annual Spud Count and Year-Over-Year Change in Well Count**

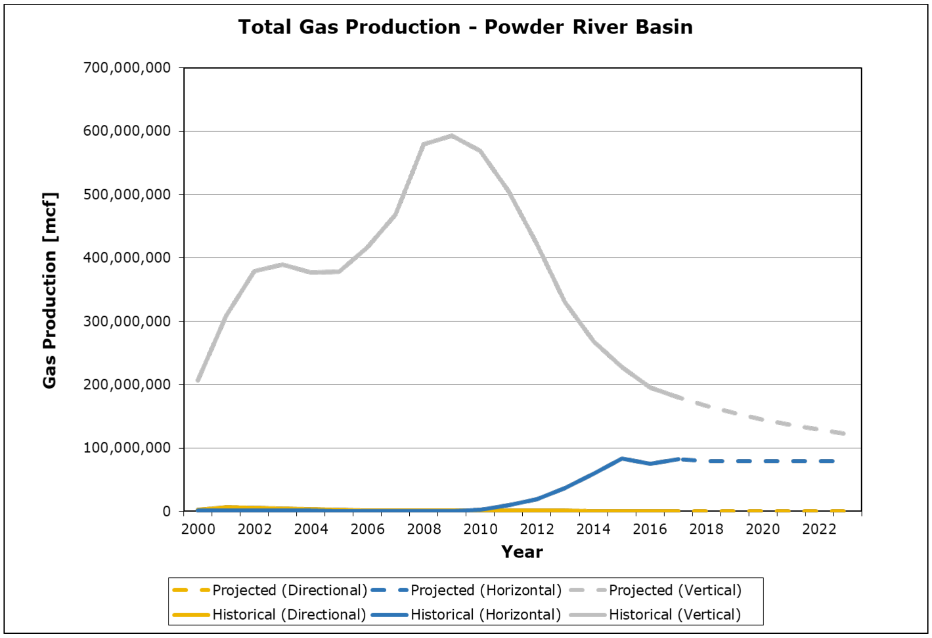


**Figure 29. Powder River Basin - Total Gas Production**

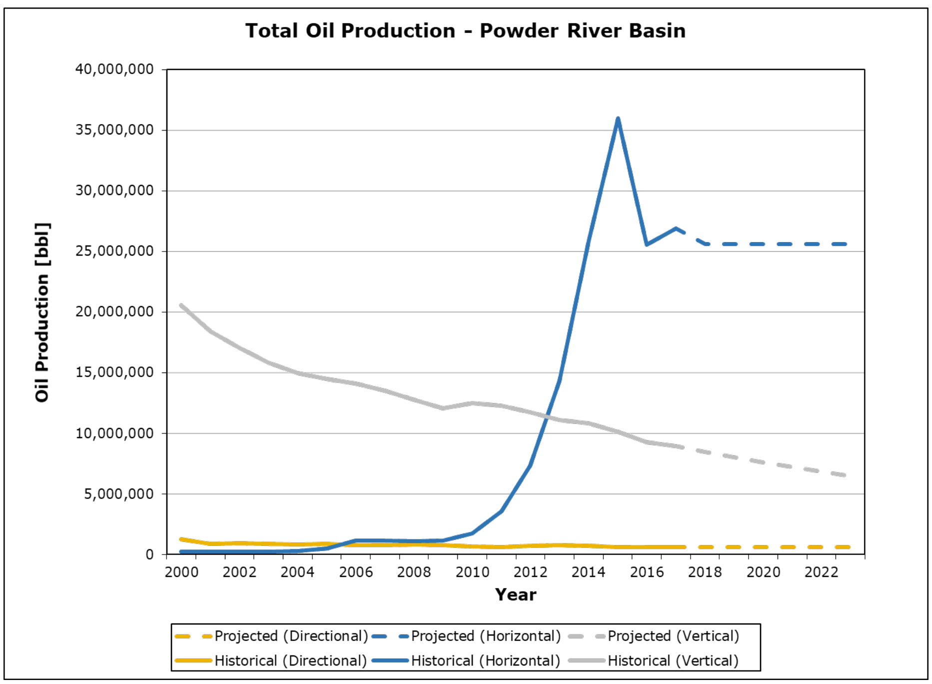


**Figure 30. Powder River Basin - Total Oil Production**

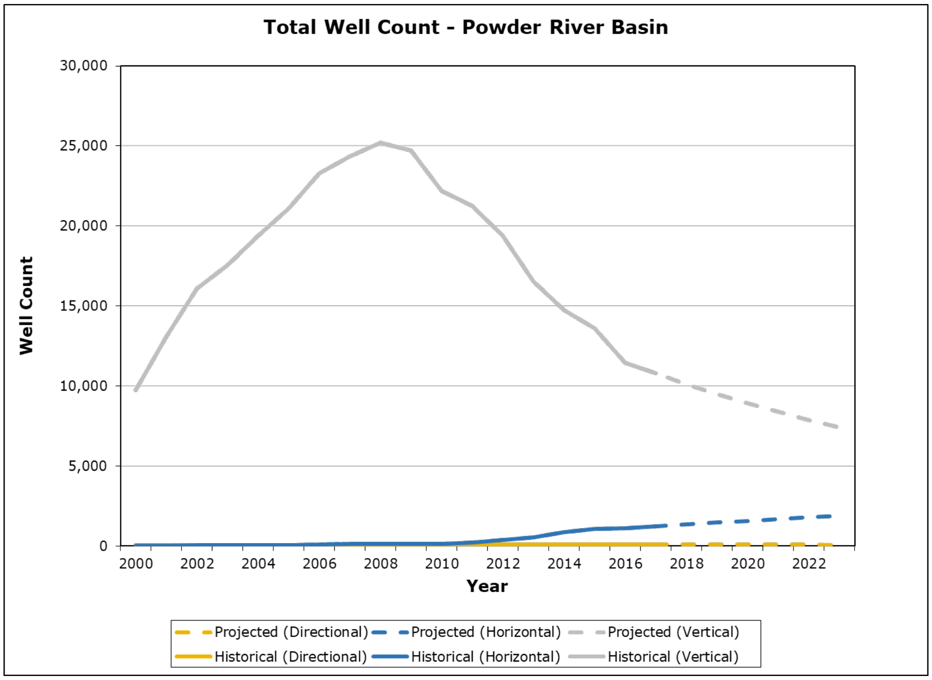


**Figure 31. Powder River Basin - Total Well Count**

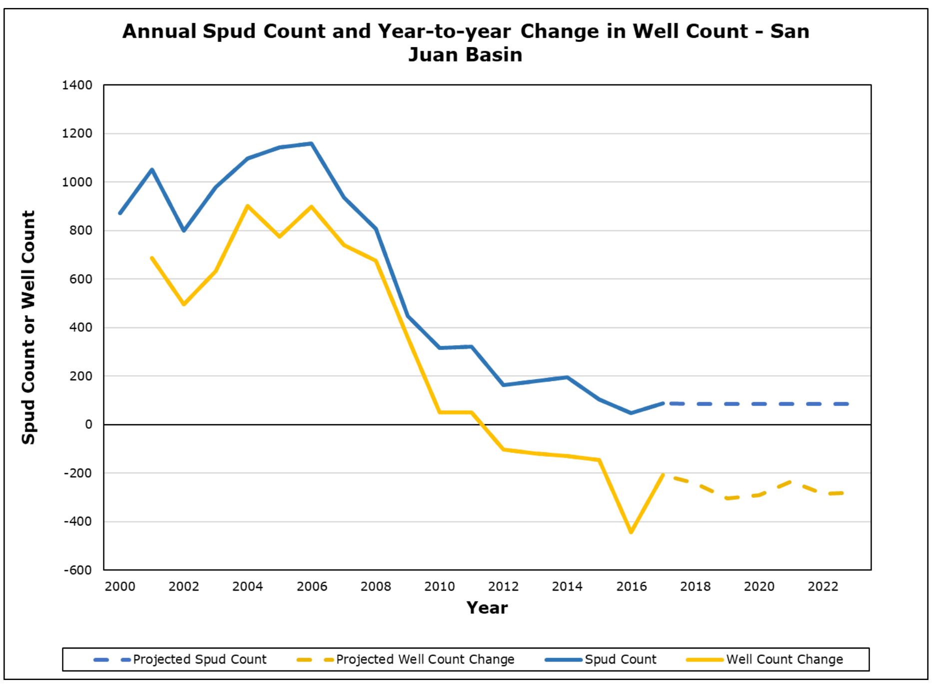


**Figure 32. San Juan Basin - Annual Spud Count and Year-Over-Year Change in Well Count**

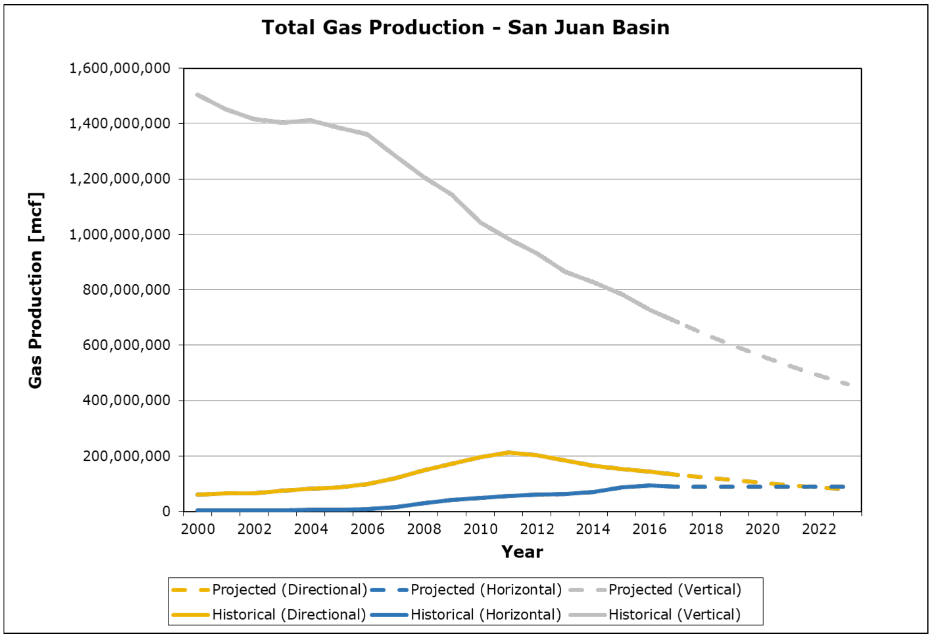


**Figure 33. San Juan Basin - Total Gas Production**

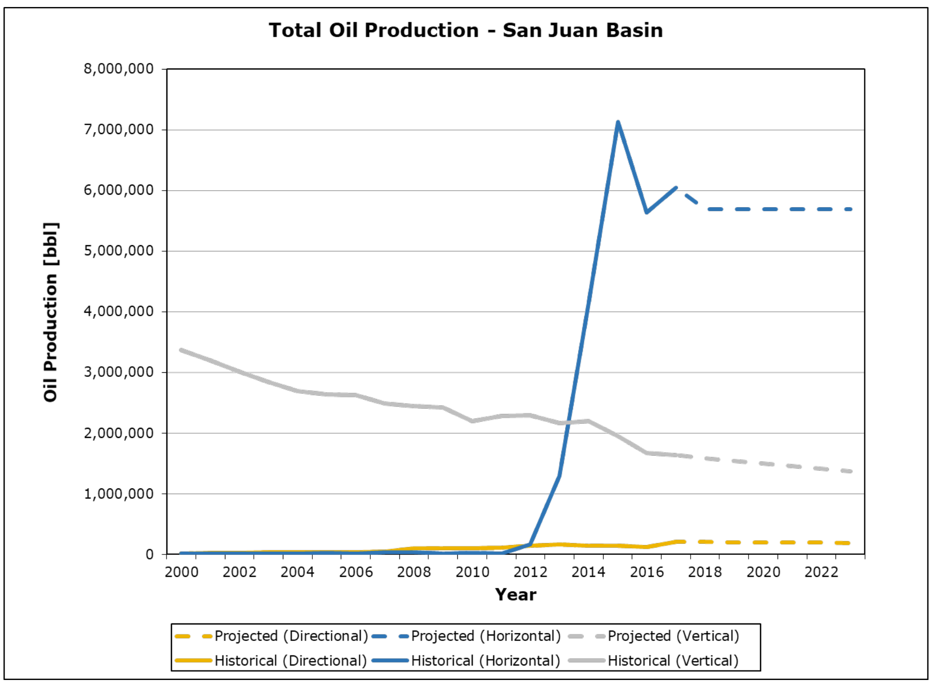


**Figure 34. San Juan Basin - Total Oil Production**

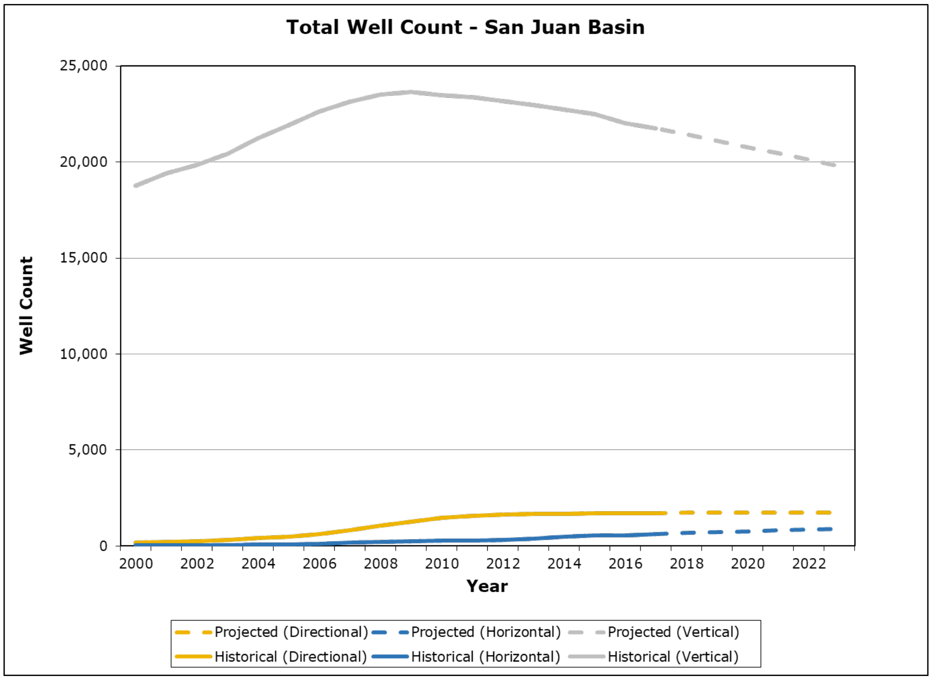


**Figure 35. San Juan Basin - Total Well Count**

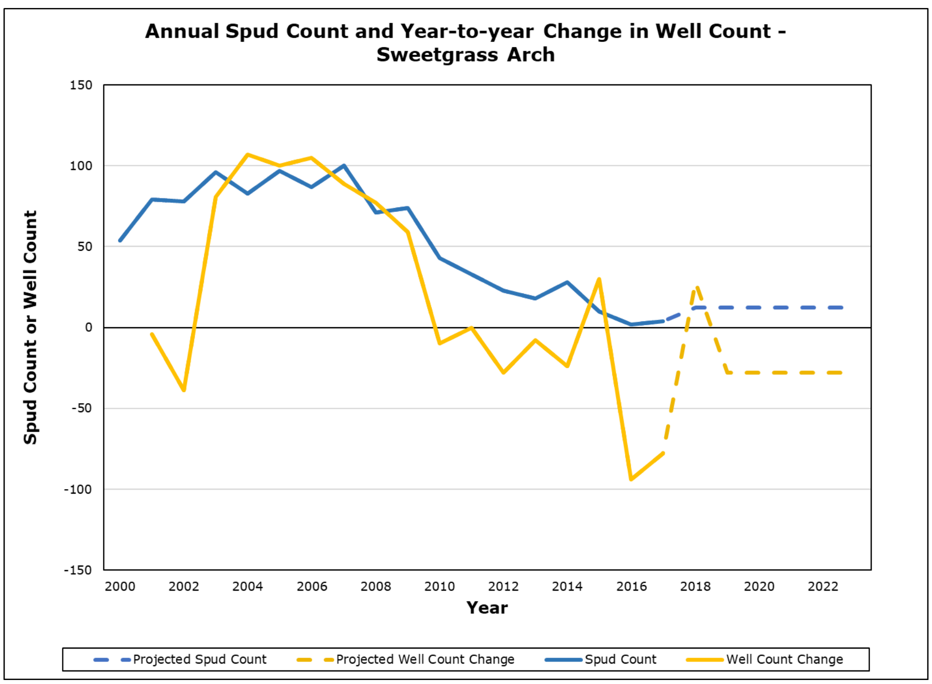


**Figure 36. Sweetgrass Basin - Annual Spud Count and Year-Over-Year Change in Well Count**

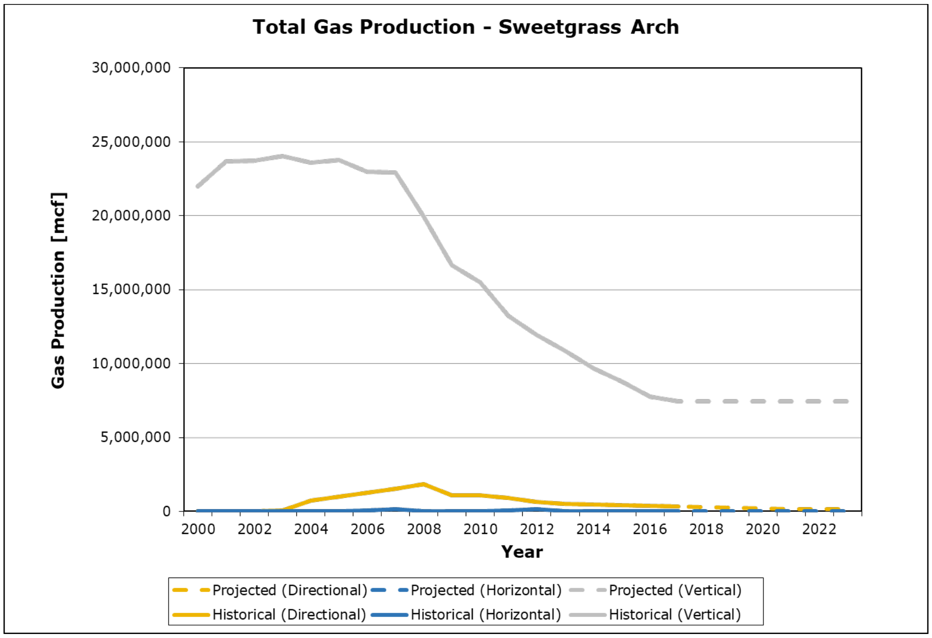


**Figure 37. Sweetgrass Basin - Total Gas Production**

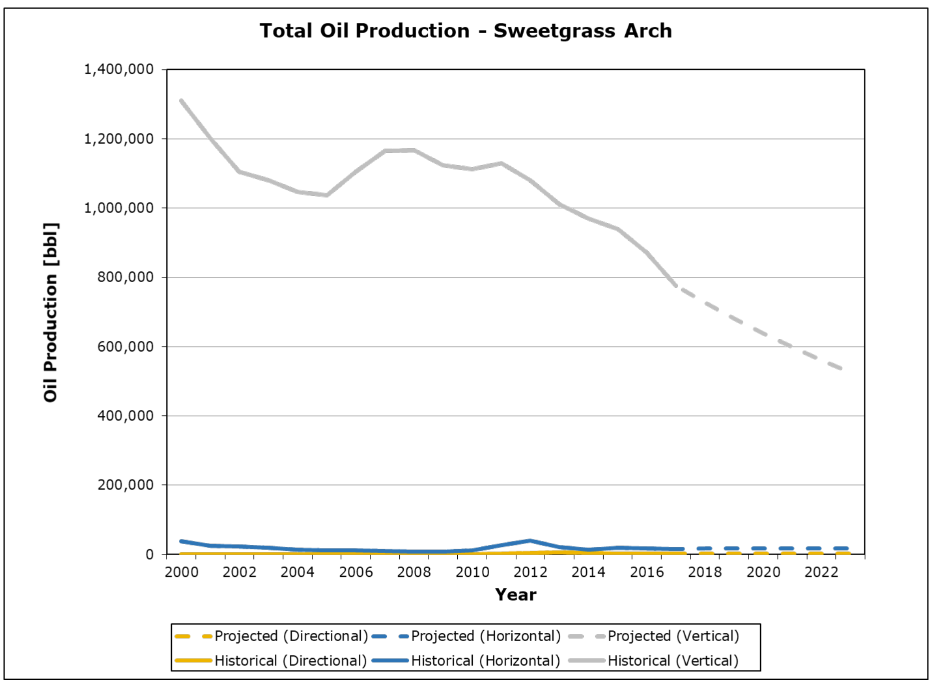


**Figure 38. Sweetgrass Basin - Total Oil Production**

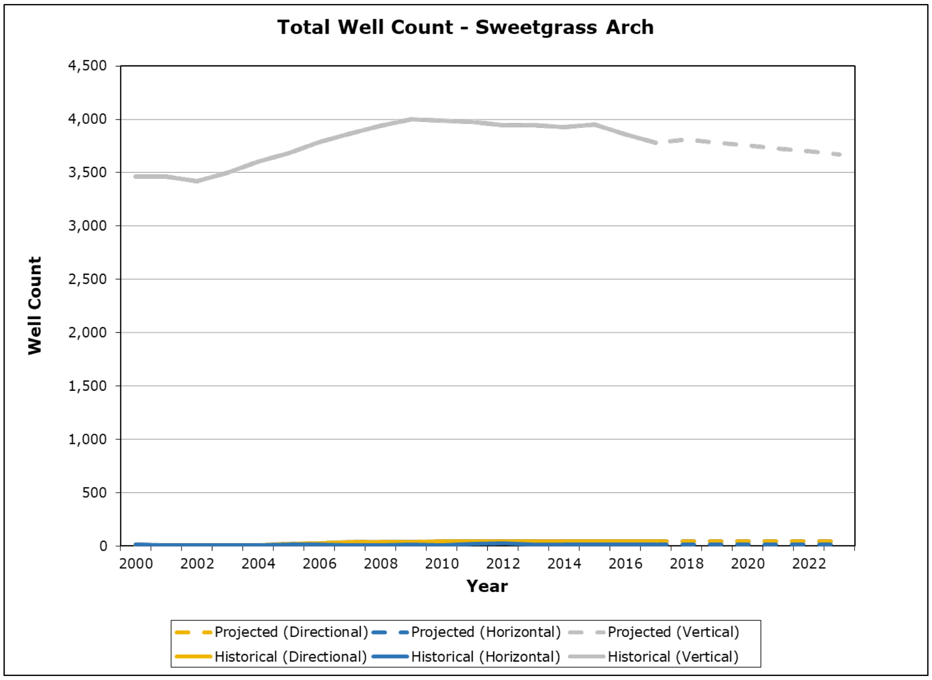


**Figure 39. Sweetgrass Basin - Total Well Count**

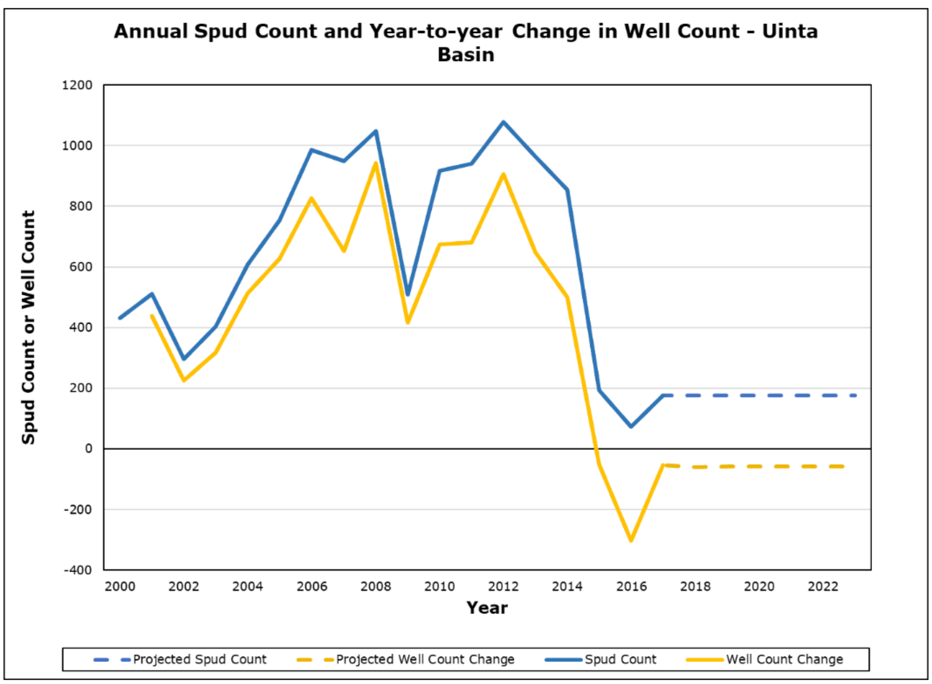


**Figure 40. Uinta Basin - Annual Spud Count and Year-Over-Year Change in Well Count**

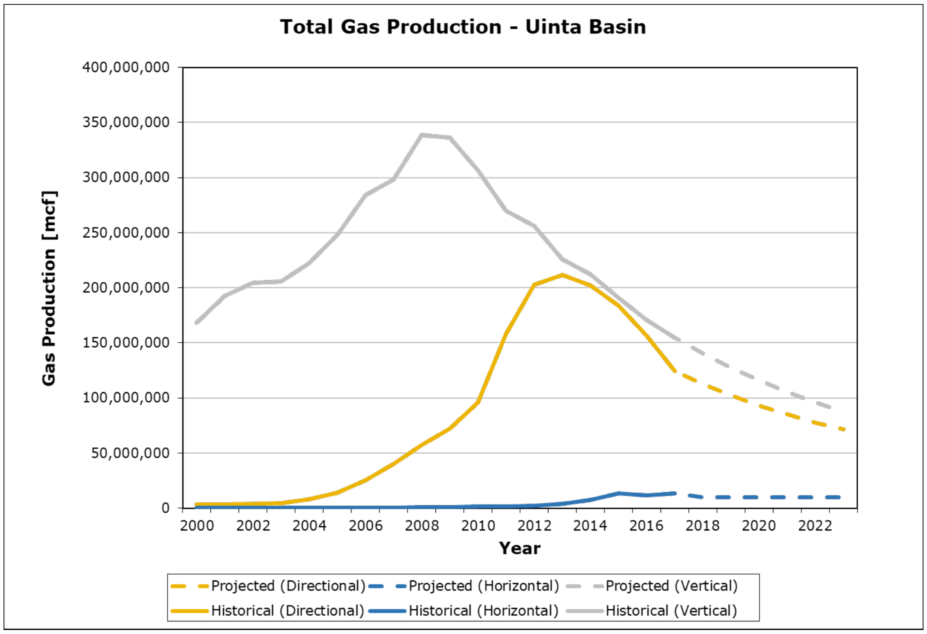


**Figure 41. Uinta Basin - Total Gas Production**

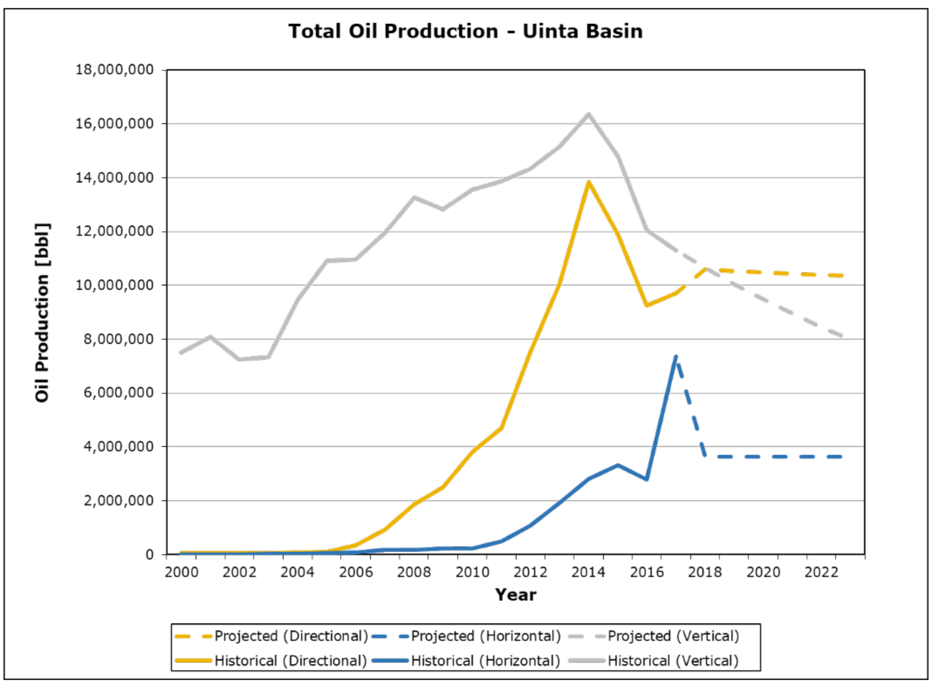


**Figure 42. Uinta Basin - Total Oil Production**

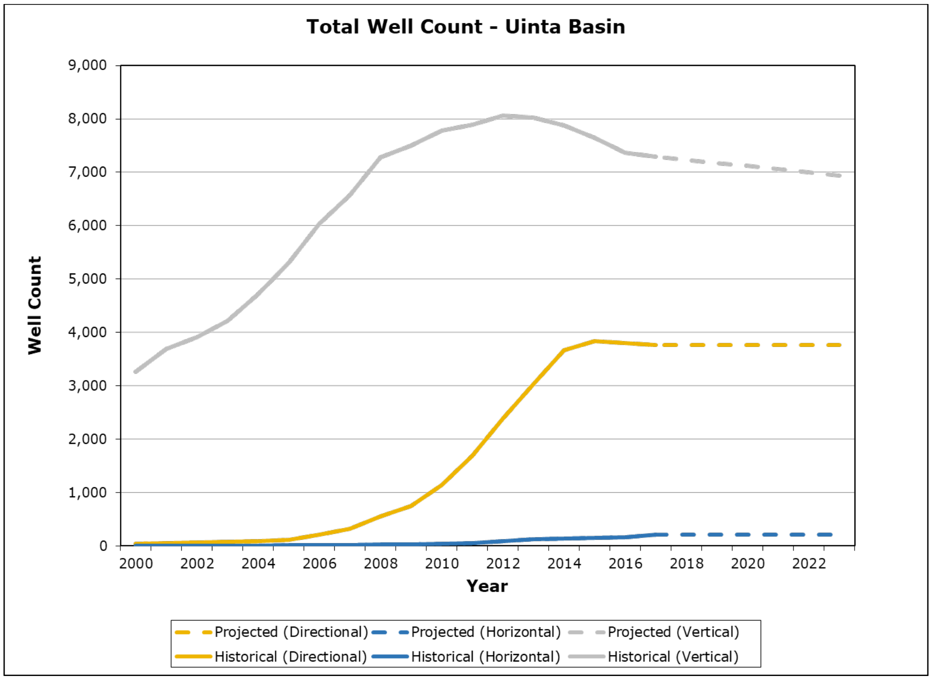


**Figure 43. Uinta Basin - Total Well Count**

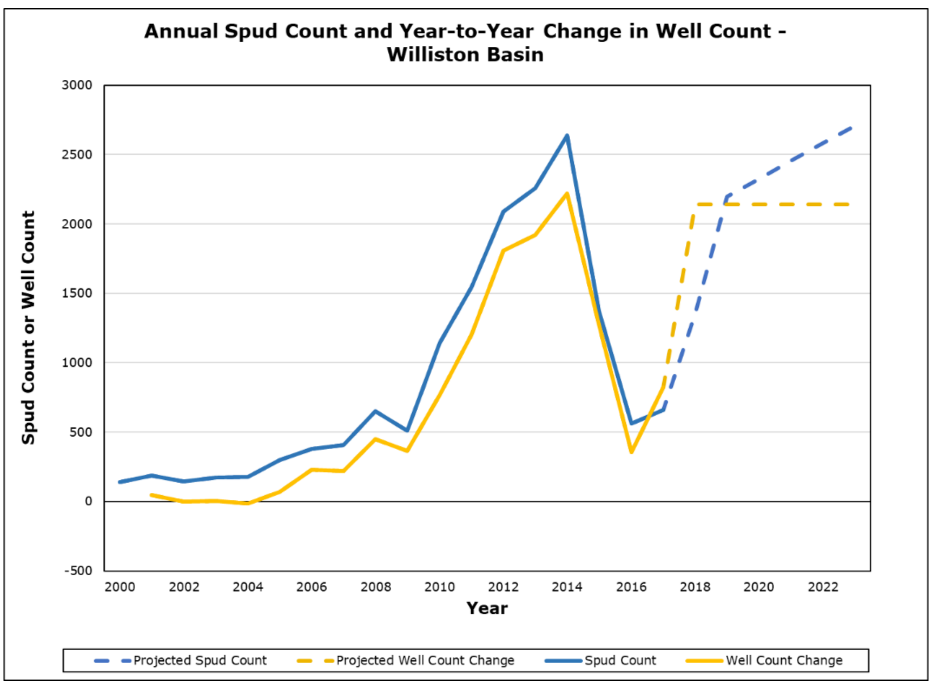


**Figure 44. Williston Basin - Annual Spud Count and Year-Over-Year Change in Well Count**

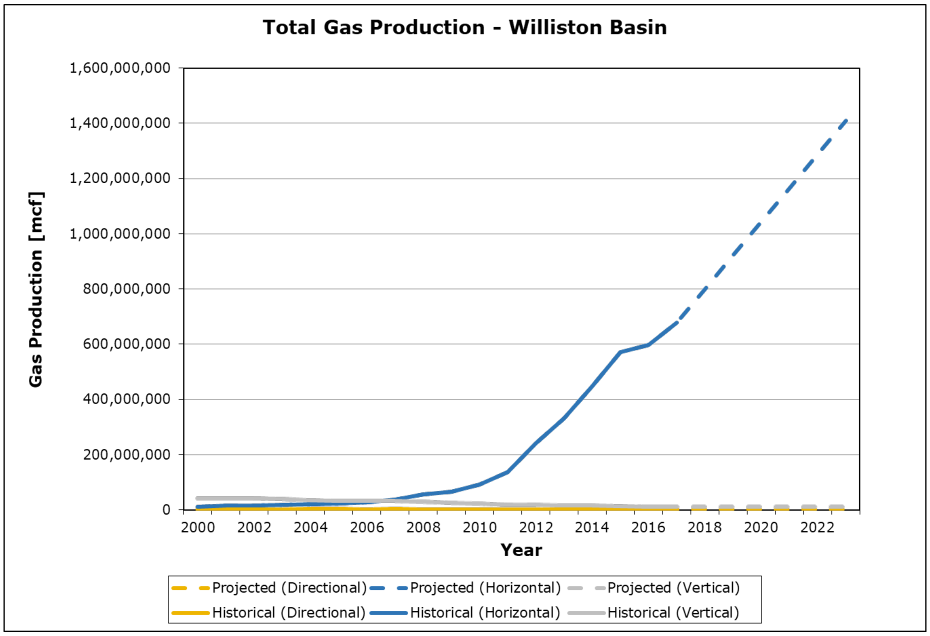


**Figure 45. Williston Basin - Total Gas Production**

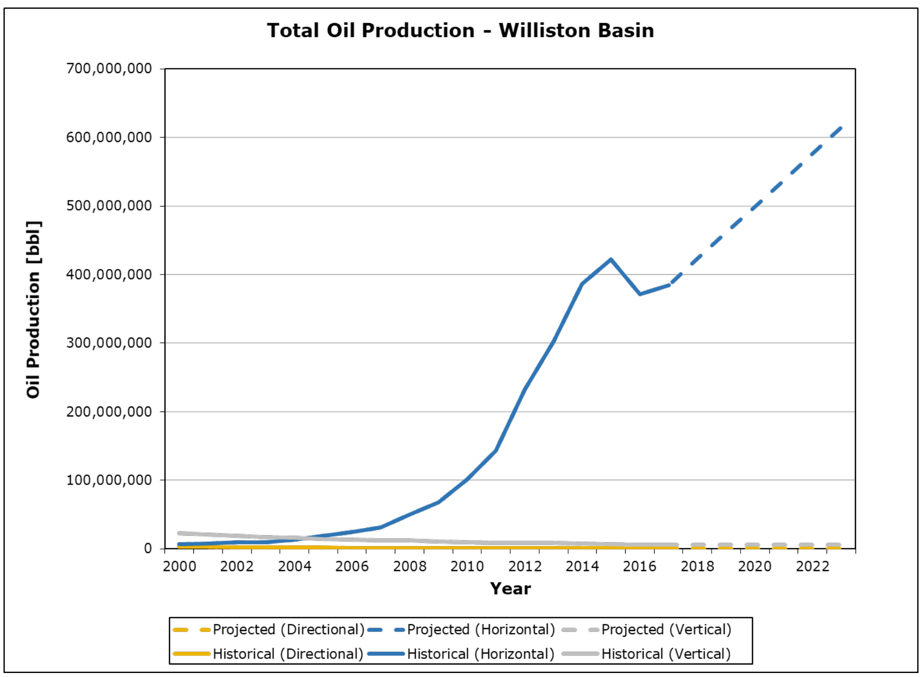


**Figure 46. Williston Basin - Total Oil Production**

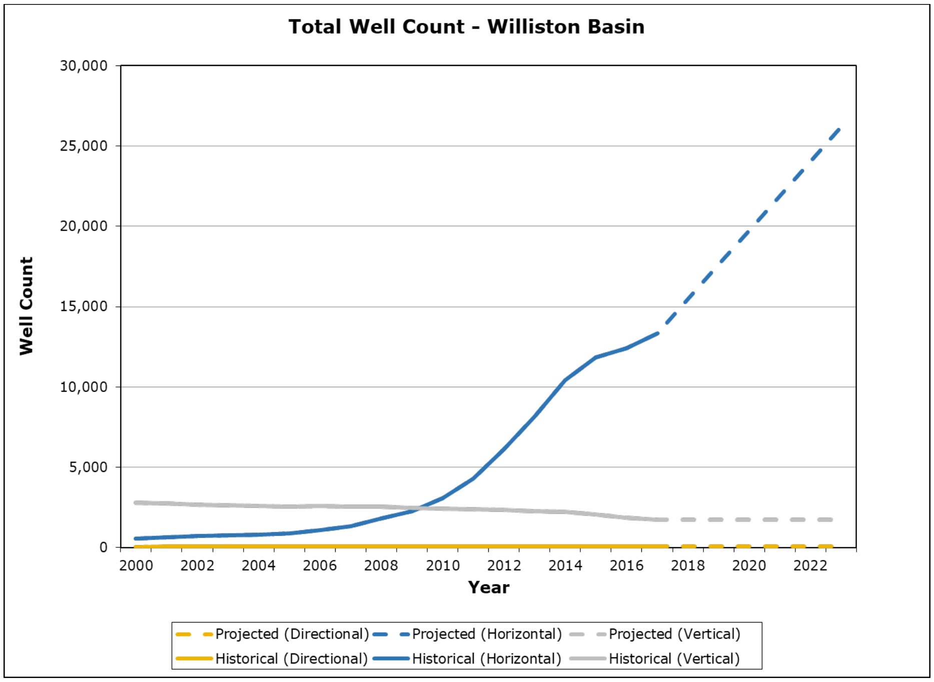


**Figure 47. Williston Basin - Total Well Count**

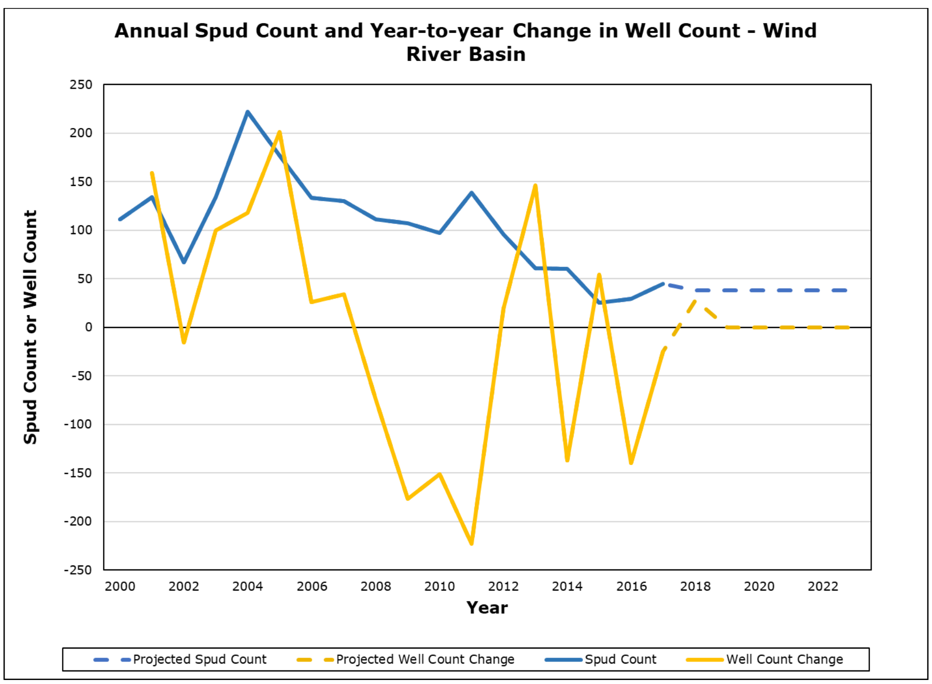


**Figure 48. Wind River Basin - Annual Spud Count and Year-Over-Year Change in Well Count**

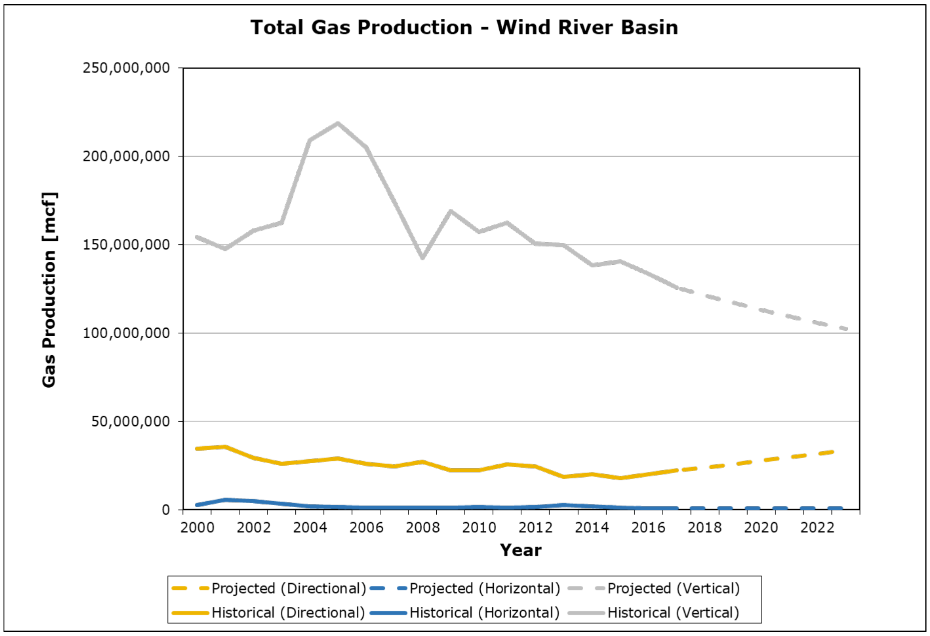


**Figure 49. Wind River Basin - Total Gas Production**

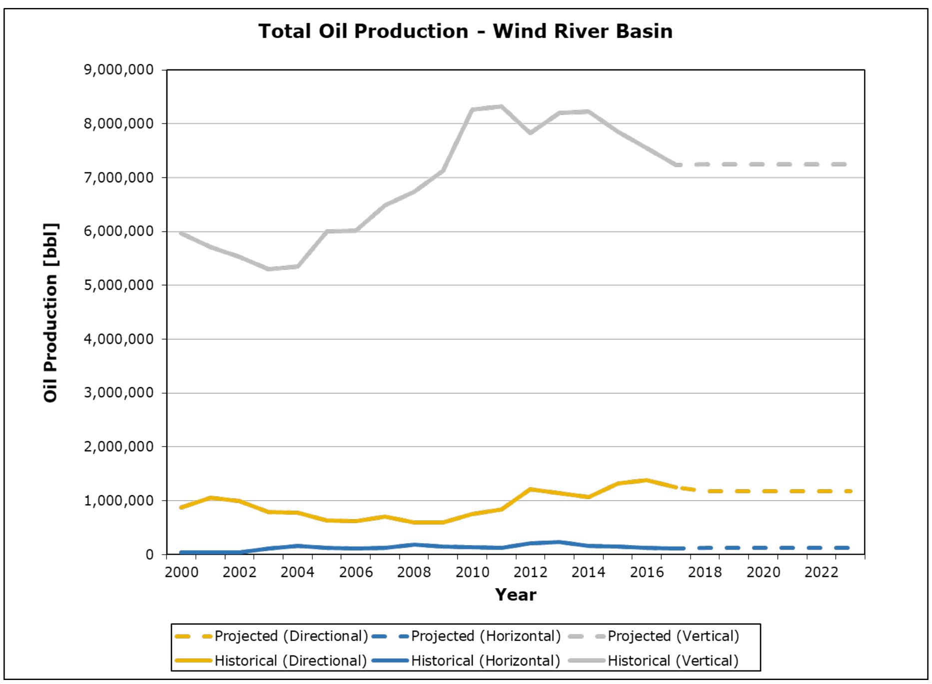


**Figure 50. Wind River Basin - Total Oil Production**

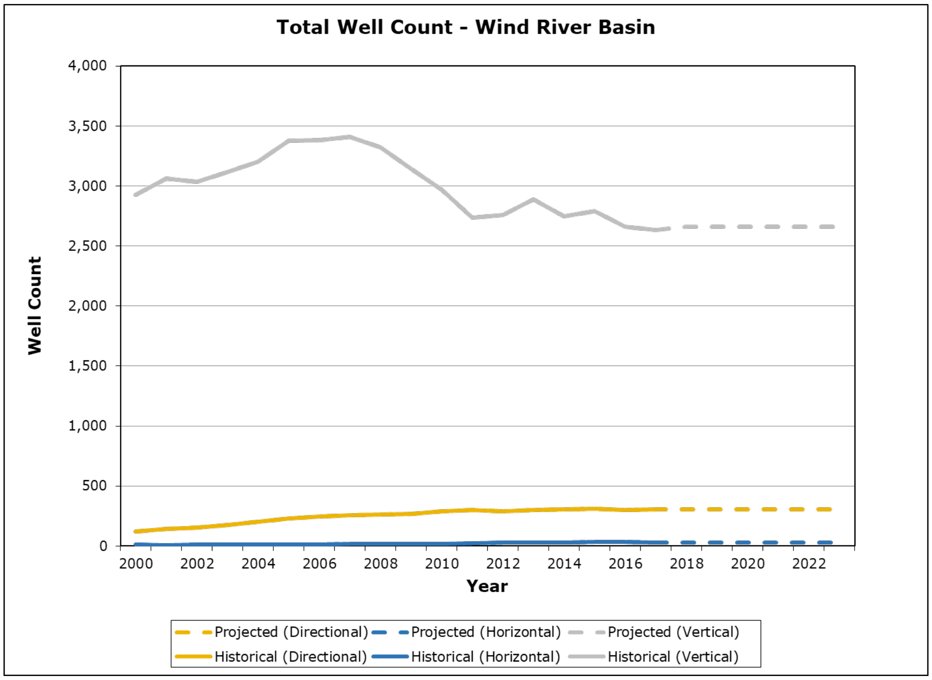


**Figure 51. Wind River Basin - Total Well Count**