TECHNICAL MEMORANDUM

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SUBJECT: Modeling Allocation Factors for the 2017 Oil and Gas Nonpoint Tool

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1.0 INTRODUCTION

The exploration and production of oil and gas has increased in terms of quantities and locations over the last eight years, primarily through the use of new technologies, such as hydraulic fracturing. As part of the 2017 National Emissions Inventory (NEI), EPA prepared county-level emission estimates for the oil and gas sector. This emissions inventory was similar in comprehensiveness and completeness on a geographic, source category, and pollutant coverage basis when compared to the 2014 National Emissions Inventory (NEI) and the 2016 Special Modeling Platform Emissions Inventory for this sector.

The purpose of this memorandum is to summarize procedures used to develop spatial and temporal modeling allocation factors for the 2017 Oil and Gas emissions inventory using data primarily from a third-party database of oil and gas wells, and other sources. EPA directed ERG to start with the analysis and files delivered to EPA's Climate Change Division in August 2018 (U.S. EPA, 2018a) for the U.S. Greenhouse Gas Emissions Inventory, and to incorporate additional datasets to develop surrogate modeling factors. All work was performed under EPA Contract No. EP-D-14-030, Delivery Orders 00-65 and 00-67, entitled "Data Analysis/Report Development."

2.0 BACKGROUND INFORMATION

EPA uses the national oil and gas emissions inventory for several purposes, including emissions modeling for regulatory activities. In support of 2017 emissions modeling, EPA developed Version 1 of the 2017 National Oil and Gas Emissions Estimation Tool (U.S. EPA, 2019). Although the activity data inputs in the Tool were at the county-level, much of the data originated from monthly well-level data that can be used for sub-county spatial and monthly temporal modeling. Additionally, through the development of the Tool, states had the opportunity to revise county-level activity data. For example, the Texas Commission on Environmental Quality (TCEQ) provided revisions to the original oil and gas well counts in the Tool. For other states, such as Indiana, 2017 production data were only available at the state level, but were allocated to the county-level based on well-level data and surrogates from Indiana Department of Environmental Management (IDEM).

For these Delivery Orders, ERG developed spatial allocation factors at both the 2-km and the 4-km grid scale level for both the Continental U.S. (CONUS) and Alaska. Additionally, ERG developed monthly temporal allocation factors by SCC, which is useful for air quality modeling.

3.0 DATA SOURCES

The modeling surrogates were developed using multiple data sources described below.

3.1 HPDI

The primary activity data source used for the development of the oil and gas spatial surrogates was data from Drilling Info (DI) Desktop's HPDI database (Drilling Info, 2018). This database contains well-level location, production, and exploration statistics at the monthly level. Due to a proprietary agreement with DI Desktop, individual well locations and ancillary production cannot be made publicly available, but aggregated statistics are allowed. For the 2017 Oil and Gas Tool, the individual well-level statistics were summed to the county-level. HPDI data represents nearly 92% of the activity data used in the Oil and Gas Tool.

3.2 Oil and Gas Commission Websites

For the remaining 8%, ERG supplemented the HPDI activity data with additional data from Oil and Gas Commission (OGC) websites. In many cases, the correct surrogate parameter was not available (e.g., feet drilled), but an alternative surrogate parameter was available (e.g.,

number of spudded wells) and downloaded. The types of information retrieved from these websites are presented in Table 1, as well as the corresponding reference listed in Section 8.

Table 1. Information Retrieved from State Websites

State	Information Retrieved	Reference
Alaska	Well Locations, Spud Counts, Well Depths	Alaska OGC, 2019
Arizona	Well Locations, Spud Counts, Well Depths	Arizona OGC, 2019
Florida	Well Locations, Spud Counts, Well Depths	Florida DEP, 2019
Idaho	Well Locations, Spud Counts, Well Depths, Gas Production, Produced Water, Well Completions	Idaho OGC, 2019
Illinois	Well Locations, Spud Counts, Well Depths, Well Completions	Illinois SGS, 2019
Indiana	Well Locations, Spud Counts, Well Depths, Oil Production, Gas Production, Well Completions	Indiana OGC, 2019
Kentucky	Well Locations, Spud Counts, Well Depths, Oil Production, Gas Production, Well Completions	Kentucky GS, 2019
Michigan	Well Locations, Spud Counts, Well Depths	MI DNR, 2019
Missouri	Well Locations, Spud Counts, Well Depths	Missouri DNR, 2019
Nevada	Well Locations, Spud Counts, Well Depths	Nevada DMR, 2019
Ohio	Well Locations, Produced Water	Ohio DNR, 2019
Oregon	Well Locations, Spud Counts, Well Depths	Oregon OGC, 2019
Pennsylvania	Well Locations, Produced Water	Pennsylvania DEP, 2019
Tennessee	Well Locations, Spud Counts, Well Depths	Tennessee DEP, 2019
Virginia	Well Locations, Spud Counts, Well Depths	Virginia DEP, 2019

3.3 EPA Greenhouse Gas Inventory for Completions

EPA supplemented the completion information from HPDI by implementing the methodology for counting oil and gas well completions developed for the U.S. National Greenhouse Gas Inventory (U.S. EPA, 2013). Under that methodology, both completion date and date of first production from HPDI were used to identify wells completed during 2017.

4.0 DATA COMPILATION

In total, over 1.07 million unique wells were compiled from the above data sources. The wells cover 34 states and 1,177 counties. Well locations are presented in Figure 1. Each well was uploaded into ArcGIS, and assigned to the associated 2-km and 4-km grid identifier.[1]

[1] The 4-km grid description was provided by EPA, and ERG developed a 2-km grid using the 4-km grid. EPA also directed ERG to use an updated county boundary map, "cb_2017_us_county_500" from: https://www2.census.gov/geo/tiger/GENZ2017/shp/cb_2017_us_county_500k.zip (U.S. EPA, 2019b).

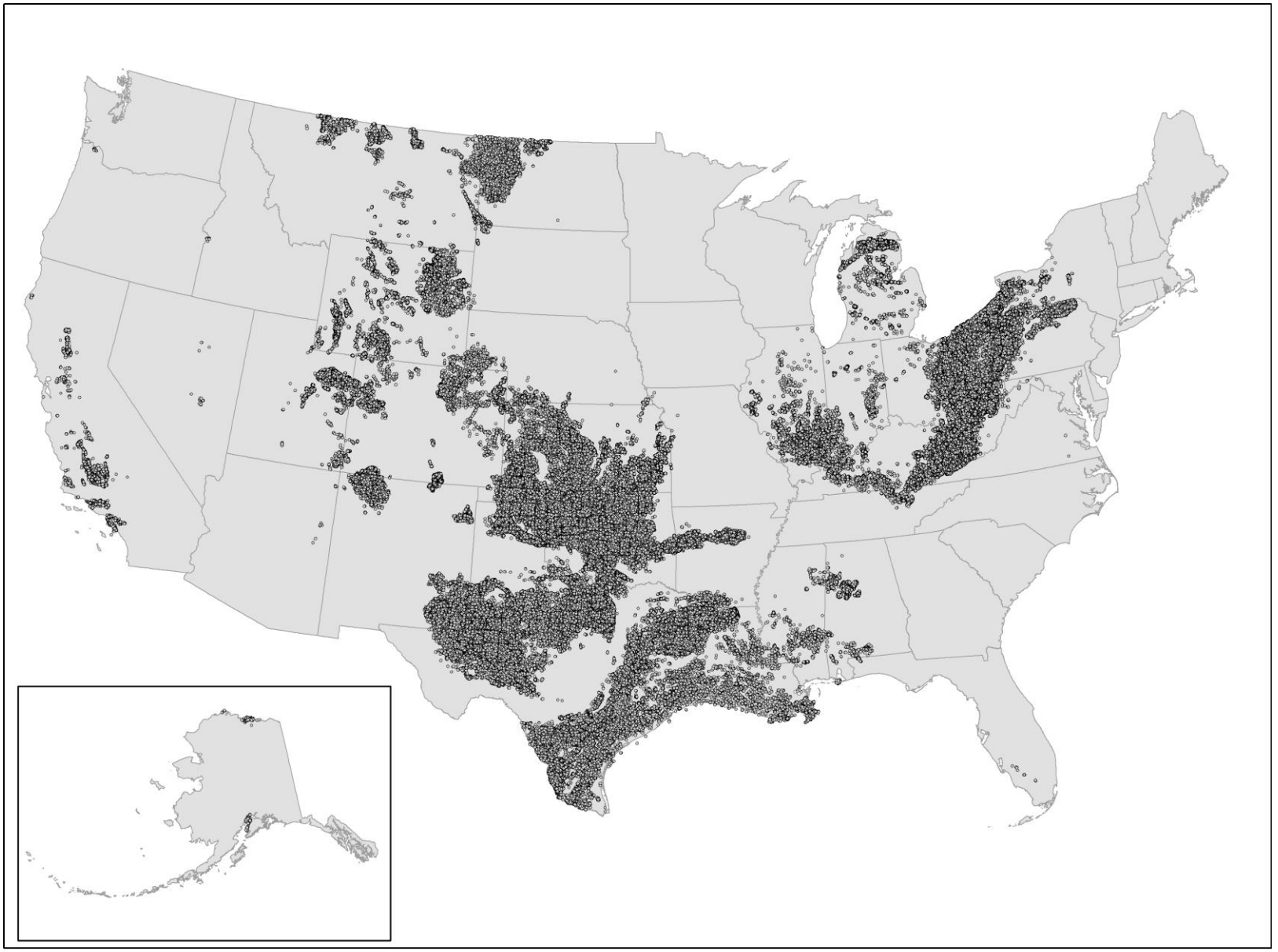

Figure 1. Compiled Well Locations for the U.S

For the development of sub-county modeling surrogates, attribute data (e.g., production, well counts, produced water, etc.) for each well were assigned both 4-km and 2-km modeling grid identifiers. By default, attribute data were initially summed to the 2-km modeling grid level. If the data for the attribute was based on less than 3 wells within the 2-km modeling grid, then the wells were summed to the 4-km modeling grid. For the majority of the attributes, wells remained in the 2-km modeling bins. Table 2 summarizes the well counts of the 26 attributes by modeling grid.

Table 2. Well Counts by Attribute and Modeling Grid

Oil and Gas Attribute	Number of Wells in 2-km Modeling Grid	Number of Wells in 4-km Modeling Grid	Total Number of Wells
Associated Gas Production	269,236	41,170	310,406
CBM Production	35,265	2,963	38,228
CBM Well Counts	35,265	2,963	38,228
Completions – All Wells	14,147	8,682	22,829
Completions – CBM Wells	149	130	279
Completions – Gas Wells	2,614	2,263	4,877
Completions – Oil Wells	11,049	6,624	17,673
Condensate Production – CBM Wells	4,932	833	5,765
Condensate Production – Gas Wells	63,758	16,833	80,591
Feet Drilled	12,218	6,927	19,145
Gas Production	339,292	52,431	391,723
Gas Well Counts	339,292	52,431	391,723
Oil Production	565,506	63,100	628,606
Oil Well Counts	565,508	63,098	628,606
Produced Water – All Wells	620,553	250,684	871,237
Produced Water – CBM Wells	26,073	2,287	28,360
Produced Water – Gas Wells	138,320	28,937	167,257
Produced Water – Oil Wells	420,359	44,025	464,384
Spud Counts – All Wells	12,218	6,927	19,145
Spud Counts – CBM Wells	130	85	215
Spud Counts – Gas Wells	2,725	1,709	4,434
Spud Counts – Oil Wells	9,033	5,463	14,496
Total Exploratory Wells	19,850	10,259	30,109
Total Production Wells	972,988	85,569	1,058,557
Total Wells	985,000	86,003	1,071,003
Unconventional Well Completions	8,324	3,584	11,908

Figure 2 presents the combined 2-km and 4-km modeling grid coverages.

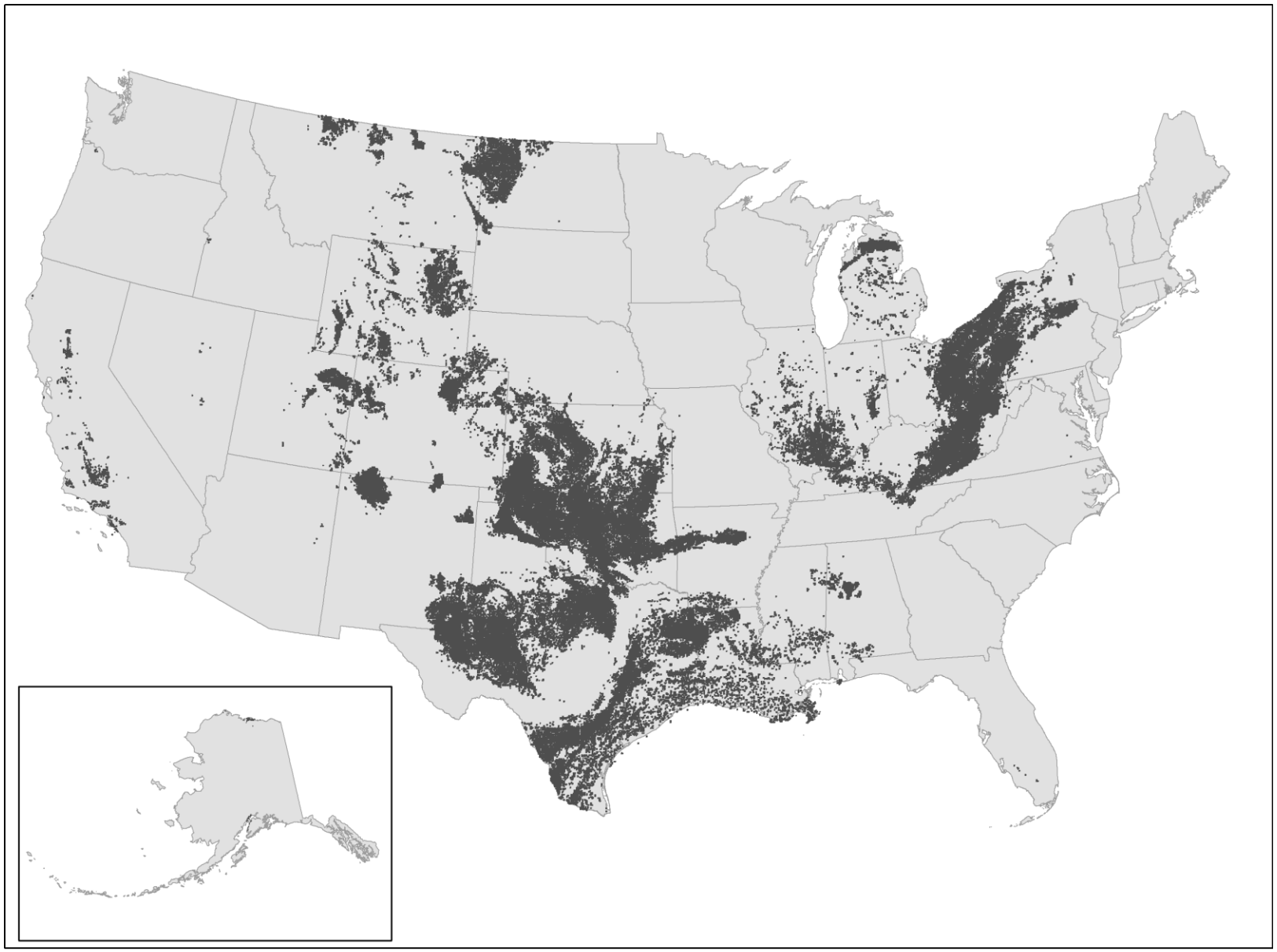

Figure 2. Compiled Well Locations Placed at U.S. 2-km and 4-km Grids

5.0 OIL AND GAS SURROGATES

The 2017 Nonpoint Oil and Gas Emissions Estimation Tool contains emission estimates for 34 states and 1,171 counties. Additionally, emissions are estimated for 55 oil and gas source classification codes (SCCs), those that begin with 2310xxxxxx. The list of SCCs from the Tool is presented in Appendix A. In total, there are 29,214 unique county-SCC pairs with emissions.

Despite the large number of SCCs, emission surrogates were allocated to the 2-km and 4-km level for twenty-six surrogates. These surrogates are presented in Table 3.

Table 3. Oil and Gas Surrogate Codes

EPA Surrogate Code	EPA Surrogate Description	Surrogate Spatial Allocation Factor Name
670	Spud count – CBM Wells	SPUD_CBM
671	Spud count – Gas Wells	SPUD_GAS
672	Gas production at Oil wells	ASSOCIATED_GAS_PRODUCTION
673	Oil production at CBM Wells	CONDENSATE_CBM_PROD
674	Unconventional Well Completion Counts	SPUD_HF
676	Well count – all producing	TOTAL_PROD_WELL
677	Well count – all exploratory	TOTAL_EXPL_WELL
678	Completions at Gas Wells	COMPLETIONS_GAS
679	Completions at CBM Wells	COMPLETIONS_CBM
681	Spud count – Oil Wells	SPUD_OIL
683	Produced Water at all wells	PRODUCED_WATER_ALL
6831	Produced Water at CBM wells	PRODUCED_WATER_CBM
6832	Produced Water at Gas wells	PRODUCED_WATER_GAS
6833	Produced Water at Oil wells	PRODUCED_WATER_OIL
685	Completions at Oil Wells	COMPLETIONS_OIL
686	Completions at all wells	COMPLETIONS_ALL
687	Feet drilled at all wells	FEET_DRILLED
691	Well counts – CBM Wells	CBM_WELL
692	Spud count – All Wells	SPUD_ALL
693	Well count – all wells	TOTAL_WELL
694	Oil production at oil wells	OIL_PRODUCTION
695	Well count – oil wells	OIL_WELL
696	Gas production at Gas wells	GAS_PRODUCTION
697	Oil production at Gas Wells	CONDENSATE_GAS_PROD
698	Well counts – Gas Wells	GAS_WELL
699	Gas production at CBM wells	CBM_PRODUCTION

Appendix B presents the county-SCC pairs with the primary surrogate codes. If the primary surrogate was not available, then an alternate surrogate was assigned. Appendix C presents the surrogate assignment progression. In cases where there is no well-level location data for a particular county, then a surrogate code of 400, which is allocation by rural land area, was assigned as an alternative surrogate.

6.0 SURROGATE CALCULATIONS

Since nonpoint oil and gas emissions are at the county-level, the surrogate factors need to be developed for portions within the county.

6.1 Spatial Surrogate Calculations – 4-km Grid Scale

ERG used EPA's Spatial Allocator program to align the 2-km and 4-km gridded activity data parameters to develop the 4-km spatial allocation files (Appendix D). Gridded activity data were summed to the county-level and compared to the original county-level totals to ensure all data were allocated properly.

6.2 Temporal Surrogate Calculations

Monthly surrogates were prepared for county-SCC combinations which overlap with data extracted from HPDI, state Oil and Gas Commission websites, and RIGDATA (S&P Global Platts, 2018). The following steps were used to generate the monthly surrogates:

a. Sum allocation factors to the monthly timeframe
b. Sum allocation factors to annual timeframe
c. Divide summed monthly allocations by the summed annual allocations to calculate monthly spatial allocation factors

For county-SCC combinations that were not extracted from HPDI, the surrogate parameter was evenly distributed by month. Appendix E presents the temporal factors by the county-SCC combinations.

7.0 FINAL DATA PRODUCTS

Final data products for this effort include:

- Appendix E – Monthly temporal factors by County and SCC. The temporal allocation factors were in one-record per line (ORL) format with the following data fields, and are presented in Appendix E:
    - FIPS
    - SCC
    - JANFRAC
    - FEBFRAC
    - MARFRAC
    - APRFRAC
    - MAYFRAC
    - JUNFRAC
    - JULFRAC
    - AUGFRAC
    - SEPFRAC
    - OCTFRAC
    - NOVFRAC
    - DECFRAC

- Appendix F – Shapefiles of the Well Attributes for the Continental U.S. (CONUS) and Alaska
- Appendix G – 4-km surrogate code text files for the CONUS only. For the 4-km spatial allocation factors, ERG prepared SMOKE-ready files for 26 surrogate codes. The 4-km spatial allocation factor files contain the following data fields:
    - Header Descriptions
    - Surrogate Code
    - State and County FIPS Code
    - Grid-Scale Column Value
    - Grid-Scale Row Value
    - Spatial Allocation Factor
    - Fractionated grid-level total value
    - County-level total

- Appendix H – CONUS and Alaska 2-km and 4-km merged county-level heat maps for 26 well attributes.

8.0 REFERENCES

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Appendix A – 2017 Nonpoint Tool Oil and Gas SCCs

(See APPENDIX_A_2017_NONPOINT_SCC.xlsx)

Appendix B – 2017 Nonpoint Oil and Gas Tool County FIPS, SCCs, and Surrogate

(see APPENDIX_B_2017_TOOL_COUNTY_SCC_SURROGATE.xlsx)

Appendix C – Surrogate Priority

(See APPENDIX_C_SURROGATE_PRIORITY.pdf)

Appendix D – Surrogate, County FIPs, and 4-km Grid Cells

(see APPENDIX_D_SURROGATE_COUNTY_GRID.xlsx)

Appendix E – Monthly Temporal Factors

(see APPENDIX_E_MONTHLY_TEMPORAL_FACTORS.xlsx)

Appendix F – CONUS and Alaska GIS Shapefiles

(see APPENDIX_F_CONUS_AK_ATTRIBUTE_SHAPEFILES.zip)

Appendix G - 4-km Surrogate Modeling Files

(see APPENDIX_G_4_KM_SURROGATE_FILES.zip)

Appendix H – Well Attribute Heat Maps

(see APPENDIX_H_WELL_ATTRIBUTE_HEAT_MAPS.zip)