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MEMORANDUM

To:	Dale Wells, Lisa Devore, Gordon Pierce; CDPHE Mark Jones, Kerwin Singleton, Rita Bates; NMED Daniel Powers, Tom Johnson, Mark Hutson; SUIT Tom Moore; WESTAR-WRAP
From:	John Grant, Rajashi Parikh, Amnon Bar-Ilan; Ramboll Environ
Subject:	National Oil and Gas Emissions Analysis, Task 2: San Juan Basin Regional Analysis

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This memorandum describes the San Juan Basin[1] oil and gas (O&G) emissions analysis developed as part of the National Oil and Gas Emissions Analysis, Task 2: Regional Analysis. The analysis includes three components:

1. Southern Ute Indian Tribe (SUIT) O&G Well-site Emissions: Obtained wellhead compressor engine and tank input data collected by SUIT and compared inputs and/or emissions to emissions estimated by the US Environmental Protection Agency (EPA) O&G Tool.
2. EPA Nonpoint O&G Tool Input Updates: Checked with the US Bureau of Land Management (BLM) Farmington Field office on availability of O&G nonpoint source input factors that could be used to update the EPA O&G Tool.
3. O&G Volatile Organic Compound (VOC) Emissions Missing from Inventory: Determined whether findings of Frankenberg et al. (2016) could be used to estimate the quantity of VOC emissions missing from the National Emission Inventory (NEI).

SUIT O&G Well Site Emissions

SUIT collected a dataset of 2015 inventory inputs and emissions from detailed data provided by O&G operators on SUIT land. SUIT provided this dataset in spreadsheet format[2]. We analyzed the emission inventory data to determine whether US Environmental Protection Agency (EPA) O&G Tool (version 1.5) emission inventory inputs could be developed for wellhead compressor and condensate tanks.

Wellhead Compressor Engines

The SUIT dataset includes 1,059 nonpoint source engines. For 19 of 1,059 engines greater than 500 horsepower, we assumed that these were lateral, not wellhead compressor engines. The remaining

[1] For this analysis the San Juan Basin is defined according to the American Association of Petroleum Geologists (AAPG) basin 580.

[2] Email from Daniel Powers (Southern Ute Indian Tribe Air Quality Program), March 30, 2017

1,040 engines are likely to be composed primarily of wellhead compressor engines and water pump engines. There is no water pump engine source category in the O&G Tool, nor is there information in the SUIT-dataset upon which to differentiate engine application. Therefore, the remaining 1,040 engines were assumed to be wellhead compressor engines.

Table 1 shows EPA O&G Tool default and SUIT data-sourced inputs. The following differences are noted in the inputs:

- We were unable to differentiate between inputs for coalbed methane (CBM) and natural gas wells in the SUIT dataset. The same inputs were assumed for CBM and gas wells.
- The SUIT data includes a greater fraction of rich burn engines (82%) relative to EPA O&G Tool defaults (70%).
- The SUIT data includes 2-cycle engines (15%), the EPA O&G Tool assumes 100% 4-cycle engines.
- The SUIT data-sourced average horsepower for lean burn engines is 35% lower than the EPA O&G Tool default.
- The SUIT data-sourced average horsepower for rich burn engines is 68% higher than the EPA O&G Tool default.
- SUIT data was not available for load factor, fraction of engines with controls, or hours of operation; EPA O&G Tool defaults were assumed.
- The fraction of wells needing compression was 17% higher than EPA O&G Tool defaults.
- Data is not available for tribal well counts in the EPA O&G Tool; the Tool does not differentiate between tribal and non-tribal O&G activity or emissions.

Table 1. EPA O&G Tool default and SUIT data-sourced inputs.

Parameter	EPA O&G Tool Estimate	SUIT Dataset Estimate
Basin Factors (applicable to gas and CBM wells)		
Fraction of Rich-burn Engines	0.70	0.82
Fraction of Lean-burn Engines	0.30	0.18
Lean Burn Load Factor	0.75	0.75[A]
Rich-burn Load Factor	0.76	0.76[A]
Fraction of 2-cycle Engines	0.00	0.15
Fraction of 4-cycle Engines	1.00	0.85
Fraction of Compressors Engines <50 HP	0	0
Fraction of Compressors Engines between 50-499 HP	1.00	1.00
Fraction of Compressors Engines >500 HP	0.00	0.00
Fraction of Controlled Lean-burn Engines	0.18	0.18[A]
Fraction of Controlled Rich-burn Engines	0.31	0.31[A]
Lean-burn Engine Horsepower (HP)	138	90
Rich-burn Engine Horsepower (HP)	133	224
Hours of Operation per year (HRS/YR)	8439	8439[A]

Parameter	EPA O&G Tool Estimate	SUIT Dataset Estimate
Activity Inputs		
Fraction of wells in the county needing compression	0.21	0.38
SUIT Gas Well Count	n/a	1,876
SUIT CBM Well Count	n/a	858

[A] Parameter not available in SUIT dataset, EPA O&G Tool default was applied.

Updated wellhead compressor emissions for O&G wells on SUIT land were estimated by running the EPA O&G Tool with updated SUIT dataset-sourced inputs for wellhead compressor engine basin factors and O&G activity inputs (see Table 1). Default EPA O&G Tool emissions from wellhead compressors at O&G wells on SUIT land were estimated by scaling default O&G Tool (version 1.5) output emissions by the ratio of 2014 gas and CBM wells on SUIT land (2,725 total) to O&G Tool estimates of gas and CBM wells in La Plata and Archuleta counties (3,031 total). NOx emissions increased by 27% from Tool default to SUIT inputs and emissions increases for other pollutants are in the range of 5% to 71%. Emission increases result from differences in O&G Tool inputs including engine prevalence, engine cycle, engine type (rich or lean), and average horsepower. The inclusion of all engines under 500 horsepower as wellhead compressor engines in the SUIT inputs could also be a factor in higher wellhead emissions from SUIT dataset-based emissions since some engines could be used for other applications. For example, there may be water pump engines in the SUIT database; as noted above, there is no water pump engines source category in the EPA O&G Tool.

Table 2. Wellhead emissions for O&G wells on SUIT land with O&G Tool default and SUIT data-sourced inputs.

	Emissions (tpy [A])		
Pollutant	**O&G Tool Inputs**	**SUIT Inputs**	**Percent Difference**
NOx	2,729	3,457	27%
VOC	98	167	71%
CO	3,730	3,921	5%
PM10	32	46	43%
SO2	1	2	32%

[A] tons per year

Condensate Tanks

The number of condensate tanks in the SUIT dataset is very small, 9 total tanks; liquid hydrocarbon production on SUIT land accounted for less than 0.4% of San Juan basin condensate production in 2014. Data was not available to estimate condensate tank basin factors listed below which are required by the EPA O&G Tool.

- Gas Wells - Fraction of condensate directed to tanks
- Gas Wells - Fraction of condensate tanks with a flare

- Gas Wells - Flare capture efficiency (%)
- Gas Wells - Flare control efficiency (%)
- Gas Wells - VOC emission factor (pounds VOC per barrel [lb VOC/BBL])
- Gas Wells - Volume of flash gas vented (thousand cubic-feet per barrel [MCF/BBL])

We did not estimate SUIT-specific condensate tank EPA O&G Tool inputs or emissions.

EPA Nonpoint O&G Tool Input Updates

Per information provided by Farmington Field Office BLM staff[3] all of the most recent emission inventory input data collected by BLM is available in the Colorado Air Resources Management Modeling Study (CARMMS) (Ramboll Environ and Kleinfelder, 2016). CARMMS O&G inventory input data was reviewed and incorporated into the Western States Air Resources Council-Western Regional Air Partnership (WESTAR-WRAP) Greater San Juan Basin emission inventory study (Grant et al., 2016) input factor estimates for which neither operator data nor data from Subpart W Greenhouse Gas Reporting Program (GHGRP) were available. WESTAR-WRAP emission inventory well-site inputs were converted to basin factors and provided to EPA for use in the O&G Tool[4]. Therefore, the most recent data from the BLM Farmington Field Office has been incorporated into the EPA O&G Tool.

O&G VOC Emissions Missing from Inventory

Frankenberg et al. (2016) took airborne measurements of methane in the 4-Corners region. Most of the measurements were taken in San Juan County, New Mexico; measurements were also taken in other counties including La Plata County, Colorado and Montezuma County, Colorado. Two hundred and fifty (250) plumes were measured with methane emission rates ranging from 2 kilograms per hour (kg/hr) to 5000 kg/hr. Methane plume sources identified included gas processing plants, storage tanks, pipeline leaks, well pads, and a single coal mine venting shaft. The top 10% of emitters were estimated to contribute 49-66% of total point source methane emissions (0.23-0.39 Tera grams/day). Figure 1 shows the cumulative methane flux distribution for the measured plumes.

[3] Email from Jeff Tafoya (BLM), July 25, 2017.
[4] Email from John Grant (Ramboll Environ), May 12, 2017.

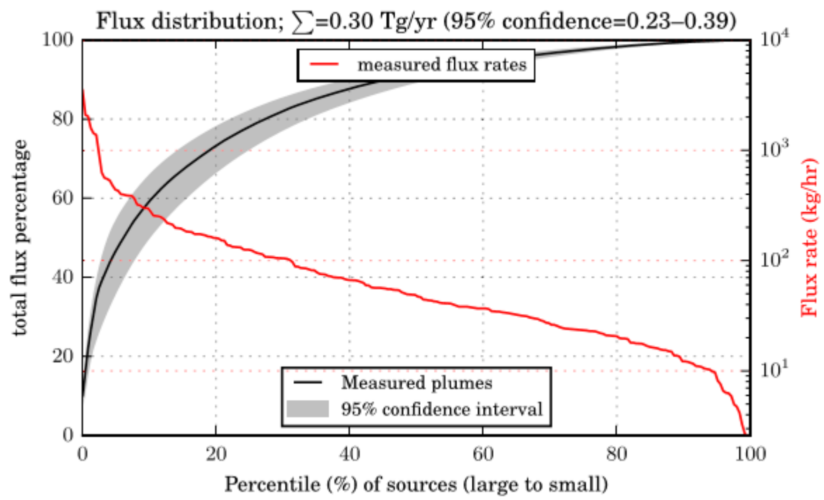

Fig. 5. Black line denotes cumulative distribution function of summed fluxes against flux percentiles (in descending order). Red line denotes corresponding flux rates at the respective percentile. The gray area shows the 95% confidence interval of the distribution, using a nonparametric bootstrap method.

Figure 1. 4-Corners region methane plume cumulative distribution (source: Frankenberg et al. [2016]).

Frankenberg et al. (2016) confirmed that high methane emissions in the 4-Corners region are related to natural gas extraction and coal mining and that no single emission source explains high methane emissions in the 4-Corners region. Smith et al. (2017) determined that O&G methane emissions were not correlated with gas production. Frankenberg et al. (2016) note that future work is needed to differentiate between transient and persistent emission sources.

Methane emission measurements in Frankenberg et al. (2016) are related to VOC emission as oil and gas source methane emissions sources are likely to include methane and VOC emissions together. The relationship between methane and VOC emissions from a given source is determined by the composition of gas emitted. Tank emissions typically have a high VOC content (e.g., tank emissions are estimated to be 58% VOC and 9% methane by weight in the Greater San Juan Basin, Grant et al. [2016]); high methane emissions from a tank would typically also be associated with high VOC emissions. The relationship between VOC and methane emissions from a produced gas emission source is determined by the produced gas VOC and methane content. Produced gas from coalbed methane wells typically has a high methane content and very low VOC content; VOC emissions from a leak of produced gas at a coalbed methane well are expected to be much smaller than methane emissions. High methane emissions from a leak of produced gas from a gas or oil well could be associated with high VOC emissions depending on the produced gas VOC and methane content. High methane emissions from a leak of treated gas downstream of a gas processing plant is not expected to be associated with high VOC emissions, since treated gas is expected to have a very low VOC content.

In order to use findings on methane emissions from Frankenberg et al. (2016) to update the criteria air pollutant emission inventory, more detailed information would be needed on the methane plume emission distribution by bottom-up emission inventory source category in order to apply representative VOC to methane ratios to estimate VOC emissions. Alternatively, directly estimating VOC in addition to methane emissions in such studies could allow for bottom-up criteria pollutant emission inventory improvement.

Recommendations

The SUIT collects detailed O&G well-site emission inventory data which should be incorporated into the EPA O&G Tool. The use of SUIT data would increase the accuracy of O&G Tool emissions since the SUIT collected detailed data not yet incorporated into the Tool. Modifying the O&G Tool to accept tribe specific data for O&G activity, basin factors, speciation factors, and emission factors could facilitate incorporation of data collected by the SUIT.

The BLM Farmington Field Office did not have available any new data on O&G nonpoint source input factors that could be used to update the O&G Tool.

Based on review of Frankenberg et al. (2016), sufficient information was not collected in that study to update the O&G VOC emission inventory. Key pieces of data that would allow for VOC inventory improvements which are not available in Frankenberg et al. (2016) are: (a) more detailed information on the methane plume emission distribution by bottom-up emission inventory source category and/or (b) estimates of VOC emissions (only methane emissions were reported in Frankenberg et al. [2016]).

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