

The referee provided excellent feedback that we have addressed in the responses given below. Their suggestions have helped to improve the clarity of our manuscript.

**Major comments:**

1. Most readers are probably not that familiar with the operation of a water treatment and recycling facility. I assume that this facility was exclusively used for well oil and gas drilling flowback water treatment? It would be helpful to provide some more information on the technical operation and operational scale of this facility.

<Response> 1. This is a dedicated facility for treating produced water including drilling and flow-back waste materials. We have added more information on the facility in section 3.5 including description of the key process step and also note operational volumes.

2. It would be valuable to discuss differences in atmospheric data and observed ozone in 2011 to 2012 a bit more in depth in respect to differences in meteorological and snow cover conditions between both years.

<Response> 2. Additional discussion is now given to meteorological differences between the two years of measurements at BSR in section 3.1, with additional supporting data from elsewhere (i.e. UGWOS reports, in particular MSI 2014). We add information regarding meteorology in 2012 compared to 2011.

3. The PMF analysis exclusively attributed NMHC observations to potential emission sources. Atmospheric NMHC are likely also determined by chemistry and meteorological (including mixed layer depth and transport direction). I am wondering if and how omission of these influences effects the robustness of the PMF results.

<Response> 3. Receptor models like PMF implicitly assume there are no changes that result from atmospheric transformation between emissions and receptor. Any atmospheric chemistry that oxidizes VOCs in the atmosphere will bias the receptor “profile” results from the true emissions profiles. In very cold conditions, these changes should be relatively small. However, the profiles generated will underestimate the ratios of more reactive species that are oxidized more quickly in the atmosphere. Figure 6 shows strong similarity between identified factors and source profiles.

Meteorology should not affect the relative ratios of the emissions profiles. The receptor will either “see” or not see the emissions source. So the temporal variability that results from local meteorology, wind speeds, directions, and mixing heights will simply aid the model in finding a robust solution. The only exception would be that the receptor model may not “see” emissions that originate from directions where the wind does not come from frequently enough to identify them.

**Other comments (by order of occurrence):**

24945/8: Please clarify if this statement relates to proven oil reservoirs within the US or worldwide.

<Response> Clarified as this comment is for US proven reserves.

24946/19: NMHC have already been defined in line 16.

<Response> This error is corrected.

24947/2: . . .CH<sub>4</sub>), and carbon . . .

<Response> This error is now corrected in the manuscript.

24947/9: Provide technical specs of canisters used.

<Response> Details of the canisters are now included in this section.

24947/18 – 24948/8: Provide mole fraction range of NMHC calibration standards used and if the calibration range covered the span of observed mole fractions in field samples. If not, then an explanation should be provided how higher mole fraction field samples were treated. Also, please provide an uncertainty estimate for the NMHC data and a detection limit estimate.

<Response> As noted by the reviewer finding the appropriate balance between manuscript and supplementary material is difficult, in particular when a variety of analysis methods and data are included. We have added the requested information regarding our calibration approach. Our routine calibration curve approach has been to adjust trapping time and we note this in the text. Our routine curves contain 95% of our measurement range. Of course our measurement range was unknown to us prior to the study. At the end of each winter period we

perform a calibration curve that extends beyond our maximum observed value. Through this approach we have been able to define our upper limit that was not exceeded for reported data. Some of our "source canister measurements" required 1-minute trapping to ensure that the upper limit of detection was not exceeded for ethane. Measurement uncertainty estimates are given in Table S1.

24948/15: From this explanation it seems that the chromatography data were processed by automated routines, both for peak identification and integration results? How are these procedures quality controlled?

<Response> Our QA/QC procedures were originally developed for the UK national hydrocarbon network. These are described in detail in a recent 20-year review paper that is now referenced. The procedures follow a systematic approach that considers retention time and peak width behavior that ensures that peaks are correctly identified and also without co-elution or peak merging issues.

24950/6: How is the noise level (N) determined?

<Response> Noise is based on the uncertainty in the species measurements input into the receptor model. So the noise is a function of the analytical detection limit and the precision of the measurements.

24951/16: I don't quite see how Figure 3 obviously shows this.

<Response> We have changed the language associated with Figure 3 as the figure does not show background, production and transport.

24952/10: The 'Thermo55i' instrument is not clearly defined in the methods section.

<Response> Extra detail describing this instrument is now added.

24952/9-28: This paper, and this section in particular, builds a lot on material that is not shown in the manuscript itself, but in the Supplemental Materials section. This is a development that can be found more and more in recent publications, likely in the effort to keep manuscripts short and for saving publication cost. I am not a fan of this publishing at all, mildly spoken. I think that

text of the manuscript should not discuss graphs, tables, etc ‘hidden’ in the Supplement section. Those should be provided with the main body of the paper, so that the reader does not have to flip back and forth between two documents for following the discussion. In my opinion, the manuscript should be a standalone document, with the Supplemental Materials Section providing no more than supporting information that goes beyond the primary discussion of the paper.

<Response> As noted earlier maintaining flow while avoiding cluttering a manuscript is a challenge. In this case the text, without Fig S6, should enable an understanding of the difference between total NMHC and summed speciated NMHC. If the reader wants more detail they can choose to look at the supplementary Figure S6. We carefully considered each and every figure and table. Our aim is to provide tables and figures in the supplementary material that provide additional information that is not essential to follow the presented analyses, but is instead potentially really useful for the reader who seeks more detail and background. While we understand, and to some extent concur with the referee regarding the problems with shorter papers with supplemental materials, we feel that we have achieved an acceptable balance with the key figures and tables in the manuscript.

24952/17: From the text alone it is not clear what variable is fitted against what? <Response> This error is now corrected in the manuscript and the variables are noted.

24953/2: . . .small, however, suggesting . . .

<Response> This sentence is edited in the manuscript.

24953/25: This is surprising, but potentially a very important point that should, if at all possible, be investigated in more depth.

<Response> This point has been reviewed and considered in more depth. Figure S7 clearly shows some hours with elevated O<sub>3</sub> when reported NO<sub>x</sub> values are relatively low. Thus this figure shows greater scatter for the high O<sub>3</sub> bin at BLDR compared to BSR, in particular for low NO<sub>x</sub> values. Inspection of the data shows that these points are for hours between 16:00 and 20:00, when actinic flux values are low, and do not coincide with hours when ozone production rates are highest. A careful review of the hour to hour changes of pollutant values shows that NO<sub>x</sub> values at BLDR are more variable compared to total NMHC, and to NO<sub>x</sub> and total NMHC

values at BSR. We do not currently offer an explanation for this greater variability of NO<sub>x</sub> at BLDR as numerous poorly characterized relevant factors may be at work (e.g. source variability; removal by titration; measurement uncertainties). Furthermore since this scatter does not refute the importance of high total NMHC values, we prefer to simply note the possible difference in behavior at the two sites. Figure S7 is therefore supplementary to our main focus, which is the speciated NMHC data and its impact at BSR.

24954/12: . . .bootstrapping, and the . . .

<Response> This error is now corrected in the manuscript.

24955/8: . . . contribution . . .

<Response> This error is now corrected in the manuscript.

24955/11: . . .However, for . . .

<Response> This error is now corrected in the manuscript.

24955/14: Factor 3 weighing declines . . .NMHC, e.g. nonane, . . .

<Response> This sentence is now edited in the manuscript.

24955/24: However, the . . .

<Response> This error is now corrected in the manuscript.

24956/29: However, factor . . .

<Response> This error is now corrected in the manuscript.

24957/4: . . .ethane, propane, . . .

<Response> This error is now corrected in the manuscript.

24957/7: . . .ethylbenzene, and . . .

<Response> This error is now corrected in the manuscript.

24957/9: . . .n-heptane, and . . .

<Response> This error is now corrected in the manuscript.

24957/10 . . .contribution from . . .

<Response> This error is now corrected in the manuscript.

24958/13: However, the . . .

<Response> This error is now corrected in the manuscript.

24958/18: Round mole fraction results to full ppbv. One might also want to consider to compare these BTEX values with health exposure thresholds.

<Response> These values are now rounded. Given the high values measured near the facility we did consider health exposure thresholds. However as we were measuring ambient air and that the values inside the facility were likely to be considerably higher we feel that such comparisons could be misleading. While it is clear that exposure is important we feel that aspect is outside of the scope of this paper in the context of the presented analysis.

24958/19-29: These calculation and arguments are hard to follow. What is the surface scale of the inventory emission rate? How do you get an emission intensity of 250 t mile<sup>-2</sup> and what does this mean? What is the time scale there?

<Response> We have edited this section that should now be easier to follow. As noted the inventory is calculated annually hence values are per year. To compare the facility with the rest of the development the emissions are scaled to a mile<sup>2</sup>. As such the facility has an emission rate of 250 times that for the rest of the development as a whole.

24958/26: . . .these data suggest that . . .

<Response> This error is now corrected in the manuscript.

24959/24: Meteorology should probably also be mentioned as an important influence.

<Response> Yes, we have edited this sentence accordingly.

24959/26: Suggest rounding values to no more than 3 significant figures.

<Response> These values are now set to 3 significant figures.

24960/2: Suggest rounding values to no more than 3 significant figures.

<Response> These values are now set to 3 significant figures.

24960/15: . . .data identify . . .

<Response> This sentence is edited in the manuscript.

24960/15: The data don't really 'estimate'. I suppose that 'one could estimate from the data' . . .

<Response> Yes this sentence is edited accordingly.

24961/25: ..., for 5 and 15 March 2011, and ...

<Response> This error is now corrected in the manuscript.

24962/3: . . .for ~2%, and . . .

<Response> This error is now corrected in the manuscript.

24962/8: . . .flux, so would . . .per

<Response> This error is now corrected in the manuscript.

24962/14: . . .reactivity, and that . . .

<Response> This error is now corrected in the manuscript.

24963/1-3: I suggest rewording this section, stating that the observations of coinciding high NMHC and elevated ozone conditions suggest that these NMHC play a role in ozone production.

<Response> This sentence is now modified in the manuscript.

24963/27: I suggest replacing the term 'reduction', as it kind of might be understood as if levels were lower due to some measures of emission control. I think it would be better to state that 'ambient levels were lower'.

<Response> This sentence is now modified as suggested in the manuscript.

**Figures/Tables:**

24974: . . .NO<sub>x</sub>, and NMHC . . . .

<Response> This error is now corrected in the manuscript.

24976: This graph shows a cluster of data with high NMHC and high NO<sub>x</sub>, but remarkably low ozone (pink diamonds). What were the conditions that suppressed ozone production on these days?

<Response> Figure 4 includes all available O<sub>3</sub> hourly average data points between 11:00 and 20:00 mst for every day during the period January 1 – March 31, 2011. Many of the data points, in particular those at times that are several hours after local noon, or during January when insolation is lower, therefore correspond to hours of the day when actinic flux levels are insufficiently high to promote significant O<sub>3</sub> formation, even under clear sky conditions. O<sub>3</sub> mixing ratios for these points are always therefore low, even when O<sub>3</sub> precursor mixing ratios are high. They result in the noticeable cluster of purple diamonds at high NO<sub>x</sub> mixing ratios in the figure. Winter ozone production in the Upper Green River Basin, in contrast to the Uintah Basin located to the south, has not been observed during the month of January.

24977: What does the ‘b’ stand for in ‘CO-b’ and ‘methane-b’. Name the factors in figure caption.

<Response> Minus background (-b) is now properly noted in the figure caption.

Figure 7 and 8: Inconsistent use of capital letters for compounds names.

<Response> This compound names are now consistent in labels and keys.

Figure 9: Mention in figure caption that circle size scales with relative mole fractions of ppbC? ‘Mass’ is probably not the correct term to use here?

<Response> The caption has the requested notation that relates to the sum of compounds from given classes as μg converted from ppbv mixing ratios.