Quantifying methane emissions from orphan oil and gas wells in Canada

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Introduction

Across Canada, there are 470,000 non-producing oil and gas wells, a highly uncertain source of methane emissions and other environmental risks.[1] Among these, orphan wells – sites for which no legally responsible operator remains – have been identified as high emitters in a previous study based in the United States (US).[2]

Approximately 72% of Canada's non-producing wells are in Alberta and British Columbia (BC).[3] To date, published direct measurements of non-producing wells in both provinces were made at only 230 wells, of which 20 are orphan.[1,3,4,5] The lack of direct measurements contributes to the high uncertainty in methane emissions from non-producing and orphan wells in national greenhouse gas inventories.[1,3,4] It also makes it unclear if the conclusions from the US study[2] are applicable to Canada.

Previous studies have also found that the distribution of methane flow rates from non-producing wells is highly skewed with a small proportion of wells dominating emission factors and total emissions,[1,3] highlighting the need for a faster detection method capable of detecting these higher emitters. Aerial surveys, especially using helicopters, have received a growing interest since they can conduct tens of site-specific measurements per day without being limited by ground access, as opposed to labour- intensive ground measurements.[6] However, the detection limit of helicopter surveys is much higher,[7] accentuating the need for a hybrid methodology combining accuracy of ground quantification with the spatial reach of aerial surveys.

To understand if orphan wells present higher methane emissions than other non-producing wells, we develop a database of measurements at 378 wells, including 143 orphan wells, in Alberta and BC. We also present a helicopter survey deployed at 191 orphan wells in Northern Alberta to compare emissions estimates using a ground-measurement methodology versus a hybrid, ground- and helicopter- measurement method.

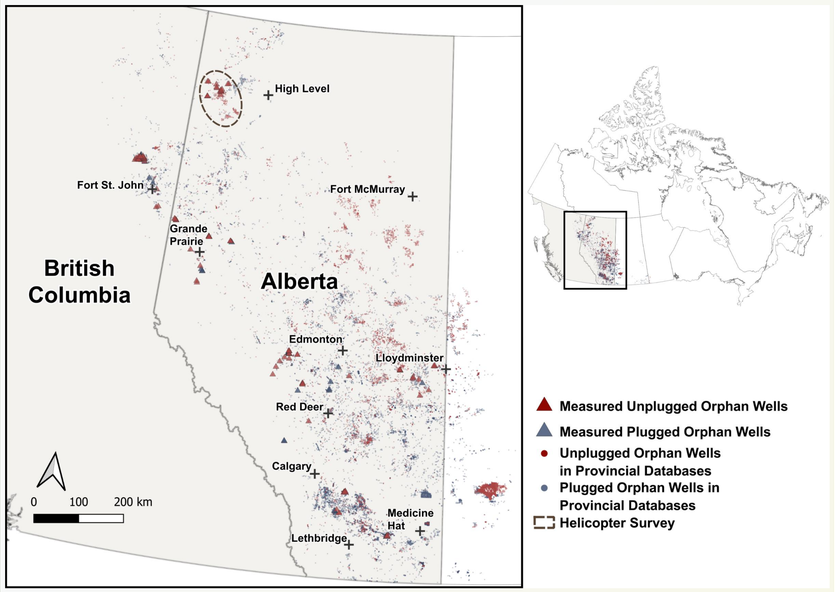

Figure 1: Orphan wells measured (Including in this study) and available in provincial databases in Alberta and BC. Unplugged wells are shown in red, plugged wells in blue. Approximate area of the helicopter survey is outlined by the dashed line.

Methods

Site selection

- We selected high well-density areas using provincial well-location data and visual inspection of density maps
- We prioritized sites with landowner permission (private land) and vehicle access (Crown Land)
- We deployed helicopter surveys in remote northwestern Alberta where ground access and prior measurements were limited [Figure 1]

Measurement methodology

1. Ground measurements done with direct static-chamber measurements performed separately at the wellhead and surface casing vent (SCV) at each site. High-flow sampler, and flowmeter measurements at SCVs of a subset of sites.
2. Seven helicopter flyovers in a grid pattern using the Airborne LiDAR Pipeline Inspection System (ALPIS) from Lasen Inc. [New Mexico, US]. The system outputs the following detection categories: no detection, small, medium, or large.

Ground measurements of methane flow rates

From 143 ground measurements at orphan wells, we found a methane flow rate distribution ranging from -1.2×10^1 to 3.9×10^7 mg/h . The mean flow rate of orphan wells measured in Alberta (1.6×10^5 mg/h) was two orders of magnitude higher than in BC (6.0×10^3 mg/h). We note that the geographical distribution of orphan and non-orphan wells across Alberta and BC are different with some regions having more measured orphan wells and others having more measured non-orphan wells.

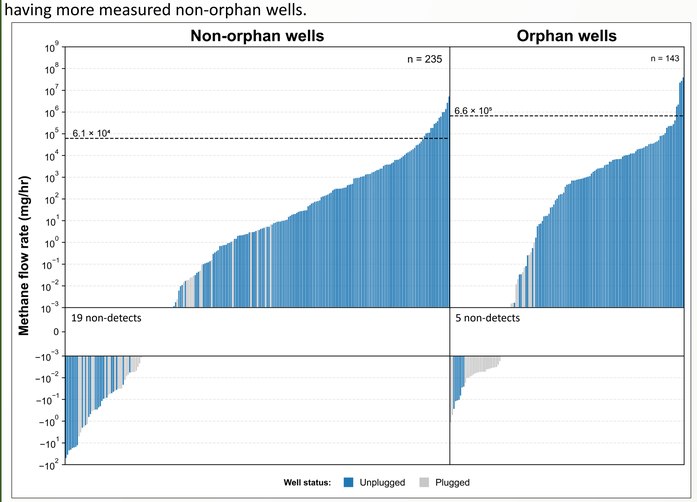

Figure 2: Measured methane flow rates by well status for orphan and non-orphan wells. The dotted line represents the mean flow rate of each dataset.

We found one order of magnitude difference between the mean flow rate from orphan wells (6.6×10^5 mg/h) and non-orphan wells (6.2×10^4 mg/h), when the measurements were not disaggregated by well attributes. Our dataset of orphan wells is also more skewed with 99% of total methane emissions coming from 8% of wells, compared to 11% for non-orphan wells.

Well attributes

We looked at the distribution of different attributes of both our orphan and non-orphan wells dataset to explain the observed difference in mean methane flow rate.

- **Status**: Our dataset of orphan wells contains slightly more abandoned wells.
- **Type**: Gas wells represent a greater portion of our orphan dataset.
- **Deviation**: Our dataset of orphan wells contains fewer vertical wells and more deviated wells.
- **Age:** Both datasets have a similar average age at measurement with 32 years for orphan wells and 30 years for non-orphan wells.
- **Depth**: Our non-orphan wells dataset contains more shallow wells in the 500-750 m depth range. However, the average well depth is similar for both datasets, 1570 m for orphan wells and 1510 m for non-orphan wells.

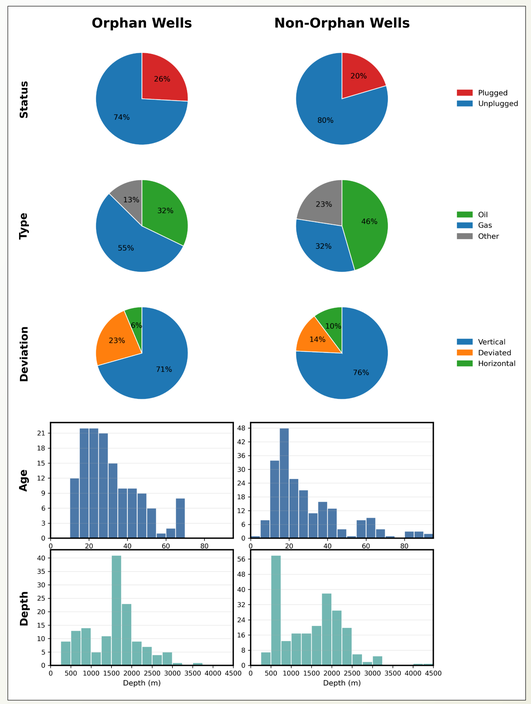

Figure 3: Attribute distribution of the orphan and non-orphan well datasets

Helicopter methane detections

Of the 191 orphan wells surveyed, ALPIS detected methane at 25 sites: 8 small (4%), 2 medium (1%), and 15 large (8%); 166 wells (87%) were non-detects. 18 of the helicopter-surveyed wells were also measured on the ground within two weeks [Figure 4]. Using the results of these paired measurements and 90 controlled releases,[7] ALPIS small detections corresponded to a mean flow rate of $\sim 3.1 \times 10^5$ mg/h. We note that both the paired measurements and controlled releases were conducted in regions that may not be representative of all orphan well sites.

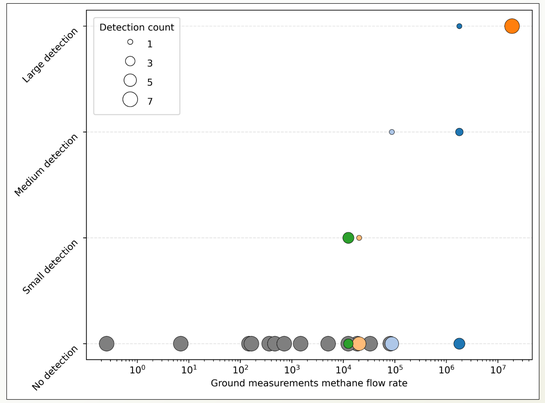

Figure 4: Helicopter detection results of the 18 wells measured on the ground.

Provincial methane estimates

We estimated methane emissions for Alberta and BC using (1) ground measurements only and (2) a multi-scale approach combining helicopter screening with ground quantification. Case 1 yields 68 kt/yr (29-120 kt/yr) and Case 2 yields 60 kt/yr (33-93 kt/yr). Both scenarios are at least twice the Environment and Climate Change Canada (ECCC) estimate of 31 kt/yr (18-50 kt/yr), but one-third of the estimate from Klotz et al. (210 kt/yr) [Figure 5].

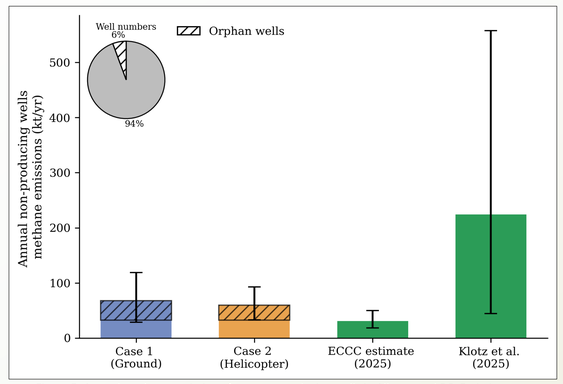

Figure 5: Annual methane emissions from non-producing wells in Alberta and BC. Emissions are separated by orphan status.

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