January 24, 2025

VIA ELECTRONIC SUBMISSION & ELECTRONIC MAIL
California Air Resources Board
Landfill Methane Regulation
LMR@arb.ca.gov

RE: Recommendations for Revisions to the Landfill Methane Regulation from Californians Against Waste, The Environmental Integrity Project, RMI and Industrious Labs.

To Whom It May Concern,

Californians Against Waste, The Environmental Integrity Project ("EIP"), RMI, and Industrious Labs ("Commenters") respectfully submit the following comments to the California Air Resources Board ("CARB") to facilitate and improve revisions to the Landfill Methane Regulation ("LMR")[1].

We hope that CARB will consider and include these recommendations in the anticipated LMR revisions. Specifically, we recommend that CARB:

- Better define certain terms in the 2010 LMR and include additional defined terms;
- Update and improve surface emission monitoring in several ways:
  - Reduce the surface methane concentration threshold;
  - Ensure monitoring occurs only during normal atmospheric pressure conditions;
  - Include the UAS OTM-51 method as an allowed alternative to SEM;requirements, subject to all appropriate limitations in EPA's ALT-150 Letter;
  - Include a specific process for approval of alternative test methods;
  - Require that SEM be conducted via drones or similar advanced monitoring technologies, and require that this monitoring occur biweekly instead of quarterly;
  - Improve walking pattern and other requirements when Method 21 walking SEM is used; and
  - Improve recordkeeping and reporting requirements.
- Require fenceline monitoring;
- Establish a super emitter response program;

[1] Cal. Code Regs. tit. 17§§ 95460-95476 (2010).

- Improve requirements for the gas collection and control system:
    - Address gas collection and control system downtime by treating 5 days of downtime as a violation;
    - Include improved requirements to address emissions from the active face;
    - Include requirements that would reduce the number of flooded wells;
    - Harmonize the revisions with federal requirements and include additional requirements;
    - Consider requiring remote wellhead tuning technologies; and
    - Require earlier installation of systems.
- Strengthen and streamline landfill cover requirements;
    - Set minimum standards for cover material, especially alternative daily cover; and
    - Consider biocovers in certain circumstances.
- Ban recirculation practices; and
- Require site-specific component leak monitoring and repair plans.

We are available to answer any questions and/or provide additional information as requested. We appreciate this opportunity to provide comments.

I. Background

A. Municipal solid waste landfills produce a significant amount of methane emissions

Municipal solid waste ("MSW") landfills are the third largest source of anthropogenic (human-caused) methane emissions in the United States. Methane is a powerful climate-altering greenhouse gas with about 80 times the global warming potential of carbon dioxide over a 20-year time period. [2] Landfills are estimated to be the third largest source of methane emissions in the U.S. in 2022.[3] However, emissions are likely even higher, where the Greenhouse Gas Reporting Program ("GHGRP") overestimates the performance of landfill gas capture systems and is not including large methane plumes captured in aerial surveys.[4]

[2] Intergovernmental Panel on Climate Change ("IPCC") *Climate Change 2021: The Physical Science Basis* 1017. (2021), https://report.ipcc.ch/ar6/wg1/IPCC_AR6_WGI_FullReport.pdf .
[3] EPA, *DRAFT Inventory of Greenhouse Gas Emissions and Sinks: 1990-2021* ES-13 (2024), https://www.epa.gov/system/files/documents/2024-02/us-ghg-inventory-2024-main-text.pdf
[4] *See* Revisions and Confidentiality Determinations for Data Elements Under the Greenhouse Gas Reporting Rule, 88 Fed. Reg. 32852, 32860, 32877-9 (proposed May 22, 2023) (to be codified at 40 C.F.R. pt. 98).

B. California landfills produce the second highest reported methane emissions in the country.

California ranks second in the nation for estimated methane emissions from MSW landfills. The waste sector is the second largest methane source in California.[5] California's municipal solid waste methane emissions in 2023 are estimated at about 22 million metrics tons of CO_2 equivalent[6]: about the same as 1.3 million passenger cars driven for a year In California.[7]

Communities of color are disproportionately impacted by health-harming air and water pollution. Landfill methane is also a precursor for tropospheric ozone and is co-emitted with hazardous air pollutants and volatile organic compounds (e.g., benzene, vinyl chloride) that harm public health.[8] The grave health impacts of landfills aren't felt proportionately. Of California's highest-emitting landfills (those that report estimated methane emissions higher than 500,000 tons of carbon dioxide equivalent, which are the top nine out of 300 active and closed landfills):

- 90% of the highest-emitting landfills are in communities with larger Black, Indigenous, or People of Color ("BIPOC") populations than the national average.
- 70% of the highest-emitting landfills are in communities where more than half the residents are BIPOC.[9]

Accordingly, California MSW landfills' emissions are not only producing dangerous, climate-altering methane emissions, but they're also negatively impacting surrounding communities' health.

1. Enhanced monitoring techniques and flyovers show that reported methane and NMOC emissions are likely higher

A recent study[10], published in the journal *Science*, led by Carbon Mapper scientists alongside researchers from NASA Jet Propulsion Laboratory, Arizona State University, University of Arizona, Scientific Aviation, and the U.S. Environmental Protection Agency ("EPA") (hereinafter "the 2024 Carbon Mapper study"), provides the largest comprehensive

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[5] California Air Resources Board, *Potential Updates to the Landfill Methane Regulation*, Public Workshop (Dec. 18, 2024) at 7 *available at* https://ww2.arb.ca.gov/sites/default/files/2024-12/Staff_Presentation_on_Potential_Updates_to_the_Landfill_Methane_Regulation.pdf [hereinafter "CARB 2024 LMR Workshop"].

[6] Data from EPA Greenhouse Gas Reporting Program based on a 20-year global warming potential for methane.

[7] Calculated utilizing: U.S. EPA Greenhouse Gas Reporting Program (GHGRP) 2022; EPA, *Landfill Methane Outreach Program (LMOP)* (July 2023). EPA, *GHG Equivalency calculator*, *available at* https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator.

[8] EPA LMOP, *Frequent Questions about Landfill Gas*, https://www.epa.gov/lmop/frequent-questions-about-landfill-gas#whatcomponents (last visited Jan. 22, 2025).

[9] Statistics derived from CalEnviroScreen 4.0, https://oehha.ca.gov/calenviroscreen/report/calenviroscreen-40 (last visited April 2024). Landfill geographic points are derived from the EPA, Greenhouse Gas Reporting Program (GHGRP) 2022 and EPA, Landfill Methane Outreach Program (LMOP) (July 2023).

[10] Cusworth, D. et al., "Quantifying methane emissions from United States landfills," *Science* (March 28, 2024) *available at* https://www.science.org/doi/10.1126/science.adi7735

assessment of hundreds of U.S. landfills using direct observations through airborne surveys. The study reveals the outsized impact of landfill point source emissions, which are responsible for a disproportionately large share of pollution. The Carbon Mapper study also sheds light on potential gaps in traditional model-based emission accounting methods that may benefit from sustained direct measurement using emerging surface-, air-, and space-based monitoring technologies.

2. Key findings of the 2024 Carbon Mapper Study

Carbon Mapper et al. found that "evaluating this large data set yielded insights that site owners and operators, policymakers, regulators, and civil society can use to better assess and act on landfill emissions."[11] Fifty-two percent (52%) of surveyed landfills had observable point source emissions, which far exceeds the 0.2% to 1% detection rate observed for super-emitters from surveyed oil and gas infrastructure in California and the Permian Basin.[12] Generally, landfill point source emissions are more persistent compared to their counterparts in oil and gas production. For those landfills with observed emissions, 60% had emissions that persisted over months or years.[13] These persistent emissions totaled 87% of all quantified emissions in the study.[14] Comparatively, the majority of methane super-emitters in the oil and gas sector are related to irregular, short-duration events.[15]

The 2024 Carbon Mapper study also found significant gaps in landfill leak detection and quantification protocols. Advanced monitoring strategies, such as remote sensing from satellites, aircraft and drones can provide a more accurate picture of landfill methane emissions than walking surface emission monitoring ("SEM"). When combined with improved ground-based measurements, remote sensing can provide consistent, comprehensive measurements to better inform models, guide mitigation efforts and verify emission reductions.

Finally, the 2024 Carbon Mapper study also found little agreement with reported and quantified emissions at U.S. landfills, indicating that current methods used to report facility emissions, such as the EPA's GHGRP, are missing or misrepresenting large sources of methane.[16] On average, Carbon Mapper found that aerial emission rates were 1.4 times higher than GHGRP.[17].

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[11] Carbon Mapper, *Study finds landfill point source emissions have an outsized impact and opportunity to tackle U.S. waste methane* (March 28, 2024), https://carbonmapper.org/articles/studyfinds-landfill [hereinafter "2024 Carbon Mapper News Release"].
[12] *Id*.
[13] *Id.*
[14] *Id.*
[15] *Id.*
[16] *Id*.
[17] *Id*.

3. CARB and Carbon Mapper 2023 Study

As detailed in the CARB Summary of 2020, 2021 and 2023 Airborne Methane Plume Mapping Studies,[18] CARB partnered with the University of Arizona, and in 2021 partnered with Carbon Mapper to conduct plume mapping flights over the state, resulting in the detection of 502 methane plumes from oil and gas and landfills.[19] CARB shared the findings with operators in the form of "incidence reports," and operators were asked to follow up and identify the source of emissions, if possible, and report their findings to CARB.[20] The report noted that operators were generally responsive, but that the response time was slow—particularly for landfills.[21] The report states, "Additional regulatory language could address operator response rate, response speed, and response quality as well as consider if there are additional sources that need to be covered."[22] CARB further states:

> Finally, there are co-benefits of using this technology to initiate leak repairs. In addition to methane, which is non-toxic, oil and gas developments and landfills are known to emit hazardous air pollutants (HAPs), which can cause acute and chronic health problems. Furthermore, exposure to these emissions is not equally shared by all people; indeed, disadvantaged communities often suffer from higher exposures to these co-emitted pollutants. Therefore, using this technology to initiate rapid repair of high-emitting sources can have a co-benefit of reducing pollutant exposure for affected communities.[23]

CARB already acknowledges the importance of plume mapping in detecting both HAP and methane emissions quicker. Therefore, the revisions to the LMR should include advanced technologies that identify earlier emission exceedances and also include more robust requirements that corrective action is required sooner.

C. Issues with current SEM requirements

Traditional surface-based surveys with handheld methane sensors provide an incomplete picture of emissions. SEM has several limitations, including, but not limited to[24]:

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[18] CARB, *Summary Report of the 2020, 2021, and 2023 Airborne Methane Plume Mapping Studies* (April 2024), *available at* https://ww2.arb.ca.gov/sites/default/files/2024-04/2020-2021-2023%20Airborne%20Summary%20Report_FINAL.pdf [hereinafter "2024 CARB Summary Report"].
[19] *Id*. at 4.
[20] *Id*.
[21] *Id.*
[22] *Id*. at 24
[23] *Id*.
[24] The list below was identified in a 2024 EPA enforcement alert for MSW landfills. This alert reminds MSW landfill owners and operators of their Clean Air Act obligations and notes where EPA has found recurring compliance issues, leading to significant releases of methane and other air pollutants. EPA, *Enforcement Alert: EPA Finds MSW Landfills are Violating Monitoring and Maintenance Requirements* https://www.epa.gov/enforcement/enforcement-alert-epa-finds-msw-landfills-are-violating-monitoring-and-maintenance (last visited Nov. 21, 2024) [hereinafter "2024 EPA MSW Landfill Enforcement Alert"].

- Inspectors failing to follow the prescribed method for determining compliance with the surface methane standard, Method 21[25]:
    - Variations from prescribed methods (sampling time, sampling speed and instrument calibration);
    - Subjectivity (identification of areas of potential emissions outside of the prescribed path); and
    - Areas excluded from monitoring (improperly excluding areas from monitoring as "dangerous" and regular side slopes).[26]
- Sensitivity to environmental conditions (e.g. atmospheric pressure).

Furthermore, traditional SEM surveys are physically demanding with many miles of walking and potential hazards for technicians (e.g. terrain, weather conditions, and exposure risks). Due to these limitations, traditional SEM surveys miss methane leaks that could be mitigated, and there is often a disconnect between the results of walking surveys and those conducted with more advanced, automated monitoring methods or by federal or state enforcement personnel.

For example, aerial surveys conducted were able to detect significant methane plumes coming from the landfill's active working face ("active face" or "working face," which Commenters define as where the waste is being disposed on a regular basis, including both areas of the landfill with uncovered waste and areas of the landfill under daily cover), an area currently excluded from SEM due to safety concerns.[27] Surveys in the United States and Canada show active face emissions can represent 60-79% of total site emissions, meaning SEM effectiveness would top out at 21-40% of emissions.[28] In addition, Flux Lab commented on the detection performance of walking SEM relative to advanced detection technologies in recent controlled release experiments, noting that "through all of the SEMs we did, we only had one positive indication despite the fact that there were definitely a lot of leak sources active."[29] In his presentation in the 2024 CARB LMR Workshop, Dr. Risk attributed this to the wide spacing, lower resolution, lower sensitivity, and the human dimension of walking SEM, as described in **Figures 1 and 2** below:[30]

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[25] This is a method for determination of VOC leaks from process equipment using a portable instrument to detect. EPA, *Method 21* (Aug. 3, 2017), https://www.epa.gov/sites/default/files/2017-08/documents/method_21.pdf (last visited November 21, 2024).

[26] *See* Scarpelli, Tia et al., "Investigating Major Sources of Methane Emissions at US Landfills," *Env't Science Tech.* (November 29, 2024), 58, 49, 21545–21556, *available at* https://doi.org/10.1021/acs.est.4c07572.

[27] *Id.*; Risk, Dave, "Advanced Leak Detection Technologies for Landfill Methane," (2024), at slide 18, *available at* https://ww2.arb.ca.gov/sites/default/files/2024-12/Session-2_FluxLab.pdf

[28] Risk, Dave, *Advanced Leak Detection Technologies for Landfill Methane* (December 18, 2024), 18, *available at* https://ww2.arb.ca.gov/sites/default/files/2024-12/Session-2_FluxLab.pdf

[29] Recording: Public Workshop on Potential Updates to the Landfill Methane Regulation, held by CARB (Dec. 18, 2024) at 1:52:00, https://www.youtube.com/watch?v=NCXHDOZIH44; *See Id.*

[30] Risk, Dave, *Advanced Leak Detection Technologies for Landfill Methane* (December 18, 2024), 18-19, *available at* https://ww2.arb.ca.gov/sites/default/files/2024-12/Session-2_FluxLab.pdf.

Figure 1: Walking SEM coverage findings from Dave Risk 2024 CARB LMR Presentation

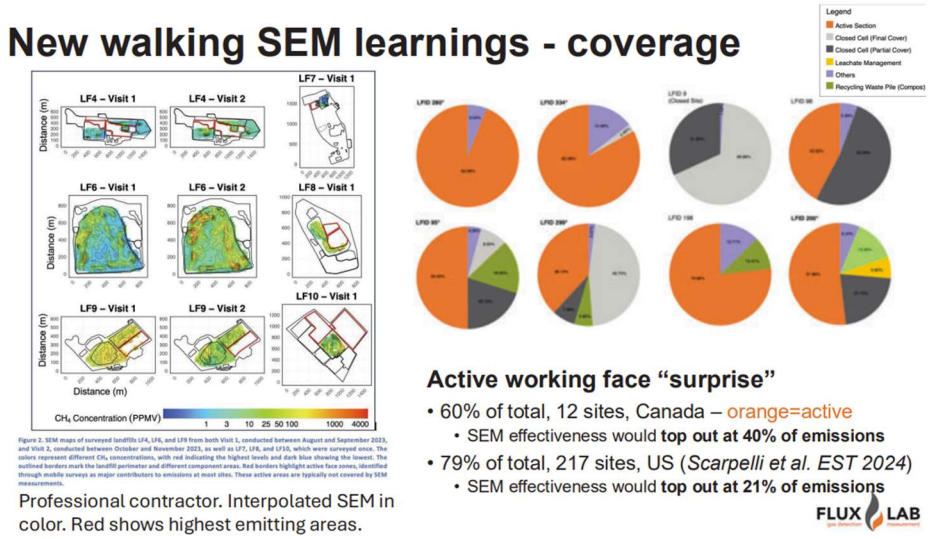
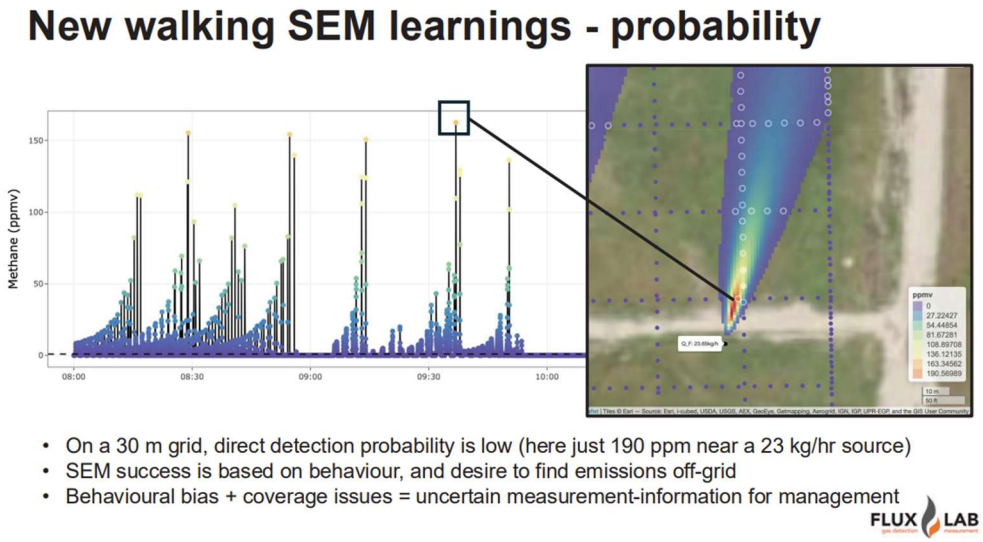


Figure 2: Walking SEM probability from Dave Risk 2024 CARB LMR Presentation



D. Developments in enhanced monitoring

Recent advances in methane monitoring technology — from satellites to aircraft to drones to fixed sensors — are transforming landfill operators' ability to detect, locate, and reduce their emissions in real time. CARB acknowledged in the 2024 Workshop that they demonstrated the capability of airborne imaging technology to detect methane plumes and quickly pinpoint large emissions that supports timely mitigation on the ground.[31] There are now dozens of companies — often originating from the oil and gas sector — that provide equipment and/or

[31] CARB 2024 LMR Workshop at 10.

services for methane detection at landfills.[32] The presentation from Dave Risk of Flux Lab notes that at least 98 advanced leak detection technologies and methodologies exist.[33]

In recently released white papers published online, EPA includes a review of aerial technologies and approaches, identifying remote sensing[34] and direct sampling[35] as new technologies used to monitor landfill methane emissions. EPA also notes that satellite and aircraft remote sensing technologies can detect and quantify methane emissions quicker than direct sampling methods and spatial resolution of remote sensing highlights large point source emissions making them more visible.[36] EPA also notes that direct sampling (in-situ) methods are less susceptible to weather conditions like cloud cover and solar reflectance and can better capture point and diffuse area sources of methane, which gives a more accurate representation of overall methane emissions from a site.[37] EPA also published a white paper on unmanned aircraft system ("UAS") technologies that can be used to monitor surface methane emissions.[38] Finally, in another white paper, EPA also includes case studies and recommendations for how fenceline monitoring could be required at MSW landfills.[39] CARB should approach the LMR revisions by considering all of these enhanced monitoring options together—aerial monitoring, UAS, and fenceline monitoring—to better identify and quantify methane emissions from MSW landfills.

Moreover, as described above, imaging spectrometers on aircraft and satellites have surveyed hundreds of landfills across the United States, identifying and quantifying large emission events and prompting successful mitigation activities. Some landfill operators are also integrating near-ground advanced methane monitoring technologies into their operations, using drone surveys or rovers to monitor for areas of elevated methane concentration and inform leak repairs and operational decisions. SnifferDRONE already deploys its technology at more than 150 landfills, and the method has been approved by EPA as an alternative test method for

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[32] *See See also* EPA, LMOP Webinar: Detecting Landfill Methane Emissions with Drones (Sept. 28, 2023), *available at* https://www.epa.gov/system/files/documents/2023-10/lmop_webinar_september_28_2023.pdf [hereinafter "LMOP Drone Webinar"].

[33] Risk, Dave, *Advanced Leak Detection Technologies for Landfill Methane* (Dec. 18, 2024), 20, *available at* https://ww2.arb.ca.gov/sites/default/files/2024-12/Session-2_FluxLab.pdf

[34] "Remote sensors measure reflected and scattered radiation from the Earth's surface to determine the concentration of methane (column-based concentration) without direct sampling of atmospheric gases. This category can be further divided into approaches that use remote sensors on 1) aircraft or 2) satellites." EPA, *White Paper Series: Municipal Solid Wate Landfills-Advancements in Technology and Operating* Practices, "Aerial Monitoring for Examining Landfill Methane Emissions" (October 2024), 2 [hereinafter "Aerial Monitoring White Paper"].

[35] "Aircraft are used to directly sample "in-situ" atmospheric gases and measure methane using an onboard sensor (e.g., cavity ring down spectrometer (CRDS)." *Id.* at 2.

[36] *Id.* at 6.

[37] *Id.* at 7.

[38] EPA, *White Paper Series: Municipal Solid Waste Landfills-Advancements in Technology and Operating Practices*, "Unmanned Aircraft Systems (UAS) Technologies for Landfill Methane Monitoring"(Dec. 2024) [hereinafter "UAS White Paper"].

[39] *See* EPA, *White Paper Series: Municipal Solid Waste Landfills – Advancements in Technology and Operating Practices*, "Fenceline Monitoring" (Dec. 2024) [hereinafter "Fenceline Monitoring White Paper"].

SEM.[40] In addition, fixed sensor systems positioned across the landfill surface or along the perimeter can provide methane concentration data continuously, helping operators address leaks in real time and evaluate emissions trends over time.[41]

Below, are several examples of how advanced monitoring technologies can provide timely, actionable data for leak detection and repair and to guide and assess best management practices. Relative to walking methods, these technologies can provide greater coverage of the landfill surface, improve worker safety and efficiency, provide more frequent data, and ensure objectivity and transparency.

- **Aerial and satellite remote sensing**: At Sunshine Canyon Landfill in California, aerial flyovers by Carbon Mapper detected large methane plumes from intermediate cover slopes during overpasses in 2016.[42] The landfill then updated its infrastructure and made several changes to the landfill cover and gas collection system to reduce landfill emissions.[43] Subsequent overpasses in 2017 observed a marked decrease in methane emissions (and concurrent increases in landfill gas ("LFG") collection), and these results were validated by fewer neighborhood odor complaints.[44] Through its 2020, 2021, and 2023 Airborne Methane Plume Mapping Studies, CARB documented other examples of successful voluntary leak repairs, prompted by aerial observational data.[45] Current and planned satellite constellations – such as MethaneSAT, GHGSat, and Carbon Mapper/Planet, have the capability to scan large areas and identify high-emission events at frequent cadences, such as days to weeks.[46] California allocated $100 million in funding to support a constellation of satellites that can monitor for large methane plumes to inform and verify fast mitigation.[47]
- **Drones and automated ground-based approaches**: In lieu of walking SEM, operators can use a drone-based alternative test method (OTM-51/ALT150) with a methane detection payload on a drone, coupled with a ground-level-to-drone sampling system. Sniffer Robotics is the only commercial provider that meets these requirements at this time. Drone-based systems can provide operators with more timely, comprehensive, and

[40] Letter from Steffan Johnson, EPA, Office of Air Quality Planning and Standards to David Barron, Sniffer Robotics, LLC (Dec. 15, 2022) at 8-9 *available at* https://www.epa.gov/system/files/documents/2022-12/Barron%20Sniffer%20Alt%20with%20OTM%2051%20attached_signed.pdf [hereinafter "OTM-51 Approval Letter"].
[41] *See* Fenceline Monitoring White Paper.
[42] *See also* Aerial Monitoring White Paper at 3-4.
[43] Earthdata, *From Cow Manure to Landfills: Mapping Methane in California,* https://www.earthdata.nasa.gov/news/feature-articles/from-cow-manure-landfills-mapping-methane-california (last ipdated Dec. 15, 2024).
[44] *Id.;* Ayandele, Ebun et al., RMI, *Key Strategies for Mitigating Methane Emissions from Municipal Solid Waste* (2022), *available at* https://rmi.org/insight/mitigating-methane-emissions-from-municipal-solid-waste/
[45] 2024 CARB Summary Report at 13-17; *See also* Aerial Monitoring White Paper at 3-4.
[46] *See also* Aerial Monitoring White Paper at 4-5.
[47] Press Release, CARB, California launces international methane-reduction iniative during climate week, (Sept. 20, 2023), *available at* https://ww2.arb.ca.gov/news/california-launches-international-methane-reduction-initiative-during-climate-week.

objective data to inform mitigation activities while keeping workers safe. Additionally, there are methane-detecting drone methods that sample at elevation, either through active imaging (e.g., open-path TDLAS Pergam sensors) or in-plume sensing (e.g., closed-path TDLAS by SeekOps or OA-ICOS by ABB). These drone methods can help identify leaks and inform operational decisions, such as where to expand the gas collection system or improve cover materials.[48] For example, San Bernardino County and Orange County conduct leak surveys with methane-detecting drones at their landfills.[49] Other landfills are automating leak detection with small rovers equipped with methane sensors that traverse the surface (e.g., Specialized Robotic Solutions, HATS Consoar).[50]

- **Continuous monitoring and real-time data**: There are several kinds of continuous monitors, from laser-based systems with reflectors (e.g., LongPath, Boreal Laser) to in-plume sensors (e.g., SOOFIE, Qube, Sensirion) to eddy covariance towers (e.g., Li-COR) that can measure methane across the landfill surface, downwind of the facility, or along the perimeter/fenceline. During the industry panel at EPA's Fall Technology Conference, WM, Republic Services, and GFL mentioned deployment of fixed sensors for high-frequency monitoring and to support odor management.[51] EPA's fenceline monitoring white paper includes a case study of Arbor Hills Landfill in Michigan, which as part of an agreement with the Michigan Department of Environment, Great Lakes & Energy ("EGLE") installed and operates six monitoring stations along the perimeter of its facility, equipped with sensors for methane, hydrogen sulfide, and meteorological instrumentation.[52] The sensor data is available to the public online.[53]
- **Automated well-tuning systems:** These automated systems can take continuous measurements of LFG composition, flow, temperature, pressure, and liquid levels and make automated adjustments to the gas collection and control system ("GCCS") to increase methane capture and reduce fugitive emissions[54] In addition, continuous wellhead data can alert operators to other mitigation opportunities, such as remediating an area of damaged cover or de-watering a flooded well. Gas capture data can then verify

[48] LMOP Drone Webinar.
[49] Patino, Vania, "Drones take flight to tackle methane leaks at Orange County landfill," *Spectrum News 1* (Nov. 12, 2024), *available at* https://spectrumnews1.com/ca/southern-california/public-safety/2; Shackleton, Olivia, "SCS Develops 5-year landfill operations contract for California county," *Waste Today* (July 16, 2019), *available at* https://www.wastetodaymagazine.com/news/scs-five-year-landfill-operations-contract-california/
[50] Mann, Shelley, "Specialized Robotic Solutions robot can monitor surface emissions at landfills," *Waste Today* (February 23, 2024), *available at* https://www.wastetodaymagazine.com/news/specialized-robotic-solutions-robot-can-monitor-surface-emissions-on-landfills/ this article mentions california deployment; STAR grant is using autonomous rovers for SEM at CA landfills. EPA, *Grantee Research Project Results: Integrating Measurements Across Platforms to Feasibly Assess Emissions and Mitigation of Methane and VOCs from Landfills* (last updated April 28, 2023), *available at* https://cfpub.epa.gov/ncer_abstracts/index.cfm/fuseaction/display.abstractDetail/abstract_id/11433/report/0
[51] EPA, "MSW Landfill Technology Workshop-Presentation 3: Industry panel, *Regulations.gov*, (Dec. 9, 2024) *available at* https://www.regulations.gov/document/EPA-HQ-OAR-2024-0453-0016
[52] EPA Fenceline Monitoring White Paper at 4-6.
[53] GFL Environmental "Arbor Hills Landfill Air Monitoring," *available at* https://arborhillsmonitoring.com/Home/Index (last visited Aug. 6, 2024); *See also* EPA Fenceline Monitoring White Paper at 4-6.
[54] EPA, White Paper Series: Municipal Solid Wate Landfills-Advancements in Technology and Operating Practices, "Increasing Landfill Gas Collection Rates" (Oct. 2024), 10 [hereinafter "GCCS White Paper"].

the efficacy of mitigation activities. Companies providing this technology currently include LoCI Controls and Apis Innovation. LoCI Controls deploys its real-time data and control solution at more than 65 landfills, including several landfills in California, both private and county-owned.[55] More than 75 landfills in the U.S. and Canada are actively using Apis Innovation's automated wellhead tuning technology.[56]

As discussed further below, OTM-51 is available for CARB to incorporate into its test methods and procedures in the LMR. CARB should also create a streamlined process for allowing other alternative methods that can demonstrate quality assurance and quality control with SEM requirements. Additionally, many operators already utilize the technology above, which is demonstrated to detect emissions at landfills and should also be considered for inclusion in the revised LMR. Finally, fenceline monitoring requirements, when paired with more advanced monitoring technologies and a super emitter response program ("SERP"), could also better enable operators and regulators to measure emissions from MSW landfills. Subsections in Section II below will specifically address how CARB could integrate enhanced monitoring into the revised LMR.

II. Revisions CARB should make to the LMR.

We urge CARB to continue leading the regulatory landscape for landfill methane in its upcoming revisions to the LMR. Commenters appreciate and support many of the proposed concepts presented by CARB in its 2024 Workshop. Additionally, CARB can and should revise the LMR to be stricter and more innovative through enhancing SEM requirements, creating fenceline monitoring requirements, establishing a SERP, improving gas collection and control system requirements, streamlining and strengthening landfill cover requirements, banning recirculation practices and requiring site-specific component leak monitoring and repair plans. Specifically, by strengthening SEM requirements, including a SERP and requiring fenceline monitoring, CARB would be innovating an overall monitoring program for the landfill sector that could serve as a regulatory model that could be adapted as technology evolves and more information is gathered. All these recommended revisions to the LMR are discussed in greater detail in the following sub sections.

A. CARB should better define certain terms.

CARB could make meaningful improvements that are a very low lift by simply defining certain terms. CARB should use the following definitions, and include these as defined terms in a revised LMR:

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[55] Loci Methane Capture and Emission Reduction, "LoCI Controls Announces Methane Emission Reductions Across its Portfolio of Environmental Attribute Projects," (Dec. 5, 2024), *available at* https://locicontrols.com/loci-news/loci-controls-announces-methane-emission-reductions-across-its-portfolio-of-environmental-attribute-projects.
[56] *See* Apis, *MSW Landfill Technology Workshop-Presentation 10* (Dec. 9, 2024), *available at* https://www.regulations.gov/document/EPA-HQ-OAR-2024-0453-0018.

1. **Instantaneous measurement**: individual measurements of methane concentrations
2. **Zone-averaged measurement**: average concentration for each pre-determined zone area.
3. **Drone monitor**: unmanned aerial system carrying a methane detector capable of traversing the entire landfill with a detector sampling the surface.
4. **Penetration in cover**: wellhead, part of a gas collection or operation system, and/or any other object that passes through the landfill cover. Penetrations in the cover also include cracks or seeps that are not the result of an object passing through the cover. Examples of what is not a penetration for purposes of the LMR include but are not limited to: survey stakes, fencing including litter fences, flags, signs, utility posts, and trees so long as these items do not pass through the landfill cover.
5. **Leak (SEM):** any landfill surface or gas collection and control system component location where the measured methane concentration exceeds 200 ppmv using a hand-held methane detector; in the case of methane emissions measured as a path-integrated methane concentration, a location where the measured path-integrated concentration exceeds 200 ppm.

B. CARB should update SEM in several ways

As previously discussed, walking survey, grid pattern monitoring is insufficient to detect leaks. The White House National Strategy to Advance an Integrated U.S. Greenhouse Gas Measurement, Monitoring, and Information System, published in November 2023, states:

> [R]ecent airborne methane surveys suggest that emissions may be higher and more persistent than previously expected. Emissions of landfill gas to the air are determined in part by the design and operation of the gas collection and control system and the operational characteristics of the site. Factors such as flooded collection wells, cover integrity issues, planned maintenance activities, and equipment failures can result in elevated emissions compared to reported GHGRP estimates and can persist for extended periods of time. In many cases, the presence of preventable excess emissions that may require action cannot be known without some form of methane emissions measurement. Walking survey [SEM] required quarterly by Clean Air Act regulations are not able to detect all anomalous emissions at a landfill that occur over a large footprint, some extending for hundreds of acres.[57]

Additionally, as identified in the 2024 EPA Enforcement Alert, operators and their contractors are failing to comply with the SEM requirements in the federal Clean Air Act

[57] The White House, *National Strategy to Advance an Integrated U.S. Greenhouse Gas Measurement, Monitoring, and Information System* (Nov. 2023) at 50, https://www.whitehouse.gov/wp-content/uploads/2023/11/NationalGHGMMISStrategy-2023.

("CAA").[58] Specifically, EPA noted that "[r]ecent inspections also revealed widespread shortcomings in the SEM program at MSW landfills, including methane emissions at higher rates of exceedance, with many above 50,000 ppm, which is 100 times higher than the regulatory limit."[59] Issues such as monitoring speed and time, departing from the established path, expired calibration gas, and improperly excluding areas from monitoring were also documented by EPA.[60]

CARB can directly address these identified issues with SEM requirements in the revisions to the LMR by:

1. Reducing the SEM concentration threshold;
2. Requiring that SEM monitoring occurs only under normal atmospheric conditions;
3. Including the UAS OTM-51 method as an allowed alternative to SEM requirements, subject to all appropriate limitations in EPA's ALT-150 Letter[61];
4. Including a specific process for approval of alternative test methods;
5. Requiring that SEM be conducted via drones or similar advanced monitoring technologies, and require that this monitoring occur biweekly instead of quarterly;
6. Improving walking pattern and other requirements when Method 21 walking SEM is used; and
7. Improving recordkeeping and reporting requirements.

Each of these recommended improvements are discussed in further detail in the sections below.

1. Commenters support CARB's proposed concept to reduce the surface methane concentration threshold.

In its April 2023 proposed regulatory framework, Canada's regulatory agency, Environment and Climate Change Canada ("ECCC") proposed a 200 ppmv instantaneous surface emission threshold.[62] In 2009, CARB also proposed an instantaneous SEM standard of 200 ppmv.[63] Although ECCC did not propose the 200 ppmv standard in its draft regulations

[58] 40 C.F.R. §§63.1958(d), 63.1960(c)-(d). 2024 EPA MSW Landfill Enforcement Alert.
[59] *Id*.
[60] *Id*.
[61] OTM-51 Approval Letter. ALT-150 is approved as an alternative to requirements in 40 C.F.R. §§ 60.34f(d) and 60.36(c)-(e), which include the SEM operational standards and compliance provisions for monitoring following Method 21 performance evaluation requirements (in 40 C.F.R. § 60.36f(d)(3)). ALT-150 was approved by EPA on January 19, 2023. Recent Postings of Broadly Applicable Alternative Test Methods 88 Fed. Reg. 3408 (Jan. 19, 2023).
[62] ECCC, Reducing Canada's Landfill Methane Emissions: Proposed Regulatory Framework, Government of Canada, https://www.canada.ca/en/environment-climate-change/services/canadian-environmental-protection-actregistry/publications/reducing-landfill-methane-emissions.html [hereinafter "ECCC Proposed Regulatory Framework"].
[63] CARB, *Preliminary Concepts for Potential Improvements to Landfill Methane Regulation* (May 18, 2023) at 12, *available at* https://ww2.arb.ca.gov/sites/default/files/2023-05/LMR-workshop_05-18-2023.pdf.

issued in June 2024, ECCC did cite to the success of CARB's more than a decade long 25 ppmv integrated standard when discussing operators' concerns with this and the lower, 200 ppmv, SEM threshold.[64] As previously discussed, where ECCC initially considered proposing the standard that CARB considered previously, now is the time for CARB to reduce the 500 ppmv SEM threshold. Further, where CARB has found that landfills are already largely operating below 200 ppmv[65], it would be feasible to adjust the threshold below 500 ppmv to the originally contemplated 200 ppmv. We support CARB's proposed concept to reduce the threshold to 200 ppmv.[66] We also support the corrective action and re-monitoring timelines discussed.[67]

2. CARB should require that SEM occurs only under normal atmospheric conditions.

Higher methane emissions are directly associated with atmospheric conditions, like lower barometric pressure.[68] Studies conclude that "fluctuations in barometric pressure have a more pronounced correlation with landfill gas recovery than the absolute pressure values, highlighting the importance of changes in barometric pressure in determining LFG recovery efficiency."[69]

Accordingly, CARB should revise its SEM requirements to ensure that monitoring is conducted when atmospheric (also barometric) pressure is representative of normal site conditions[70]. Wellheads are operated with respect to atmospheric pressure. Therefore, short-term variability in the local pressure can impact the effectiveness of the GCCS, where the vacuum pressure is set monthly, and thus impacts surface emissions. Emissions decrease when atmospheric pressure rises and increase when the pressure falls.[71] Canada's ECCC cautions in

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[64] "Several stakeholders, including landfill operators and engineering consultants, expressed concerns related to proposed surface methane concentration limits and monitoring requirements. Although a requirement to maintain surface methane concentrations below 500 ppmv has been in place at landfills regulated in Quebec since 2009, an additional concentration limit is included in the proposed Regulations requiring that a "zone-average" surface methane concentration (the average of surface methane concentration measurements in a zone of no more than 4 500 m2) must not exceed 25 ppmv. This "zone-average" concentration limit has been implemented under California regulations since 2010 and is intended to represent the achievable average methane concentration for an active landfill gas recovery system." Env't and Climate Change Can., *Regulations Respecting the Reduction in the Release of Methane (Waste Sector)* (June 29, 2024) *available at* https://canadagazette.gc.ca/rp-pr/p1/2024/2024-06-29/html/reg5-eng.html [hereinafter "ECCC Proposed Rules"].

[65] CARB, *Preliminary Concepts for Potential Improvements to Landfill Methane Regulation* (May 18, 2023) at 12, *available at* https://ww2.arb.ca.gov/sites/default/files/2023-05/LMR-workshop_05-18-2023.pdf

[66] CARB 2024 LMR Workshop at 32.

[67] *Id*. at 35-36.

[68] GCCS White Paper at 5.

[69] *Id*. at 6.

[70] Although current Clean Air Act requirements stipulate that "[m]onitoring must be performed during typical meteorological conditions," the LMR does not contain this requirement. 40 C.F.R. §§ 60.35f(c)(3), 60.765(c)(3). Moreover, the recommendations included in this section would require operators to document that SEM occurred during normal operating conditions.

[71] James L. Hanson & Nazli Yesiller, Cal. Polytechnic State Univ., *Estimation and Comparison of Methane, Nitrous Oxide, and Trace Volatile Organic Compound Emissions and Gas Collection System Efficiencies in California Landfills* 22 (2020), https://ww2.arb.ca.gov/sites/default/files/2020-06/CalPoly%20LFG%20Flux%20and%20Collection%20Efficiencies%203-30-2020.pdf; Liukang Xu, et. al., *Impact of Changes in Barometric Pressure on Landfill Methane Emission*, 28 Glob. Biogeochemical Cycles 679, 685 (2014), https://doi.org/10.1002/2013GB004571.

technical guidance that SEM should not be conducted "[i]f atmospheric pressure is rising sharply or is considerably higher than the average for the area."[72] Therefore, SEM conducted during periods of elevated atmospheric pressure would result in atypical measurements.

Thus, CARB should ensure that SEM is conducted when barometric pressure is within the range of average daily variation at the site. Landfill operators should be required to (1) submit information showing this range; and (2) record and report the barometric pressure at the site during each sampling event to demonstrate that it is within the required range.

3. CARB should include the OTM-51 Method as an allowed alternative to SEM requirements.

As previously explained, via letter dated December 15, 2022, which is classified by EPA as ALT-150, EPA approved the UAS-based alternative method for SEM as Other Test Method 51 on its Air Emission Management Center ("EMC") Website.[73] EPA's December 15, 2022 letter in part, provides that OTM-51 is an approved alternative method to meet federal requirements under 40 C.F.R. Parts 60, 61 and 63 subject to certain limitations.[74]

Through ALT-150, EPA approved OTM-51 as an alternative or modification to SEM procedures required under, in part, 40 C.F.R. Part 60, Subparts WWW[75], XXX[76], Cf[77]; 40 C.F.R. Part 63, Subpart AAAA[78]; and 40 C.F.R. Part 62, Subpart OOO.[7980] Because of EPA's extensive record of reviewing numerous requests for alternatives and modifications to test methods and procedures, EPA identified that it is equitable and efficient to approve alternative test methods that are broadly applicable to a class, category or subcategory of sources.[81] Subsequently, in January 2023, EPA posted notice in the Federal Register of several of its alternative test method approvals: those issued between January 1, 2022 and December 31, 2022.[82]

Accordingly, CARB can and should incorporate UAS OTM-51 method, subject to all appropriate limitations and provisions explained in EPA's ALT-150 Letter, into the LMR revisions. By including this method, CARB makes clear that UAS-based monitoring is allowed

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[72] Env't and Climate Change Can., *Estimating, Measuring and Monitoring Landfill Methane-Technical Guidance Document* 30 (last updated April 17, 2023), https://drive.google.com/file/d/1fqods0nXDSEUEmZu7nnkHZwXfGtemWPr/view?usp=sharing [hereinafter "ECCC Technical Guidance"].
[73] The EMC website linking to the Approved Alternative Test Methods also links to the same ALT-150 Approval Letter. *See* EPA, EMC-Broadly Applicable Approved Alternative Test Methods, https://www.epa.gov/emc/broadly-applicable-approved-alternative-test-methods (last visited Dec. 11, 2023).
[74] ALT-150 Approval Letter at 1.
[75] 40 C.F.R. §§ 60.753(d), 60.755(c)-(e).
[76] 40 C.F.R. §§ 60.763(d), 60.755(c)-(d).
[77] 40 C.F.R. §§ 60.34f(d), 60.36f(c).
[78] 40 C.F.R. §§ 63.1958(d), 63.1960(c)-(d).
[79] 40 C.F.R. §§ 62.16716(d), 62.16720.
[80] EPA, Recent Postings of Broadly Applicable Alternative Test Methods, 88 Fed. Reg. 3408, 3409 (Jan. 19, 2023).
[81] *Id*.
[82] 88. Fed. Reg. 3408, 3409.

as an alternative for performing SEM.[83] In its recently updated landfill methane regulations, the State of Washington was the first state to explicitly allow the option of using ALT-150 for SEM, and ECCC is also proposing that ALT-150 be allowed in its SEM requirements.[84] CARB should follow Washington and Canada's examples.

4. CARB should include a specific process for approval of alternative test methods.

As discussed, the technology for enhanced monitoring with advanced technologies is rapidly evolving. CARB can and should accommodate these advances in technologies by prescribing a clear path and process for operators and/or technology vendors to seek approval for alternative test methods in its revised LMR. As described above, there are many technologies and methods that provide better spatial and temporal coverage of the landfill surface relative to walking SEM. CARB should swiftly approve monitoring approaches that demonstrate equivalent or better performance in methane detection, similar to Colorado's Alternative AIMM Program for the oil and gas sector[85], and publish test methods that describe the operating parameters and action thresholds that can be used by all landfills.

In revisions to federal New Source Performance Standards ("NSPS") for the oil and gas sector, EPA includes alternative test methods for methane detection technology and the process for seeking approval and the requirements such request must follow.[86] CARB should include this same or a similar provision in the revised LMR that explicitly allows for alternative test methods and provides a process for seeking approval of the alternative method.

CARB could further improve upon the oil and gas NSPS alternative test method provision and process by shortening the timeframe for determining whether the alternative test method is adequate. The NSPS allows 270 days[87], and CARB could likely realistically approve or disapprove alternative test methods within 100 days.

[83] Operators in California would benefit from this clarity. In its ALT-150 Approval Letter, EPA states that "[f]or subpart Cf of 40 CFR 60, which is an Emission Guideline to be used by delegated state and local authorities to develop an individual State Plan, the availability or applicability of this alternative method must be determined on a case-by-case basis." ALT-150 Approval Letter at 8. By specifically including this method in the LMR revisions, CARB eliminates the confusion of "case-by-case basis" in seeking approval from EPA to use the alternative method.
[84] UAS White Paper at 4.
[85] Colorado Dep't of Public Health and Env't, *Approved Instrument Monitoring Method (AIMM) for oil and gas*, *available at* https://cdphe.colorado.gov/oil-and-gas-compliance-and-recordkeeping/approved-instrument-monitoring-method-aimm-for-oil-gas (last visited Jan. 20, 2025).
[86] 40 C.F.R. § 60.5398b(d).
[87] 40 C.F.R. § 60.5398b(d)(1)(iii).

5. CARB should require bi-weekly SEM monitoring using advanced monitoring technologies.

As previously highlighted, EPA found that many MSW landfill operators and their contractors are failing to properly follow Method 21 walking SEM requirements.[88] Additionally, cost is a barrier to conducting walking SEM more frequently than once per quarter. EPA estimated that the annual cost for conducting quarterly walking surveys at 25 foot intervals was approximately $80,000 (2012 dollars) per year per landfill.[89] But with advanced technologies, operators can cost-effectively and safely monitoring multiple times per month, as EPA noted in its Aerial Monitoring White Paper: "[i]f aerial technologies could be used as a replacement for, or as a tool to reduce the frequency of manual (ground-level) surface monitoring events, they could result in lower labor costs and increased efficiencies."[90]

Additionally, CARB noted in the 2024 Workshop that "[r]esearch shows seasonal variability/intermittency" and that "[c]ompliance inspections have found leaks in areas after several years of no reported leaks."[91] However, CARB's proposed concept remains focused on requiring quarterly SEM monitoring. Where walking SEM is both expensive and can frequently fail to adequately measure surface emissions, CARB should consider requiring that SEM monitoring be conducted via advanced technologies biweekly instead of quarterly and cover the entire landfill surface area.

a. Requiring SEM monitoring with advanced technologies is more cost effective, safer and allows operators to monitor more of the surface of than landfill than walking SEM.

Advanced technologies for detecting and quantifying methane are generally cheaper than manual methods used in walking SEM. Specifically, satellite, aircraft, drone, and mobile truck methods range $3,000 to $14,000 per survey[92], and fixed sensors that take continuous measurements cost between $7,000-$30,000 annually.[93] In addition to potential cost savings and performance improvements, these advanced monitoring technologies also enhance workplace

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[88] 2024 EPA MSW Landfill Enforcement Alert.
[89] EPA, *Small Business Advocacy Review Outreach Briefing: MSW Landfill EG* (2015), slide 12, *available at* https://www.epa.gov/system/files/documents/2021-08/appendix-c-sbarpanel-landfills.pdf.
[90] "The current ground-based SEM is a labor-intensive process that requires personnel time and exposure to potentially hazardous conditions (e.g., slopes, inclement weather, animals, and pests). Using aerial technologies could reduce labor costs and reduce the hazards for personnel. The potential costs for using aerial technologies could be higher, at least initially, for landfill owners and operators purchasing access to aerial surveys; however, these costs could be offset if reductions in manual monitoring (i.e., Method 21) could be achieved as well as overall reduced costs (e.g., labor) while simultaneously reducing site methane emissions. Being able to rapidly detect methane emissions could allow for quicker responses to landfill methane leaks and ability to take remedial actions." Aerial Monitoring White Paper at 11.
[91] CARB 2024 LMR Workshop at 41.
[92] Flux Lab, *A Controlled Release Experiment for Investigating Methane Measurement Performance at Landfills-Final Report* (July 9, 2024) at 63-64, *available at* https://erefdn.org/product/a-controlled-release-experiment-for-investigating-methane-measurement-performance-at-landfills/ [hereinafter "2024 EREF Report"].
[93] *Id*.

safety while allowing landfill operators to monitor more of the surface of the landfill that are currently exempt from walking SEM, such as the active face and steep slopes. EPA also recognizes that using advanced technologies for SEM monitoring can increase operators' accessibility to real-time data that can be used to address onsite issues quickly and efficiently.[94]

CARB could immediately allow operators to conduct SEM monitoring with closed path drones using OTM-51 by including this method as an allowed alternative test method in the revised LMR. Additionally, creating an efficient process for approving alternative test methods would also allow operators to use other advanced technologies—like open path TDLAS or LiDAR, for example—to comply with the SEM monitoring requirements. In fact, ECCC is expected to finalize a method for using open path monitors in the near future[95] and other vendors and contractors are also actively exploring establishing test methods for their technologies.[96] CARB can and should include ALT-150 as a SEM procedure in Cal. Code Regs. tit. 17§ 95471(c). CARB can also create the process for approving alternative methods in this same section.

Although advanced monitoring technologies have known challenges,[97] walking SEM using Method 21 also has known challenges, cited by EPA in an enforcement alert. EPA notes that one of the major challenges faced by ECCC in finalizing a method for open path drone monitoring is the lack of available data sets for the technology and its use in measuring methane at landfills.[98] Because CARB is the leading innovator in the regulatory landscape for landfill methane regulation, this LMR revision process presents the perfect opportunity for CARB to continue to lead. CARB can and should communicate with ECCC and vendors on how they can finalize a downward-facing laser (open path) method. CARB is in a unique position to bridge the gap—both by explicitly allowing for an established method, ALT-150, and creating a process for approving alternative methods—and by continuing to create innovative requirements that reduce methane by working with ECCC, vendors and other stakeholders to develop methods for conducting SEM monitoring with advanced technologies.

Finally, CARB should also require that the bi-weekly SEM conducted with advanced technologies monitors all areas of landfill, including those exempted under current walking SEM requirements for "difficult to monitor" sections (such as steep slopes, stormwater drainage features, elevated infrastructure).

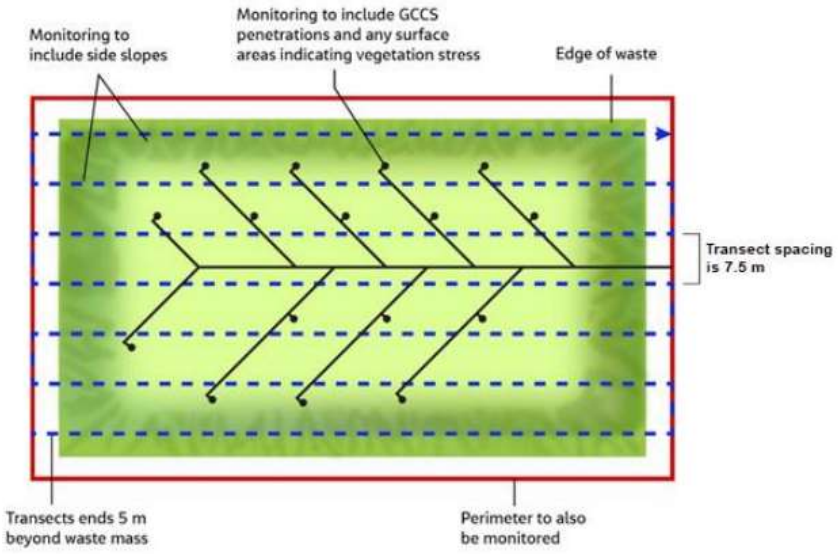
[94] UAS White Paper at 2.
[95] *Id.* at 4.
[96] *Id*.
[97] *See Id*. at 7-10.
[98] *Id*. at 10.

b. CARB should require more frequent—bi-weekly instead of quarterly—SEM monitoring with advanced technologies.

The federal CAA allows states to adopt alternative pollution standards or limitations and may also establish rules more stringent than the federal rules.[99] Therefore, in revising the LMR[100], CARB can require more frequent monitoring than the required quarterly SEM inspections in the federal standards.[101] Because several advanced technologies are demonstrated to be more cost effective than walking SEM and because these monitoring methods can survey more of the landfill, it is feasible for CARB to require that operators conduct SEM monitoring with advanced technologies bi-weekly (twice per month).

Additionally, CARB should require a scoping survey for SEM in addition to the existing requirement in the LMR that owners and operators to divide the entire landfill surface into individually identified zones of not more than 50,000 square feet and average path-integrated or surface methane concentrations calculated for each zone.[102] **Figure 3** below provides an example:

Figure 3: From ECCC Proposed Regulatory Framework: zone identification for walking SEM



The scoping survey should also require owners and operators to identify locations for drone set-up, pilot/observer base and take-offs and landings, potential obstructions (including overheard wires).[103]

[99] 42 U.S.C. § 7416.
[100] Which will be CARB's Section 111 plan to implement the federal Emission Guidelines.
[101] *See* 40 C.F.R. §§ 60.763(d), 60.764(a)(6); *see* 40 C.F.R. §§ 60.34f(d), 60.34f(a)(6).
[102] Cal. Code Regs. tit. 17 § 95471(c)(1). *See also* ECCC Proposed Regulatory Framework.
[103] ECCC Proposed Regulatory Framework.

Finally, for all SEM monitoring, CARB should require that for alternative methods approved in the future, the following criteria must be met:

1. **SEM should be conducted over more of the landfill**, including penetrations in cover and areas exhibiting potential stressed vegetation and visible cracks and ensuring that "difficult to monitor" areas are not being improperly excluded.
2. **If using an open-path drone-based measurement, CARB should require the development of monitoring plans that CARB must approve:** these monitoring plans should include:
    a. An upwind sampling location to measure background methane concentrations.
    b. Requiring drone surveys to be conducted at a moderate flight speed (not to exceed 4m/s), which is included in ALT-150.
    c. Require drones to be maintained at a consistent height above the ground using automated terrain. The height selected for the survey will be based on the methane detector specifications and site features, but should be as low to the ground surface as possible while still operating the drone safely, and with no downwash effects from the drone rotors.[104]
    d. Following ALT 150/OTM-51, drone operators must continuously monitor concentration readings from the methane detector on the drone
    e. Following ALT 150/OTM-51, provide for visual observation methods
        i. Use drone onboard camera
        ii. Operator must record instances of stressed vegetation, damaged landfill infrastructure or other indicators of methane emission.
        iii. The GPS coordinates and description of these conditions must be recorded.
        iv. These recorded areas should be monitored within the current SEM survey by temporarily deviating from the planned flight path.
3. SEM surveys must be conducted when GCCS is operating under normal meteorological conditions.
4. SEM surveys shall not be conducted when atmospheric pressure is rising sharply or considerably higher than the average for the area and shall be conducted under normal atmospheric pressure.
5. At the time of a drone-based SEM survey, operators should use a stationary anemometer or portable anemometer mounted on the drone to continuously collect and record wind speed (average and instantaneous) and record at 5-minute intervals.
6. SEM surveys must collect meteorological data, including atmospheric pressure, ambient temperature, weather conditions, date and time.
7. SEM surveys must collect monitoring data including the following information:
    a. Methane concentration in ppmv, recorded at 1 second intervals.
    b. Time stamped GPS coordinates at each sample location.

[104] ECCC Technical Guidance at 37.

c. Photographs of areas where elevated methane concentrations were measured.

6. Commenters support CARB's proposed concept to address landfills with a specified number of SEM exceedances.

In their December 2024 Workshop, CARB proposed a concept that when a landfill has greater than a specified number of SEM exceedances (e.g. ten (10) instantaneous or five (5) integrated exceedances during a three-year period), the operator would need to: increase monitoring frequency, perform cover integrity and collection system analyses and remediate issues discovered. Commenters support this approach.[105] However, we'd also urge CARB should consider persistent recurring SEM exceedances on an annual basis, as opposed to the three-year period presented. Because commenters are urging bi-weekly monitoring frequency as the SEM requirement, we would request that CARB require weekly monitoring for six (6) months for the "persistent emissions" standard.[106]

For the cover integrity analysis, CARB should require that operators conduct weekly cover integrity monitoring for six (6) months for landfills with a certain number of SEM exceedances within a year. In its recent enforcement alert, one of the compliance issues EPA noted was MSW landfill operators' failure to maintain adequate landfill cover integrity.[107] Therefore, it will be even more important that CARB requires more frequent monitoring of cover integrity when a landfill has a certain number of SEM exceedances in a year. Commenters plan to provide more detailed information at a later date to outline how landfills could have a more rigorous program to identify and correct cover integrity problems.

7. CARB should continue to require Method 21 measurements to verify detected exceedances and also include improvements to those procedures.

Although CARB should revise the LMR in Cal. Code Regs. tit. 17§ 95471 to include ALT-150 and allow for the use of advanced monitoring technologies, the Method 21 requirements under §95471(c) should still be included and strengthened. Specifically, CARB should revise the LMR to require Method 21 be used to verify detected exceedances with the enhanced monitoring technologies. Subsections (1), (2) and (3) in §95471(c) could also include additional requirements to ensure that the follow-up walking SEM inspections are performed correctly.

a. Where operators use walking SEM, CARB should improve walking pattern monitoring requirements.

SEM walking surveys consist of traversing the landfill surface following a pre-determined route, using a portable detector to measure methane concentrations immediately

[105] CARB 2024 LMR Workshop at 56.
[106] *Id.* at 57.
[107] 2024 EPA MSW Landfill Enforcement Alert.

above the ground surface. SEM walking surveys are helpful in identifying areas of fugitive emissions emanating through the landfill cover system from penetrations or fissures, leaks from the GCCS or leaks from other landfill infrastructure. However, as discussed above, the walking SEM requirements can be further improved to better quantify the methane concentrations on the surface of MSW landfills in California. The recommendations below highlight specific ways CARB can strengthen the walking SEM requirements.

First, CARB should decrease the spacing interval of the walking pattern to less than twenty-five (25) feet and include a walking speed (e.g. one meter per second (1 m/s)). By decreasing the pattern and specifying a walking speed, CARB could address deficiencies noted by EPA in their recent enforcement alert (e.g. if the pace on the serpentine path is too fast, the equipment will not have adequate time to identify an elevated concentration).[108]

Additionally, CARB's revisions should also account for inspectors not properly following Method 21 by reinforcing those requirements with additional recordkeeping requirements, as discussed more in Section II.B.6 below. CARB should also strengthen the requirements by requiring that the sampling inlet should be no more than five (5) centimeters from the surface.[109]

6. Improve recordkeeping, reporting and auditing requirements

First, Commenters support CARB's proposed concepts for applicability, reporting and other miscellaneous items that would require digital maps of infrastructure and monitoring results.[110] Commenters also support CARB's concept of determining the full extent of surface leaks.[111]

Additionally, CARB can further improve SEM by requiring more detailed and robust recordkeeping, reporting, and auditing requirements. These recommendations include:

- **All SEM monitoring readings must be reported and recorded:** Any reading exceeding the applicable limit must be recorded and reported as an exceedance. Operators must report all PPM readings with GPS location, and get approval from CARB for any deviation/excluded areas from the required walking path. The owner or operator must record the date, location, and value of each reading, along with retest dates and results if applicable. The location of each reading must be clearly marked and identified on the digital map, drawn to scale, with the location of both the monitoring grids and the gas collection system clearly identified.
- **Operators must submit a SEM report**: Any owner or operator who conducts SEM must include the following information in the annual report: date(s) of monitoring; location of the monitoring grid coordinates and of each reading, as well as coordinates of

[108] 2024 EPA MSW Landfill Enforcement Alert.
[109] ECCC Proposed Regulatory Framework.
[110] CARB 2024 LMR Workshop at 17.
[111] *Id*. at 38-40.

areas exempted from monitoring on a topographic map; measured concentration of methane in ppmv for each reading, exceedances, and all corrective actions taken.

- **For measurements performed with advanced technologies, must maintain records of**:
    a. Five (5) minute-interval anemometer readings
    b. Collected meteorological data
    c. Survey showing flight transects with path-integrated or surface concentration results and identifying results by concentration range or locations where concentrations exceed any applicable regulatory or action threshold
    d. Description of potential sources or causes of fugitive emissions at locations of elevated methane concentrations (e.g. leaking GCCS infrastructure, cover penetrations)
    e. Equipment calibration records.

Finally, CARB can further strengthen SEM and reduce methane emissions by improving the annual report requirements, which should include:

- records of all instantaneous surface readings of 100 ppmv or greater;
- all exceedances of the limits, including the location of the leak (or affected grid cell), leak concentration in ppmv, date and time of measurement, the action taken to repair the leak, date of repair, any required re-monitoring and the re-monitored concentration in ppmv, and wind speed during surface sampling; and
- the installation date and location of each well installed as part of a gas collection system expansion"

CARB should also require that the landfill owner or operator conducting SEM must submit an Instantaneous Surface Monitoring Report within thirty (30) days after the SEM monitoring survey and make this report available to the public.

C. CARB should require fenceline monitoring.

In the past several years, EPA finalized fenceline monitoring requirements for the refinery[112], chemical manufacturing[113], coke oven[114] and integrated iron and steel sectors[115]. EPA

[112] National Emission Standards for Hazardous Air Pollutants: Petroleum Refinery Sector, 85 Fed. Reg. 6064 (Feb. 4, 2020) (codified at 40 C.F.R. § 63.658).
[113] New Source Performance Standards for the Synthetic Organic Chemical Manufacturing Industry and National Emission Standards for Hazardous Air Pollutants for the Synthetic Organic Chemical Manufacturing Industry and Group I & II Polymers and Resins Industry, 89 Fed. Reg. 42932 (May 16, 2024) (codified at 40 C.F.R. pt. 63, Subpart F).
[114] National Emission Standards for Hazardous Air Pollutants for Coke Ovens: Pushing, Quenching, and Battery Stacks, and Coke Oven Batteries; Residual Risk and Technology Review, and Periodic Technology Review, 89 Fed. Reg. 55684 (July 5, 2024) (codified at 40 C.F.R. § 63.314).
[115] National Emission Standards for Hazardous Air Pollutants for Coke Ovens: Pushing, Quenching, and Battery Stacks, and Coke Oven Batteries; Residual Risk and Technology Review, and Periodic Technology Review, 89 Fed. Reg. 23294 (April 3, 2024) (codified at 40 C.F.R. § 63.7792).

promulgated these fenceline monitoring requirements and associated work practice requirements to mitigate fugitive emissions and other difficult-to-monitor sources, e.g. equipment leaks.[116] EPA collected several years of data since the refinery sector's fenceline monitoring requirements went into effect, and fenceline concentrations dropped by an average of 30 percent.[117]

Although landfills and the refinery sectors are different, because of the large footprint of a landfill and variability in emissions, requiring fenceline monitoring—alongside more robust SEM monitoring and a SERP—could indicate when, and generally, where, there are elevated emissions at landfills.[118] In fact, state agencies required fenceline monitoring in consent decrees for landfills.[119] Instead of placing monitors around the entire perimeter of the landfill, monitors are placed at strategic locations on the landfill perimeter—close to both the active face and surrounding communities (where applicable).[120]

CARB should also require fenceline monitoring in the revised LMR, focusing on placing monitors strategically around known and suspected points of fugitive emissions, especially near impacted communities. CARB can look to the flyover study and associated modeling conducted by the Michigan EGLE and other agencies to determine the number of monitors needed.[121] CARB should establish an action level for methane and other hazardous air pollutants that triggers root cause analysis and corrective action by the operator. Because methane could be produced by nearby sources—such as farms, wetlands, composting facilities—CARB should allow sources to submit site-specific monitoring plans that include site-specific modeling that assesses the particular landfills' fugitive methane emissions.[122] However, CARB should conduct robust oversight of these site-specific monitoring plans to ensure that they adequately address fugitive emissions from each particular landfill.[123]

Additionally, CARB should require that all data is posted publicly and expeditiously. At landfills in both Michigan and North Carolina, after years of odor complaints and due to other compliance issues, the state agencies required fenceline monitoring and that the results be posted publicly, also requiring robust community engagement.[124] Although the North Carolina landfill

[116] Fenceline Monitoring White Paper at 1.
[117] *Id*. at 2.
[118] *Id.*
[119] *Id*. at 3.
[120] *Id*.
[121] *Id*. at 4.
[122] *Id*. at 8.
[123] In September of 2024, EPA's Office of Inspector General ("OIG") conducted an audit of the oversight of the benzene fenceline monitoring requirements for refineries. Env't Prot Agency, Office of Inspector General, *Oversight to Ensure that All Refineries Comply with the Benzene Fenceline Monitoring Regulations*, Report No. 23-P-0030 (Sept. 6, 2023), https://www.epaoig.gov/sites/default/files/reports/2023-09/_epaoig_20230906-23-p-0030_errata.pdf (last visited Sept. 19, 2023). The report included a finding that site-specific monitoring plans did not include required monitoring needed to verify offsite source contributions to fenceline benzene levels. *Id*. As a result, EPA-approved site-specific monitoring plans for refineries relied solely upon modeling that likely overestimates near-field source emissions, resulting in unwarranted downward adjustment to the delta c value. *Id*. CARB should note this OIG report and avoid these and similar issues when approving site-specific monitoring plans.
[124] Fenceline Monitoring White Paper at 6-7.

fenceline monitoring requirement is new (consent decree was signed in August of 2024), EGLE notes that odors from the Michigan landfill (though complaints are still received) are reduced.[125]

D. Commenters support CARB's potential update to the LMR that would establish a SERP, leveraging advances in emissions monitoring technologies to quickly pinpoint large methane sources and mitigate leaks.

First, Commenters appreciate and support CARB's proposed concept to adopt a satellite alert and response provision similar to that required for the oil and gas sector in the LMR. CARB posed the following question in the December 2024 workshop:

- Should the technology approval criteria be the same for landfills as for oil and gas?
- Should the notification contents (estimated plume origin, image, etc.) be the same for landfills as for oil and gas?
- What operator response timelines are practical for landfills?
- Are additional steps needed in the process?
- What monitoring area around the plume origin makes sense for the LMR?
- What, if any, activities should be exempt from operator monitoring?[126]

Commenters will address the third, fourth and sixth questions specifically below and also provide additional feedback and recommendations.

First, Canada's ECCC included in its proposed regulatory framework methane leak detection and corrective action requirements that may be required when a third-party measures methane emissions exceeding a specific threshold, e.g. 100 kg/hr and that detection has been published or report to the ECCC.[127] However, ECCC did not include this program in their proposed regulations. Therefore, it is prudent that CARB continues to be the leading regulatory agency by establishing a similar satellite alert and response provision like that required for the oil and gas sector.

First, addressing CARB's question of additional steps needed in the process, CARB should explicitly allow any third party—whether aerial monitoring or through community monitoring—to be considered. CARB may provide for what demonstrations those third parties must make to satisfy the requirements, but CARB should specifically allow for third parties other than satellites be considered.

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[125] *Id.*
[126] CARB 2024 LMR Workshop at 23.
[127] ECCC Proposed Rules. Although ECCC did not include in its proposed regulations noticed in June of this year, CARB, as the leading innovator in landfill methane regulation, should instead look to the regulatory framework in revising its LMR.

Canada's proposed framework and the satellite alert and response provision for the oil and gas sector that CARB is considering to also include in the LMR are similar to EPA's SERP for the oil and gas sector. In the final oil and gas rule, EPA describes the SERP as a "backstop to address large methane super emitters," designed for the EPA to receive data submitted by EPA-certified third parties using EPA-approved remote sensing technologies.[128] This SERP is "designed to provide a transparent, reliable and efficient mechanism by which the EPA will provide owners and operators with timely notification of super emitter emissions," allowing the owner or operator to take action in response.[129] EPA's oil and gas SERP certification process could also provide a roadmap to CARB for specifically allowing for third-party measurements other than satellites, as outlined in more detail in the bulleted list below.

Second, we address CARB's last question that none of the areas of the landfill should be exempt from a SERP.

Third, CARB's plan to use data from Carbon Mapper satellites and to purchase additional data coverage (for a "constellation") to conduct its own monitoring and mitigation program of "select high priority areas of interest in California" is promising.[130] CARB's intention to detect methane plumes that can be traced to a specific source and operator and enable rapid mitigation is clear.[131] CARB's planned satellite constellation is innovative and certainly will fulfil its goals of serving a as a model for other states and for EPA.[132]

Fourth, addressing CARB's question about response timelines that are practical, CARB could look to the response timelines for the Arbor Hills landfill fenceline monitoring program.[133] There, the operator is required to correct exceedances within forty-eight (48) hours of detection.[134] Such a timeline would be feasible for expected leaks. Relatedly, CARB's proposed concept of a digital map would bolster the effectiveness of a SERP. Publicly available digital maps would provide information about locations of infrastructure on the landfill. This would better enable operators and third parties detecting plumes to identify likely sources and could also expedite the timeline for response, even for unexpected leaks.

Finally, CARB should consider the following parameters for its SERP:

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[128] Standards of Performance for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Climate Review, 89 Fed. Reg. 16820, 16877 (March 8, 2024)
[129] *Id.*
[130] 2024 CARB Summary Report at 23
[131] *Id*. at 24-25.
[132] *Id.* at 25.
[133] *See* Consent Decree, *Michigan Dep't of Env't, Great Lakes and Energy v. Arbor Hills Landfill, Inc.,* No. 2020-0593-CE, https://www.michigan.gov/-/media/Project/Websites/egle/Documents/Multi-Division/Arbor-Hills/2022-03-07-arbor-hills-consent-judgment.pdf?rev=34c46355d78e4eb1b2af14c9594c42b8 [hereinafter "Arbor hills Consent Decree"].
[134] *Id*. at 23-24.

- The landfill owner or operator must conduct surface emissions monitoring at the identified location and conduct mitigation activities when notified that a super emitter event has been detected by the landfill owner or operator or by a qualified third-party.
- "Super emitter event" means emissions of 100 kilograms (220.5 pounds) of methane per hour or larger.
- A qualification process for third-party notifiers.
- Pre-qualification requirements for third-party notifiers including:
    - Automatic approval for EPA-approved third-party monitors
    - A publicly available checklist of requirements for pre-qualification.
        - The checklist should clearly explain what would render third-party monitoring data invalid (e.g., monitoring results obtained while trespassing)
    - Third-party notifiers should be able to apply and demonstrate their technical expertise in the specific technologies and methodologies
    - Third-party notifiers should create a monitoring plan approved by CARB.

CARB should also require that notification to operators also be copied to CARB and the relevant local air quality management districts (air districts) and local enforcement agencies ("LEAs") to help ensure that the correct contact person/facility has been notified. Including air districts and LEAs in the notification process will enhance transparency, improve response times, and facilitate a unified approach to addressing emissions that may have regional impacts.

E. CARB should improve requirements for gas collection and control systems.

As discussed in EPA's Increasing Landfill Gas Collection Rates White Paper, several factors affect whether a GCCS is operating properly. Gas collection wells can be damaged from construction, the temperature of in-situ waste and from liquid in the wells.[135] EPA further notes that it is crucial to address the management of both gas and liquids in landfills in terms of GCCS performance.[136] Finally, atmospheric conditions and fluctuations also affect well performance.[137]

Accordingly, CARB should revise the LMR to address flooded wells and system downtime. Additionally, CARB should investigate remote wellhead tuning technologies that can dynamically adjust system parameters of the GCCS. CARB should also require earlier installation of a GCCS. Commenters also support various proposed concepts from the 2024 Workshop.

[135] GCCS White Paper at 5.
[136] *Id*.
[137] *Id*.

1. Commenters support CARB's proposed concept to require continuous monitoring of the system vacuum.

Commenters support CARB's proposal to require continuous monitoring of system vacuum and reporting when it deviates from the typical range.[138] Current regulations require continuous monitoring (flare temperature and gas flow rate) to ensure control devices are operated within the parameter ranges established during source testing — but there is no analogous monitoring for the collection system. Pressure sensors are low cost and can help monitor GCCS system uptime and performance. Further, CARB could consider requiring cloud-connected pressure sensors and flow meters on each wellhead, not just at the header, allowing operators and regulators to know if individual wells are offline or not sufficiently collecting.

2. Commenters support CARB addressing GCCS system downtime.

Commenters support CARB's proposed concept to reduce duration and emissions impact of GCCS downtime by requiring best practices such as:

- Reconnecting wells to vacuum at the end of each work day;
- Specifying mitigation measures for component downtime longer than a specified period;
- Limiting the number of wells that can be disconnected at once; and
- Limiting the size of the working face/construction area[139]

Commenters will likely provide more detailed comments on this topic in the future. However, as an initial matter, CARB should approach GCCS system downtime by establishing that a certain number of days—e.g. five (5) days of downtime[140]—constitutes a violation. CARB should also limit the active/working face and construction areas of the landfill as discussed in subsections below.

Commenters also remind CARB that the final LMR revisions should comply with the EPA's policy for startup, shutdown, and malfunction events and EPA has applied this policy to operation of the GCCS.[141]

[138] CARB 2024 LMR Workshop at 54.
[139] *Id.* at 51.
[140] Michigan's active gas collection and control system requirements require that "[t]he active gas collection and control system shall not be inoperable or unable to maintain a vacuum required by subdivision (e) for more than 5 consecutive days." Mich. Comp. Laws Ann. § 324.11512b(2)(B)(k).
[141] EPA, National Emission Standards for Hazardous Air Pollutants: Municipal Solid Waste Landfills Residual Risk and Technology Review, 85 Fed. Reg. 17244, 17252-17253 (March 26, 2020).

a. CARB should include improved requirements to address emissions from the active face.

As EPA confirmed in their "Improvements to Working Face and Daily Cover to Reduce LFG Emissions" white paper, methane emissions predominantly originate from the working face or areas with intermediate cover that do not have active gas collection wells.[142] Waste beneath freshly placed waste and adjacent to the working face produces the greatest emissions.[143] CARB can address this issue, in part, by following our recommendations that the GCCS be installed earlier. CARB should also consider the following additional recommendations that could reduce emissions from the active face.

i. Minimize the size of the active face.

Minimizing the active face would not only reduce methane emissions, but also provide operational benefits to landfills.[144] However, because the size of the working face depends on operational practices—e.g. waste delivery schedules, equipment capabilities and site layout—CARB should approach this requirement by defining acceptable active face sizes relative to the volume of incoming waste and requiring operational plans to be implemented by the operator that are tailored to the landfill's specific situation. For example, British Columbia limits the size of the working face relative to the incoming annual tonnage of waste.[145]

ii. Require operators to prepare an active face operation plan.

Additionally, CARB should require that landfills prepare an operational plan for the active face, that includes plans that the landfill will install horizontal gas collection trenches[146] below the active face.[147] The operational plan should also include adjacent gas collection wells near the active face to partially mitigate emissions.[148]

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[142] EPA, *White Paper Series: Municipal Solid Wate Landfills-Advancements in Technology and Operating* Practices, "Improvements to Working Face and Daily Cover to Reduce LFG Emissions" (October 2024), 1 [hereinafter "Work Face and Daily Cover White Paper"].
[143] *Id*. at 3.
[144] *Id*. at 6.
[145] British Columbia Ministry of Environment, *Landfill Criteria for Municipal Solid Waste,* Second Ed. (June 2016) App. A at 57, *available at* https://www2.gov.bc.ca/assets/gov/environment/waste-management/garbage/landfill_criteria.pdf.
[146] "Horizontal collectors can be placed in active landfill sections and may not significantly interfere with landfill operations compared to vertical wells, as they are installed at or beneath the surface of a waste layer. Unlike vertical wells, horizontal collectors can be installed using standard earthmoving equipment instead of specialized drilling rigs. Horizontal collectors often serve as a temporary solution to begin gas collection from newly filled landfill sections, sometimes while additional waste placement is still underway. For optimal performance, it is necessary to cover these collectors with adequate waste to prevent air from entering from the collection system through the surface. The placement, frequency, and length of horizontal collectors are usually site-specific." Work Face and Daily Cover White Paper at 7.
[147] *Id*. The idea of a comprehensive Operations Plan is also discussed in a book written by a landfill operations expert. Timothy Townsend et al., *Sustainable Practices for Landfill Design and Operation* 347-359 (2015).
[148] Work Face and Daily Cover White Paper at 7.

In addition to including the horizontal trenches and adjacent gas collection well measures in the operation plan, CARB should specifically outline requirements to reduce active face emissions, including the requirement that operators develop this plan relative to the volume of incoming waste. CARB should require that the plan include these specific items and be designed to control methane and minimize flooding by:

- Digging the trench to 1.5 to 5 feet deep into the waste;
- Minimize flooding by:
    - Trench design:
        - Plan to place trenches in areas that are not saturated and/or low lying;
        - Plan to place trenches so that the landfill leachate system can efficiently remove liquids from the waste and prevent blockages in the GCCS.
        - with a central low point; or
        - with the trench sloping towards the landfill outer slope.
    - Install stone sumps or drains at low points; or
    - Using a gravel backfill to enhance drainage and ensure contact with waste.[149]

CARB should also consider allowing operators to include in its operation plan measures in addition to horizontal collection, provided that the operator can demonstrate that these measures would reduce methane emissions. Commenters plan to provide more detailed information on this in the future.

Finally, in addition to including horizontal trenches and tuning vertical gas collection wells adjacent to the active face, CARB should also require that these requirements be addressed in the GCCS Design Plan.[150]

b. Require monitoring of the active face.

In order to assure that minimizing the active face and requiring horizontal gas collection systems controls methane emissions as intended, CARB would need to require some type of monitoring of the active face. Utilizing advanced technologies, such as methane concentration sensors, drones[151] or aerial monitoring, or a combination thereof and including a monitoring plan for the active face in the active face operation plan would be the most practical way for CARB to require this monitoring.

For fixed methane sensors, CARB could continue to innovate by exploring a method for this active face methane concentration monitoring. The method would prescribe the distance at

[149] *Id*. at 8.
[150] Cal. Code Regs. tit. 17 § 95464(1).
[151] For example, in the Arbor Hills Landfill Consent Decree, the operator is required to use drones to conduct SEM over the working face of the landfill. Arbor Hills Consent Decree at 22.

which fixed sensors would be placed downwind from the minimized working face area.[152] The method would also consider the fetch distance, which is the distance downwind from the source where the sensor can reliably capture the center of the methane emission plume.[153]

Additionally, CARB could draw from fenceline monitoring requirements in California's own refinery community monitoring and fenceline monitoring requirements[154] and recent federal fenceline monitoring requirements for refineries[155] and coke ovens[156] to establish active face methane concentration monitoring requirements. For example, CARB could consider establishing a methane action level that would trigger implementing a corrective action plan within twenty-four (24) hours.[157] Corrective actions could include application of additional daily cover and/or installing/repairing horizontal collectors. CARB should also include in the established method and in the monitoring plan that the owner or operator shall collect and record meteorological data.[158]

3. CARB should include additional requirements that would reduce the number of flooded wells.

It is common for landfill operators to discover that liquids—e.g. leachate and gas condensate—accumulate in gas collection wells.[159] The presence of liquid in the collection wells decreases the amount of gas collected and can impede gas flow, potentially leading up to the buildup of heat and pressure.[160] Data also shows that gas collection efficiency at landfills with high leachate levels is significantly lower than at landfills with lower levels of leachate.[161]

First, CARB should include in its design plan requirements[162] that the GCCS be designed to extract liquids. In their design plan, for example, operators could demonstrate that the GCCS will extract liquids by including dual phase wells, which are designed to extract both gas and liquids from the landfill simultaneously.[163] Operators could also include in their design plans vertical or horizontal gas wells equipped with dedicated leachate pumps.[164] By requiring that the design plan meet the requirement that the GCCS is designed to extract liquids, CARB will ensure both gas and leachate are effectively managed and improve overall system performance, which will reduce methane emissions.

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[152] Work Face and Daily Cover White Paper at 8.
[153] *Id.*
[154] *See* Cal. Health & Safety Code § 42705.6.
[155] *See* 40 C.F.R. § 63.658.
[156] *See* 40 C.F.R. § 63.
[157] *See* 40 C.F.R. § 63.314(e).
[158] *See* 40 C.F.R. §63.314(b).
[159] *Id*.
[160] *Id*.
[161] *Id*. at 8.
[162] Cal. Code Regs. Tit. 17 § 95464(a)(1).
[163] GCCS White Paper at 11.
[164] *Id*.

Additionally, CARB should also include monitoring[165] and corrective action requirements for flooded wells. Although the current monitoring requirements require monitoring each wellhead monthly for pressure, and includes corrective action requirements, no similar requirements address liquid in the wells.[166] Because the presence of liquid in wells impacts the efficiency of the GCCS and of the collection of gas, CARB should also require operators to monitor and initiate corrective action for wells containing leachate or other liquid. Corrective action would include pumping leachate and other liquids out of the well to restore necessary vacuum conditions to effectively collect the landfill gas.[167] For landfills without dual phase wells, leachate pumps or other measures in the design plan that extract liquids, corrective actions could also include requiring the installation of some of these methods.

Finally, CARB should also consider mandating that wastewater sludge should be dried prior to being placed in landfills. Such a requirement would avoid low-permeable wet patches in landfills and reduce clogging of leachate drainage systems.[168]

4. CARB should harmonize the LMR with federal requirements and include additional requirements.

Efficient gas capture is affected by the dynamic nature of emissions at landfills, influenced by changing atmospheric conditions and temperature.[169] The current LMR requires only monthly monitoring for pressure, and landfills are also required to monitor monthly for oxygen and temperature under federal requirements.[170] Commenters support CARB's intention to add all requirements referenced in 40 CFR § 62.1115(b)(2) in the revised LMR.[171] Commenters note that it is advantageous to harmonize the LMR with federal plan requirements. In the unlikely event that the Emission Guidelines are revised to omit these oxygen and nitrogen monitoring requirements, explicitly including these requirements in the LMR revision would preserve these important requirements.

Next, CARB should include corrective action requirements for measured exceedances of nitrogen and oxygen in the revised LMR.[172] If the prescribed standards for temperature, pressure,

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[165] Within Cal. Code. Regs. Tit. 17 § 95469(b),(c).
[166] Cal. Code. Regs. Tit. 17 § 95469(c)(1)-(3).
[167] GCCS White Paper at 11.
[168] GCCS White Paper at 12.
[169] *Id*. at 10.
[170] Although the LMR does not cover the oxygen and temperature monitoring requirements, EPA's Federal Plan to Implement the Emission Guidelines and Compliance Times does include this requirement in 40 C.F.R. Part 62, subpart F to identify that existing landfills in California must implement these requirements in addition to the LMR requirements. Federal Plan Requirements for Municipal Solid Waste Landfills That Commenced Construction On or Before July 17, 2014, and Have Not Been Modified or Reconstructed Since July 17, 2014, 86. Fed. Reg. 27756, 27758 (May 21, 2021).
[171] 2024 CARB LMR Workshop at 46.
[172] In the 2020 revisions to the NESHAP, a higher temperature standard was newly established (145 degrees Fahrenheit) and the rule replicated the NSPS approach to nitrogen and oxygen content, requiring monitoring but no corrective action or reporting. *See* Standards of Performance for Municipal Solid Waste Landfills, 81 Fed. Reg.

and oxygen or nitrogen are exceeded, then corrective action should include repairs or adjustments to the GCCS and any actions necessary to manage the presence or risk of a subsurface fire. In addition, ongoing monitoring and reporting of these parameters along with carbon monoxide content and methane content should be required. This monitoring should continue until the monitored parameters have stabilized to conditions that indicate that methanogenic decay has resumed or the fuel for the fire is exhausted.

Finally, CARB should also include revisions from the 2020 NESHAP that established enhanced monitoring requirements at wellheads where temperatures exceed 145º F that include carbon monoxide and methane content of the landfill gas at the wellhead and visual observations for evidence of subsurface oxidation such as smoke, ash, or damage to the well.[173] CARB should also require more frequent monitoring of these parameters when there was a thermal event or fire at an MSW landfill. Once the thermal event or fire is identified, the operator should monitor the temperature, oxygen, carbon monoxide, and methane content daily until conditions stabilize. Then, for the next six (6) months the operator should be required to monitor for oxygen and temperature bi-weekly and prepare a report that conditions have stabilized, demonstrating that further risk of fire and a thermal event is not present. This is warranted given the significant consequences of a landfill fire and the risk to surrounding communities.

5. CARB should consider requiring remote wellhead tuning technologies.

Although Commenters support harmonizing the LMR with the federal requirements, those monitoring requirements are still too infrequent relative to the dynamic conditions of landfill emissions. Moreover, associated corrective action requirements for positive pressure readings do not adequately capture rapid temporal changes effectively, which leads to inconsistencies in gas capture of the GCCS and thus increased emissions.[174] Therefore, Commenters support CARB's consideration of supporting automated wellhead technologies[175] that are capable of continuously monitoring emissions and adjusting the vacuum to improve pressure.[176]

Since finalizing the first CARB LMR, technologies emerged that are capable of adapting gas recovery strategies in response to meteorological conditions. Automated wellhead tuning

59332 (Aug. 29, 2016). In addition, in the 2020 NESHAP revisions, EPA finalized "minor edits" to the 2016 NSPS and EGs "allowing landfills to demonstrate compliance with the 'major compliance provisions' of the NESHAP in lieu of complying with the analogous provisions in the NSPS and EGs." National Emission Standards for Hazardous Air Pollutants: Municipal Solid Waste Landfills Residual Risk and Technology Review, 85 Fed. Reg. 17244, 17248 (Mar. 26, 2020) (codified at 40 C.F.R. pts. 60 and 63). Thus, a source may choose to comply with the NESHAP rather than the corresponding provisions of the NSPS and EGs. Practically, this amounts to operators otherwise subject to the NSPS or EGs being allowed to instead comply with the operational standards for the GCCS and the compliance provisions of the NESHAP.

[173] National Emission Standards for Hazardous Air Pollutants: Municipal Solid Waste Landfills Residual Risk and Technology Review, 85 Fed. Reg. 17244, 17270 (March 26, 2020).

[174] GCCS White Paper at 10.

[175] CARB 2024 LMR Workshop at 17.

[176] GCCS White Paper at 10.

technologies, which are in use at many landfills across the U.S., as discussed in Section I.D., are able to dynamically adjust GCCS parameters like vacuum pressure and flow rates in response to real-time data collected through continuous monitoring of atmospheric conditions.[177] This technology has the potential to actively monitor gas collection wells, notify operators as soon as issues occur, identify out-of-range parameters, and allow for automatic wellhead tuning.[178] Automated wellhead tuning can also allow operators to identify issues much more frequently than once per month, and thus could also result in a more well-functioning GCCS and reduce damage to the GCCS.[179] The automated system is also capable of improving gas quality by optimizing the balance between oxygen and methane content, which reduces air intrusion risks.[180]

Accordingly, we encourage CARB to further investigate the efficacy and cost of automated wellhead tuning for all landfills. Especially where a number of California landfills already utilize the technology, CARB should consider requiring the installation of wellhead tuning systems that automatically adjust vacuum levels based on the methane concentration in the landfill gas and other identified parameters that affect landfill gas flow and quality. SCS Engineers estimates that costs would be more affordable over time than traditional manual monitoring.[181]

Finally, at the very least, CARB should require automated wellhead tuning at landfills with persistent issues. Commenters support CARB's concept of requiring continuous wellhead monitoring and more frequent or automated wellhead tuning for landfills with frequent or persistent issues.[182] SCS Engineers also presented that their automated wellhead tuning technology would be more affordable than traditional monitoring for large landfills with issues.[183] CARB should also consider mandating the use of automated wellhead tuning at a certain size threshold.

6. CARB should require earlier installation of GCCS.

Recent information indicates that methane is being released at landfills earlier than previously thought. Thus, it is imperative to collect and control landfill gas earlier. Research from the EPA, for example, found "[a]n estimated 61 percent of methane generated by landfilled food waste is not captured by landfill gas collection systems and is released to the atmosphere. Because food waste decays relatively quickly, its emissions often occur before landfill gas

[177] *Id*.
[178] *Id.*
[179] *Id*.
[180] *Id.*
[181] SCS Engineers, *US EPA Landfill Technology Workshop-SCS RMC Automated Wellheads* (October 29, 2024) at slides 5-6, *available at* https://www.regulations.gov/document/EPA-HQ-OAR-2024-0453-0038.
[182] CARB 2024 LMR Workshop at 58.
[183] *Id*.

collection systems are installed or expanded."[184] The EPA also recently revised the decay rate constant used in its first-order decay method for estimating landfill methane under the GHGRP rules to reflect higher emissions earlier in a landfill's life.[185]

Additionally, EPA shows that it is technically feasible and cost-effective to install and expand a GCCS *within one year* after waste is placed. According to EPA's Landfill Gas Energy Project Development Handbook "early" landfill gas collection can be implemented "within a few months of waste placement."[186] In fact, by using horizontal collectors and/or bottom-up caisson wells, operators can collect gas as waste is being buried.[187] Analysis by EIP, based on Eastern Research Group's ("ERG") analysis for EPA's 2019 technology review ("2019 Technology Review") found that earlier expansion of GCCS (after 1 year) could reduce methane emissions by 400,000 tons per year at a cost-effectiveness of about $140 per metric ton of methane reduced (or just ~$2/ton CO2e using the 20-year global warming potential).[188]

Finally, the State of Washington's Landfill Methane Emissions Rule requires any owner or operator of an active MSW landfill to install and operate a GCCS *not later than 18 months* after the date that the landfill is required to comply with the rule.[189] Washington's rule also requires landfills to submit a design plan for the GCCS *within one year* of applicability, though landfills can defer GCCS installation if they demonstrate that there is no surface methane concentration greater than or equal to 200 ppm.[190] Michigan also requires that new landfills or expansions must require a GCCS during construction, prior to accepting waste.[191] Michigan requires existing landfills to provide a design plan within twelve (12) months of applicability and to install and operate a GCCS within six (6) months of approval of that plan.[192]

Accordingly, given the cost-effectiveness and methane reduction potential, CARB should require earlier GCCS installation. Specifically, CARB should require that owners and operators must install and operate a GCCS within at least one (1) year, possibly within six (6) months,

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[184] Env't Prot. Agency, *Food Waste Management-Quantifying Methane Emissions from Landfilled Food Waste* (Oct. 2023) *available at* https://www.epa.gov/system/files/documents/2023-10/food-waste-landfill-methane-10-8-23-final_508-compliant.pdf.
[185] Revisions and Confidentiality Determinations for Data Elements Undern the Greenhouse Gas Reporting Rule, 89 Fed. Reg. 31802, 31852 (April 25, 2024).
[186] Landfill Methane Outreach Program, *LFG Energy Project Development Handbook* (Jan. 2024) at 7-4 *available at https://www.epa.gov/system/files/documents/2024-01/pdh_full.pdf* [hereinafter "2024 LFG Project Handbook"].
[187] *Id*. at 7-10.
[188] Kelly, Leah, Lewis, Haley, EIP, Petition for Rulemaking to Revise the New Source Performance Standards and Emission Guidelines for Municipal Solid Waste Landfills (June 22; 2023), 21 *available at https://environmentalintegrity.org/wp-content/uploads/2023/06/FINAL-Petition-for-Rulemaking-CAA-111-Landfills.pdf* [hereinafter "EIP Petition to EPA"]; Memorandum from E. Rsch. Grp., Inc. on Clean Air Act Section 112 (d)(6) Tech. Rev. for Mun. Solid Waste Landfills to Allison Costa and Andy Sheppard, EPA, Off. of Air Quality Planning & Standards, at 29-30, 31-32, 36- 41, 44-45 (June 25, 2019) [hereinafter "2019 Technology Review Memo"].
[189] Wash. Admin. Code r. 173-408-080(5)(a)(xii).
[190] Wash. Admin. Code r. 173-408-080(1)(a),(2).
[191] Mich. Comp. Laws Ann. § 324.11512h(3)(a).
[192] Mich. Comp. Laws Ann. § 324.11512h(3)(b)

instead of eighteen (18) months[193], from the approval of the Design Plan. Additionally, CARB can expedite the timeline for submitting a design plan once meeting the threshold to within six months as opposed to one year.[194] Finally CARB can more quickly approve or disapprove of design plans, seventy-five (75) days would be feasible.[195]

F. CARB should streamline and strengthen cover requirements.

Methane oxidation in landfills is critical to mitigating the release of methane into the atmosphere, and landfill cover plays a critical role in methane oxidation.[196] Landfill covers minimize gas emissions, control odors, reduce leachate formation and prevent water infiltration into the landfill.[197]

A Cal Poly field investigation of methane gas emissions from a representative set of California landfills analyzed all operational parameters at landfills and emissions measured on the ground.[198] The researchers found that the type of cover on a landfill was a significant factor impacting the flux of emissions.[199] Specifically, they found higher methane emissions with the use of intermediate and daily covers and lower methane emissions as the percentage of the landfill area with final cover increased.[200] The report recommended limiting the working face and because daily cover had the most emissions potential, intermediate cover should be installed within days—not weeks—of waste placement.[201] Specific recommendations included:

> (1) for daily cover: minimize the area and duration of coverage and avoid highly porous and open structure bulk materials;
> (2) for intermediate cover: increase thickness up to one (1) meter (about three (3) feet) with fines content over 30%, and minimize area; and
> (3) for final cover: thickness of over 150 cm (about 4.9 feet), fines over 60%, clay over 12%, and plasticity over 20%.[202]

Moreover, as seen in **Figure 4** below, cover cracks most frequently cause emission incidences:

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[193] Cal. Code Regs. Tit. 17 § 95464(a)(2)
[194] Cal. Code Regs. Tit. 17 § 95464(A)(1).
[195] *Id*.
[196] EPA, *White Paper Series: Municipal Solid Wate Landfills-Advancements in Technology and Operating* Practices, "Improvements In Intermediate and Final Covers to Mitigate Emissions" (October 2024), 2 [hereinafter "Intermediate and Final Cover White Paper"].
[197] *Id*.
[198] James L. Hanson & Nazli Yesiller, Cal. Polytechnic State Univ., *Estimation and Comparison of Methane, Nitrous Oxide, and Trace Volatile Organic Compound Emissions and Gas Collection System Efficiencies in California Landfills* (2020), https://ww2.arb.ca.gov/sites/default/files/2020-06/CalPoly%20LFG%20Flux%20and%20Collection%20Efficiencies%203-30-2020.pdf [hereinafter "Cal Poly Report"].
[199] *Id*. at 23.
[200] *Id*. at 5.
[201] *Id*. at 351.
[202] Cal Poly Report at 350-351.

Figure 4: Causes of landfill emission plumes observed in California 2021 and 2022 Airborne Methane Plume Mapping Studies[203]

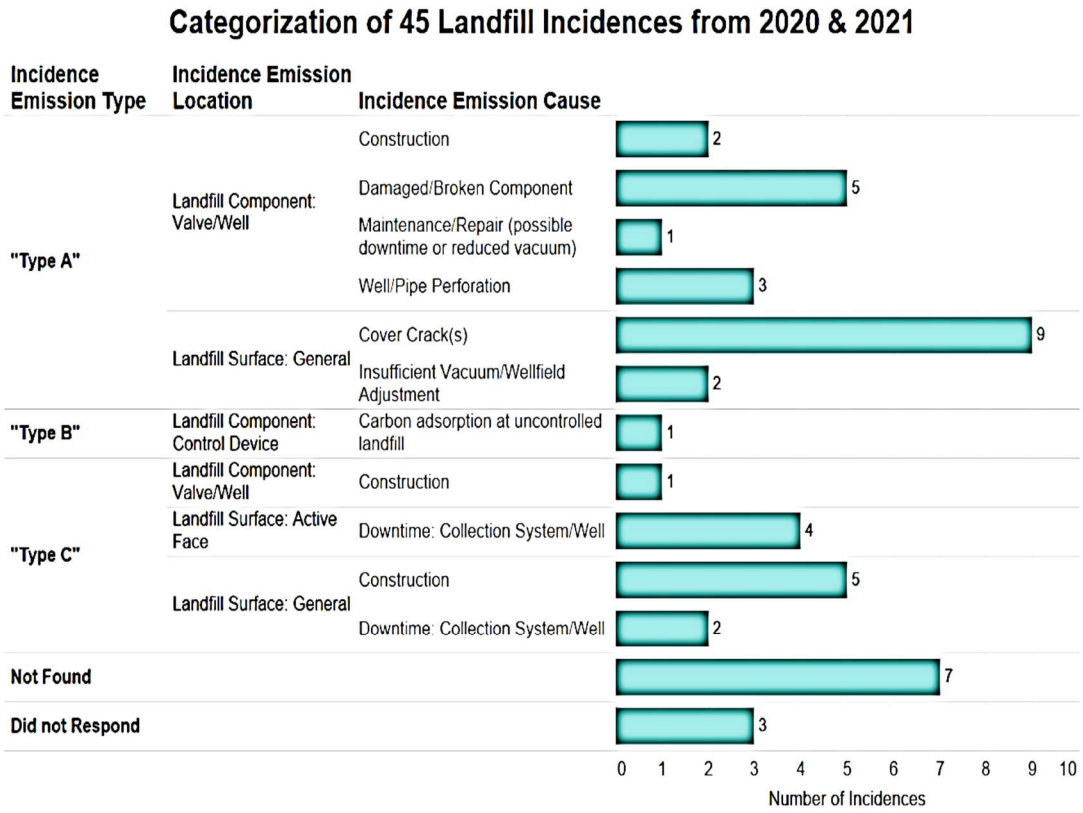

Figure 8. A graphic depicting the results of landfill operator feedback from the 2020 and 2021 airborne campaigns. Note that the Incidence classifications (Emission Type, Emission Location, and Emission Cause) were assigned by CARB staff based on operator responses.

Although landfill cover plays a critical role in mitigating landfill emissions, they are not addressed extensively in either the CARB LMR or the federal CAA requirements for landfills. In their white paper, EPA states that "additional regulatory measures would be needed to ensure the ongoing maintenance and durability of landfill covers. Bare soils, in particular, are especially vulnerable to damage from precipitation, which can compromise cover effectiveness and increase the potential for emissions."[204] Thus, CARB should revise the LMR to include a new section for landfill cover, enumerating specific requirements for daily, intermediate and final cover. CARB should ensure that these requirements are also in concert with any solid waste requirements for MSW landfills. The requirements should set standards for cover material and outline specific required actions to ensure cover integrity maintenance, such that every month the landfill operators must visually inspect the entirety of the landfill cover, both interim and final.

[203] CARB, *Summary Report of the 2020, 2021, and 2023 Airborne Methane Plume Mapping Studies* (April 2024), 21, *available at* https://ww2.arb.ca.gov/sites/default/files/2023-05/Published%20Summary%20Report%20_1.pdf.
[204] Intermediate and Final Cover White Paper at 14.

Where visual investigations indicate elevated concentrations of landfill gas, the owner or operator should conduct SEM. The requirements should further specify procedures and minimum actions the landfill operator or owner must undertake to repair the cover.

1. CARB should set minimum standards for cover material, especially for alternative daily cover.

It is critical for CARB to establish default standards for cover material. Cover materials should be required to consist of soils. There should also be minimum requirements for permeability in covers that will be in place for an extended period of time (intermediate and final covers). Selection of soils should also consider properties that would promote oxidation such as texture, porosity, and pH.

First, improvements to intermediate and final landfill covers can mitigate landfill gas emissions by promoting methane oxidation and enhancing the efficiency of gas collection systems.[205] Beginning with intermediate cover, CARB should consider whether to require that intermediate covers incorporate a high permeability layer near the surface.[206] CARB should also increase the required thickness of intermediate cover to ensure proper methane mitigation.[207] Three feet of soil cover, as recommended by Hanson et. al.[208], would more effectively control methane emissions. CARB should require that operators submit a cover design plan, or require a landfill cover section in the design plan already required under the LMR, in which they demonstrate careful material choice and design relevant to the climate and waste characteristics of their landfill. CARB should also require that intermediate cover within one (1) month.

Next, federal solid waste regulations mandate that final cover systems are designed to minimize liquid infiltration and prevent soil erosion and must include at least 18 inches of earthen material as an infiltration or barrier layer, topped by at least six inches of another earthen layer that facilitates vegetative growth.[209] CARB should include in the cover requirement section of the LMR revision specific requirements for final cover that build off of the solid waste requirements. CARB should require that final cover be installed on an ongoing basis once a landfill cell reaches its final grade or after a predetermined number of years in order to avoid long term use of intermediate covers.[210] CARB should require that the cover design plan (or the cover section of the design plan) include a specified timeline for waste placement in each cell along with a detailed schedule for installing final cover once waste placement is complete.[211]

Finally, alternative daily cover ("ADC") should rarely, if ever, be used. Although ADCs are designed to meet daily regulatory requirements, many of the materials used do not sufficiently oxidize methane and allow more liquid infiltration, which leads to higher leachate

[205] Intermediate and Final Cover White Paper at 3.
[206] *Id*. at 9.
[207] *Id.* at 14.
[208] Cal Poly Report at 350-351.
[209] *See* 40 C.F.R. §258, subpart F.
[210] Intermediate and Final Cover White Paper at 14.
[211] *Id*.

levels.[212] In its recent white paper series, EPA states that "[f]or landfills subject to NSPS/EG control requirements, minimum standards and test methods for NMOC and methane mitigation from ADCs could be established to ensure equivalency to six inches of soil, or a stricter standard. This would not conflict with state approval of ADC for all landfills in the solid waste context, but rather would be establishing further standards for landfills required to mitigate their NMOC and methane emissions under the NSPS/EG framework."[213] Several states have already identified performance-based standards for evaluation of suitability of ADC.[214] CARB should require that any operator using ADC submit demonstration that the ADC controls odors, methane and NMOC. CARB should establish a test method for operators to ensure that the permeability of ADC is equivalent to six (6) inches of compacted soil, or a stricter standard.[215] CARB should also require more frequent cover performance monitoring[216] for landfills that choose to use ADC.

2. CARB should consider including as alternative compliance options the use of biocovers.

In their 2024 Workshop, CARB presented concepts for addressing declining gas generation.[217] One way CARB could address declining gas generation is by allowing operators to install a biocover to compensate for under performance of the GCCS. To guard against unintended consequences, CARB should define what materials should be used in a biocover.

While oxidation generally occurs in most soils, biocovers—an engineered bioactive layer promoting conditions that enhance and support oxidation by methanotrophic bacteria—can be applied above existing landfill covers to improve methane oxidation and reduce emissions of methane.[218] Biocovers typically consist of a layer of oxidizing material spread over a layer of coarse materials that promotes even distribution of the gas. [219] The design of biocovers promotes

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[212] The EPA said in recent white paper that "[t]here have been many instances where intermediate covers are used for long periods of time—decades, in some cases. Potential regulation changes could include mandating the installation of final or enhanced cover once a landfill cell reaches its final grade or after a predetermined number of years to avoid long term intermediate covers. This could be enforced by requiring landfill design plans to include a specified timeline for waste placement in each cell, along with a detailed schedule for installing the final cover once waste placement is complete. Similarly, regulation requirements could strengthen around the depth of intermediate covers to ensure proper methane mitigation." Work Face and Daily Cover White Paper at 10. 11-12.

[213] Work Face and Daily Cover White Paper at 11.

[214] "Ohio EPA (2023) identified that ASTM D 6826 and 7008 provide methods for evaluating certain types of ADC, including efficacy for odor control based on ASTM E 96 Test Methods for Water Vapor Transmission of Materials. Wisconsin Department of Natural Resources (2014) similarly recommends use of ASTM E 96 to evaluate potential odor control, and notes that certain ADC types can contribute to odors and emissions issues." *Id.* at 12.

[215] *Id*.

[216] EPA defined performance monitoring for ADC as "[m]onitoring the performance of ADCs over time is critical to assess their effectiveness in controlling odors, preventing litter, minimizing disease transmission, and addressing other landfill concerns. Regular inspections, field testing, and data analysis enable proactive management of ADC application and adjustment as needed." *Id*.

[217] CARB 2024 LMR Workshop at 62.

[218] *See* Marion Huber-Humer et al., *Biotic Systems to Mitigate Landfill Methane Emissions* 26(1) Waste Mgmt. & Rsch. 33(2008), https://pubmed.ncbi.nlm.nih.gov/18338700/.

[219] *See id*; *see also* EPA, Available and Emerging Technologies for Reducing Greenhouse Gas Emissions from Municipal Solid Waste Landfills 17 (2011) [hereinafter "2011 EPA Emerging Technologies Report"]. In 2011, EPA estimated that a biocover could reduce methane emissions by 32% and would cost $48,000/acre. *Id*. at 9, 17.

methane oxidation because biocover has greater porosity and thermal insulation than traditional landfill cover.[220] Biocovers can be used as a supplement to a GCCS to capture fugitive emissions or to reduce emissions at closed landfills.[221] Research has also shown that biodegredation of NMOC occurs with biocovers, including a reduction in VOCs.[222]

In their Proposed Regulatory Framework, Canada also included an engineered biocover system, biofilter or other device utilizing thermal or biological oxidation processes that can demonstrate 90% destruction efficiency as a requirement for methane destruction.[223] It is worth noting that Canada included this requirement alongside flares and a GCCS in its list of methane destruction devices or treatment systems as being part of an operator's landfill methane control approach design. The Proposed Regulatory Framework also includes monitoring requirements to ensure methane destruction via oxidation is maintained in biosystem designs.[224] Although Canada did not go as far in the proposed regulations, even still the biocover is still defined and allowed as an alternative for controlling methane.[225]

For the requirements CARB should consider for biocovers, it should consist of two layers: a gas distribution layer and an oxidation layer. The gas distribution layer should be comprised of gravel, broken glass, sand, or similar coarse material.[226] The oxidation layer should consist of soil, finished compost, mulch, peat or other organic material that operators are required to demonstrate has oxidizing capacity.[227] The oxidation layer should be stabilized with vegetation to prevent erosion and help to control moisture in the cover.[228] CARB should specifically ban raw compost or green waste from the biocover. Biocovers should not be allowed as daily or intermediate cover.

Additionally, CARB should also consider allowing biocovers as alternative compliance options in certain scenarios. For example, an engineered biocover could be required at landfills that have no GCCS or where a GCCS has been shut down. In addition, landfill operators at which a GCCS is operated should be required to address the feasibility of using a biocover in its design plan.

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[220] Huber-Humer et al., *supra* note 219.
[221] 2019 Technology Review Memo at 26 (*quoting* Helene Hilgeret al., *Reducing Open Cell Landfill Mane Emissions with a Bioactive Alternative Daily Cover* (June 2009), https://www.osti.gov/servlets/purl/971176).
[222] 2019 Technology Review Memo at 27; Hanson & Yesiller, *supra* note 72.
[223] ECCC Proposed Regulatory Framework.
[224] Annual in situ testing to monitoring temporal changes to microbial oxidation capacity and of media properties (including, but not limited to, bulk density, organic matter, moisture etc.) and semi annual monitoring of the biocover surface to identify fissures and erosion and to confirm the biocover is properly draining are listed as possible monitoring requirements. *Id.*
[225] ECCC Proposed Rules.
[226] Huber-Humer et al.; Bala Yamini Sadasivam et al., *Landfill Methane Oxidation in Soil and Bio-based Cover Systems: a Review*, 13(1) Revs. in Env't Sci. and Bio/Technology 79 (2014), https://doi.org/10.1007/s11157-013-9325-z.
[227] *Id*.
[228] Huber-Humer et al., *supra* note 219.

G. CARB should ban recirculation practices.

Leachate recirculation is the practice of reintroducing collected leachate into a landfill. This can be conducted as a strategy for managing leachate onsite rather than incurring the cost of offsite disposal or as a means of increasing the moisture content of the waste and accelerate methane generation (operating the landfill as a "bioreactor").[229] In either case, leachate recirculation increases the total moisture in the landfill as liquids are introduced on an ongoing basis through moisture in waste as it is placed at the site and as a result of infiltration of precipitation through cover material.[230] Some landfills may also be permitted to add additional liquids to enhance the bioreactor function of the landfill.[231]

Leachate recirculation is permitted in California if the facility meets the requirements for leachate recirculation in RCRA Subtitle D and it is approved by the Regional Water Quality Control Board.[232] In addition, the state can also issue "research, development, and demonstration" ("RD&D") permits which allow the introduction of additional liquids to the landfill. USEPA adopted regulations allowing states to issue these permits in 2004 and in 2007 approved changes to California's municipal solid waste regulations allowing the state to issue this type of permit.[233] At least two such permits have been issued in California – at Yolo County Central Landfill and CWM Kettleman Hills Facility.[234] While the state regulations allow only for the issuance of RD&D permits to MSW landfills "for which the owner or operator proposes to utilize innovative and new methods" and where certain design requirements for the handling of the additional liquids are met,[235] there are a range of operational and structural problems that can be caused by adding liquids to landfills that are not fully addressed by these design requirements.

A review of bioreactor and wet landfills shows problems that can arise when liquids are added which can affect the integrity and efficiency of the gas collection system. Liquids can become "perched" in the waste mass when relatively impervious layers are located within the waste mass (such as areas where daily or intermediate cover was not fully removed before new waste was added).[236] Perched liquids are of particular concern for the control of landfill gas – gas can become isolated in a pocket or trapped beneath a layer of saturated waste where it is unable

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[229] USEPA (September 2014), Permitting of Landfill Bioreactor Operations: Ten Years after the RD&D Rule (EPA/600/R-14/335) at 3.
[230] While the cover design, including maximizing the imperviousness of the cover and managing slopes to provide runoff pathways for rainfall, can minimize infiltration, some infiltration will occur, particularly where there is daily or intermediate cover in place. *See* Intermediate and Final Cover White Paper at 1.
[231] USEPA (September 2014), Permitting of Landfill Bioreactor Operations: Ten Years after the RD&D Rule (EPA/600/R-14/335) at 3.
[232] 27 C.C.R, § 20340(g).
[233] Research, Development, and Demonstration Permits for Municipal Solid Waste Landfills 69 Fed. Reg. 13242, (March 22, 2004); 40 C.F.R. Part 258.4; Adequacy of California Municipal Solid Waste Landfill Permit Program 72 Fed. Reg. 59288 (October 10, 2007).
[234] USEPA (September 2014), Permitting of Landfill Bioreactor Operations: Ten Years after the RD&D Rule (EPA/600/R-14/335) at 29.
[235] 27 CCR, Sec. 20070.
[236] USEPA (September 2014), Permitting of Landfill Bioreactor Operations: Ten Years after the RD&D Rule (EPA/600/R-14/335) at 14; GCCS White Paper at 8.

to reach the gas collection system.[237] In addition, the rapid decomposition of the waste can lead to settlement within the waste mass, potentially damaging the gas collection infrastructure and compromising the structural integrity of the site's side slopes.[238]

Liquids can also cause exothermic reactions with certain reactive wastes, such as secondary aluminum production waste or steelmaking slag, and cause elevated temperatures that could lead to subsurface fires.[239] Without any explicit exclusions of such waste in a landfill, leachate recirculation and liquids addition increase the risk of this type of catastrophic event.

Accordingly, CARB should consider in its LMR revisions explicitly prohibiting leachate recirculation activities at landfills. CARB should ensure that these revisions are also harmonious with revisions needed in the current

H. CARB should require site-specific component leak monitoring and repair plans.

CARB requested comment on whether it should revise the LMR in regard to component leak monitoring and repair plans. Specifically, CARB suggests that the LMR could be revised to require leak detection and repair plans like those required in California's Oil and Gas Methane Regulation at 17 CCR § 95669.[240] Commenters generally support the concept of requiring specific plans for component leak detection. In CARB's presentation, it notes that landfill operators have expressed confusion as to where leak monitoring is required.[241] Increased detail regarding the components to be monitored (and possibly the method of monitoring) would likely help to address this confusion. Commenters intend to submit additional, more detailed comments on this later but offer initial thoughts here.

CARB's Oil and Gas Methane Regulation, like EPA's New Source Performance Standards[242] and Emission Guidelines[243] for the oil and gas industry,[244] generally requires the development of a site-specific plan for component leak monitoring, while setting minimum standards that must be met. This appears to allow the operator some flexibility regarding how to comply while providing a degree of certainty regarding emission reduction by holding the plans to minimum standards. In addition, the plans are required to address different kinds of components, like unsafe-to-monitor and difficult-to-monitor components.[245] Addressing

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[237] GCCS White Paper at 9.
[238] USEPA (September 2014), Permitting of Landfill Bioreactor Operations: Ten Years after the RD&D Rule (EPA/600/R-14/335) at 8.
[239] Comment submitted by Rick Carleski, Assistant Chief, Division of Materials and Waste Management, Ohio Environmental Protection Agency (Ohio EPA) (March 29,2019), Docket ID EPA-HQ-RCRA-2015-0354-0071, https://www.regulations.gov/comment/EPA-HQ-RCRA-2015-0354-0071 at 1-2, 3; Comment submitted by Lisa A. Hughey, Deputy Director of Central Office, Tennessee Department of Environment and Conservation (TDEC), Docket ID EPA-HQ-RCRA-2015-0354-0076, https://www.regulations.gov/comment/EPA-HQ-RCRA-2015-0354-0076 at 4-5.
[240] CARB 2024 LMR Workshop at 43.
[241] *Id*. at 44
[242] 17 CCR § 95669.
[243] 40 C.F.R. § 60.5397c.
[244] 40 C.F.R. § 60.5397b.
[245] *See, e.g.,* 17 CCR § 95669(d)(1)(E); 40 C.F.R. § 60.5397c(g)(2)(3).

components with more specificity will likely provide increased certainty to operators, making it easier to comply.

In the future, Commenters will likely have additional input on the monitoring approach. in the component leak regulations. However, overall, we believe that requiring site-specific component leak and repair plans with a similar level of detail and specificity to those required for the oil and gas industry is an improvement to the LMR that CARB should pursue.

III. Co-Benefits: Reducing Landfill Fire Risk and PFAS in Water Pollution Discharges

In addition to reducing emissions of methane and other air pollutants, many of Commenters' recommendations herein likely have important co-benefits. Improvements in cover practices, wellhead monitoring, and measures to reduce liquids present in the landfill can likely reduce the risk of landfill fires and subsurface thermal events. These practices are also likely to reduce the volume and/or concentration of per- and polyfluoroalkyl substances ("PFAS") in landfill leachate, which EPA has announced it plans to address in a rulemaking under the Clean Water Act.[246] Commenters plan to submit additional information to CARB on these co-benefits in the future.

IV. Conclusion

CARB leads the way for innovative landfill methane regulations since 2010. Commenters support many of the proposed concepts in the 2024 LMR Workshop. However, Commenters also identify specific and feasible recommended revisions CARB should make to the LMR. We look forward to continued conversation and engagement as CARB prepares its regulatory package. Commenters remain a resource for CARB as it continues to serve as a regulatory leader for controlling landfill methane.

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[246] EPA, Preliminary Effluent Guidelines Program Plan 16 at 35 (Dec. 2024), https://www.epa.gov/system/files/documents/2024-12/preliminary-plan-16_december2024_508.pdf.