



Technical Support Document for the Prescribed Fire Emission Inventory

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I. Introduction

Prescribed fire is planned, intentional ignition applied by land managers to reduce vegetation fuels that feed potential future wildfire, reduce wildfire risk on communities and infrastructures, restore ecosystem health, and support landscapes that depend on periodic burning. It is a planned, carefully managed tool used across California and other parts of the United States and the world. Unlike large wildfires, prescribed burns are conducted under specific atmospheric and fuel conditions to keep fire behavior low intensity and predictable. California has goals to expand the use of prescribed fire to reduce hazardous fuel buildup, improve forest resilience, and help protect communities from severe wildfire.

To support air quality planning, greenhouse gas accounting, and tracking pollutant reduction progress over time, the California Air Resources Board (CARB) maintains a Prescribed Fire Emission Inventory (“the Rx Fire Inventory”) that quantifies emissions from planned burns across the state. The Inventory provides emissions estimates for 9 criteria pollutants and 3 greenhouse gases (see Section II.3.3.1 for more information about each pollutant) released during the flaming and the smoldering phases of the burn (these combustion phases are discussed in more details in Section II.3.5 and II.3.6). The Inventory is spatially and temporally explicit and “event-based”: each individual burn record has an explicit location in latitude and longitude; a specific burn date or burner-reported date range; and information about the burn activity such as the burner, burn type (broadcast burn, pile burn, or air curtain incinerator (ACI) or carbonizer), burn acreage, fuel type, and fuel loading.

In CARB’s official statewide emission inventory database, the Rx Fire Inventory corresponds to the Emission Inventory Classification (EIC) codes 670-664-0200-0000 (Range Improvement) and 670-666-0200-0000 (Forest Management). The Inventory and these EIC categories are specific to intentional fire for land and resource management applications and do not include agricultural burning and residential backyard burning.

Major Inventory Updates During the 2025-2026 Inventory Cycle

During the 2025-2026 inventory cycle, CARB staff modernize the methodology and the data sources of the Rx Fire Inventory using 2023 activity data as the prototype.

In past editions of the Inventory (for burns conducted in 2022 and prior years), burn project perimeters and ignition dates or date ranges were based on the California Department of Forestry and Fire Protection’s (CAL FIRE) Fire History Geodatabase.

Prescribed burning emissions were estimated using the First Order Fire Effects Model (FOFEM version 6.7, developed by the U.S. Forest Service) and a custom geoprocessing tool (Emission Estimation System, EES, developed for CARB by researchers at University of California-Berkeley).

The new inventory framework differs from the previous inventory in the following ways:

- it integrates activity datasets collected and compiled by local/state/federal air and land management agencies (Section II.1.1), the most extensive data reconciliation effort among similar datasets to date;
- it uses satellite fire detect data to fill in specific burn date that was not provided by the burner in the original datasets of government record (Sections II.1.3.2.4 and II.2.4);
- it refines fuel consumption assumptions specific to fuel compartments (Section II.3.5); and
- it employs emission estimation pathways that are specific to combustion phase and burn type (Sections II.3.6 and II.3.7).

This Inventory is built by reconciling diverse and disparate data sources, applying decision logic to avoid double or triple counting and to resolve inconsistencies among multiple datasets, followed by estimation of emissions using scientifically robust methods. The outcome of these inventory refinements is a spatially and temporally explicit inventory with day-by-day emissions information that better reflects the location-specific vegetation fuels consumed during prescribed burn.

Overview of This Document

The new inventory framework integrates geospatial analysis, decision logic, and emissions science to develop a comprehensive Rx Fire Inventory for the State of California. This document describes the methodology used in the two major phases of the inventory process:

Phase 1: Activity Data Reconciliation

Prescribed fire activity data in California are reported through multiple systems, including the Prescribed Fire Information Reporting System (PFIRS), Air District records,¹ and the Interagency Treatment Tracking System (ITS). These datasets often

¹ For the purpose of this document, the use of capitalized “Air District” refers to the datasets that are collected, oversaw, or supplied by the local air districts, whereas non-capitalized “air district” refers to local air district in general context. “Air District records” include PFIRS for the air districts that use PFIRS.

differ in spatial precision, temporal coverage, and attribution. The workflow section describes how CARB consolidates these records, applies spatial and temporal matching, and uses a decision framework to classify records into inclusion or exclusion bins. This process ensures that the statewide inventory is comprehensive yet non-duplicative.

Sections II.1 and II.2 provide a step-by-step guide outlining how prescribed fire activity records are compiled, assigned unique identifiers, and how activity data are prepared for reconciliation and emissions estimation.

Phase 2: Emissions Estimation

Once activity data are reconciled into a complete activity inventory, emissions are calculated using pollutant-specific emission factors and fuel consumption assumptions. Section II.3 documents the methodology for estimating emissions from broadcast burns, pile burns, and ACI/carbonizer operations. It includes pollutant definitions, calculation formulas, and tables of emission factors derived from established models and source tests. By incorporating combustion-phase details and fuelbed characteristics, the methods improve accuracy and consistency across prescribed fire pathways.

The general emission calculation equation is:

$$\textit{Burn Acreage} \times \textit{Fuel Loading} \times \textit{Emission Factor}.$$

The subsections of Section II.3 walk through each element of this general equation for broadcast burn, pile burn, and ACI/carbonizer and explain how flaming and smoldering emissions are estimated.

Continual Inventory Refinements and Interagency Collaboration

Integrating several activity datasets that differ in spatial precision, temporal coverage, and attribution requires significant efforts in screening data records, remediating data issues where feasible, and filling in missing data elements in some cases. Some of the data issues encountered during the data reconciliation process include incomplete information on burn size, fuel type, daily ignition activity, or actual ignition dates. (Sections II.2.6 and II.2.7 have more specifics.) There are also many cases where two different agencies' datasets captured the same prescribed burn, but the burn acreage and dates are inconsistent between the datasets. These discrepancies lead to uncertainty in acreage, burn timing, and spatial attribution. They can impact the accuracy of the emission estimation or result in misallocation of emissions to

individual dates that do not represent the work that was actually done. Continued collaboration with both air districts and land management agency partners is essential to close these data gaps and ensure that the inventory accurately represents prescribed fire activity across California's diverse landscapes. CARB staff will adapt the decision logics of the data reconciliation process as activity data improve over time.

II. Methods

Section 1. Workflow for Reconciling Prescribed Fire Records with ITS Records

1.1 Overview and Data Sources

The objective of this workflow is to produce a reconciled prescribed fire activity inventory by integrating multiple reporting systems while removing identified double-/triple-counting activities based on spatial and temporal overlaps among burn records. The workflow addresses the challenge that prescribed fire data in California are collected and stored across several platforms that do not always align in space, time, or attribution.

Three datasets were used:

Air District (AD) records compiled and reconciled from two datasets: Prescribed Fire Information Reporting System (PFIRS), and the quarterly reports compiled by the California Air Pollution Control Officers Association (CAPCOA) from individual air districts to support grant programs (“CAPCOA Data”). These are event-based records entered by the burners (PFIRS) or provided by the local air districts to CAPCOA, containing burn activity information (location, acres treated, date, burn type).²

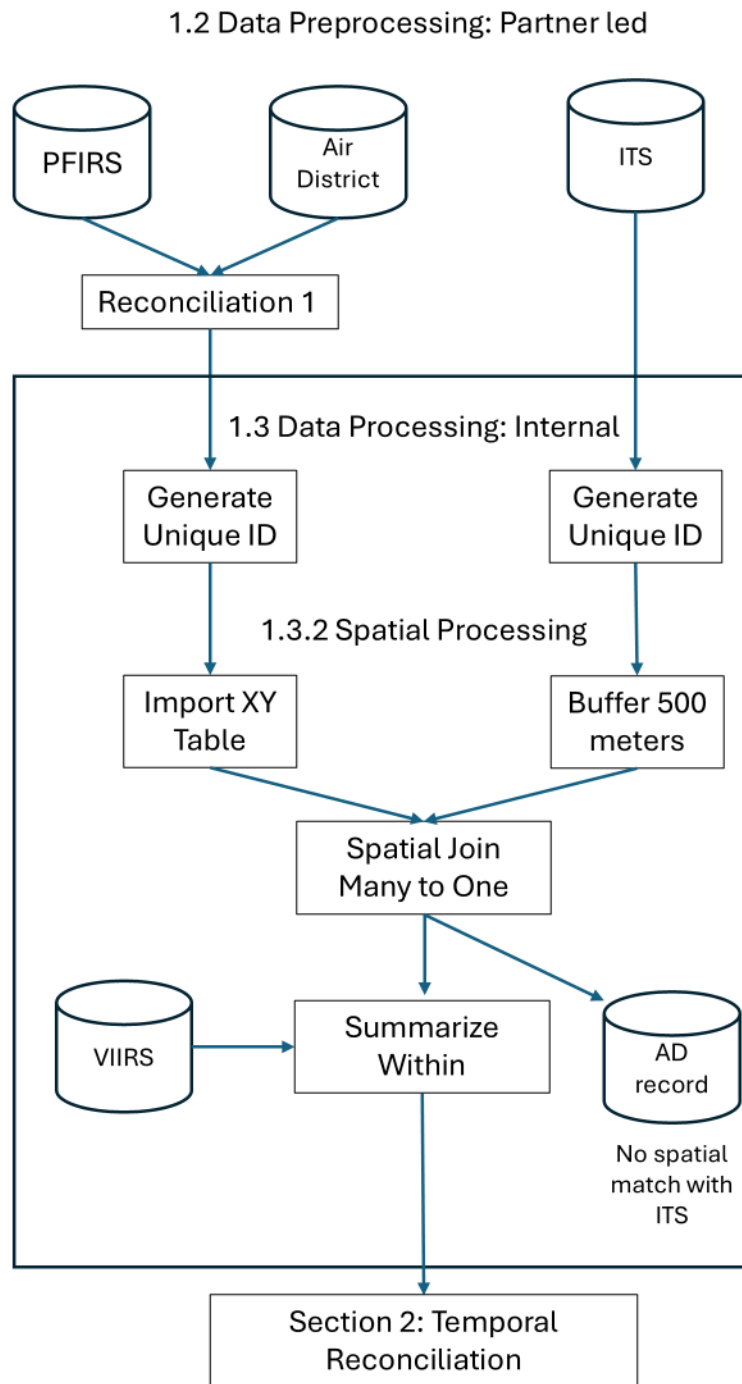
Interagency Treatment Tracking System (ITS) – Activity records and geospatial data of prescribed fire activity conducted or funded by state/federal Land Management Agencies (LMA), that were compiled and processed by the California Wildfire and Forest Resilience Task Force.

Visible Infrared Imaging Radiometer Suite (VIIRS) satellite thermal detections – Space-based observations of active fire (375-meter resolution) used to supplement burn dates.

The workflow was implemented in ArcGIS Pro, using geoprocessing tools to perform spatial joins, buffering, and summarization of VIIRS. Figure 1 provides an overview. Temporal reconciliation was conducted in a spreadsheet environment (Section 2.).

² The AD dataset is reconciled and prepared by CARB’s Agricultural and Prescribed Burning Support Section and provided to CARB’s Fire Emission Inventory staff for incorporation into the emission inventory.

Figure 1. Workflow diagram demonstrating the processing of partner-led data through a suite of geoprocessing tools to spatially reconcile the Air District and ITS data.



1.2 Reconciliation of PFIRS and Air District Records

This sub-section describes the process of reconciling PFIRS records and CAPCOA Data.³ CAPCOA Data were compared against PFIRS entries to identify cases where both systems referenced the same event. For most districts, CAPCOA Data were compiled directly from PFIRS data. As a result, when attributes in CAPCOA Data record matched those in a PFIRS record, the two were considered a match and treated as a single consolidated event.

CAPCOA Data often include additional fields used for program administration—such as monitoring details or indicators relevant to the Prescribed Burn Reporting and Monitoring (PBRM) grant program. These attributes do not describe the burn activity itself and were therefore not carried forward into the spatial reconciliation workflow.

A small number of air districts rely on reporting mechanisms outside PFIRS for portions of their burn activity. In these cases, district-tracked records that did not have a corresponding PFIRS entry were retained independently and passed forward for internal processing. PFIRS data were used where available, but CAPCOA Data records served as the primary source of information when PFIRS coverage was incomplete.

This reconciliation step produced a unified dataset that combined PFIRS and CAPCOA Data prior to internal ID generation and spatial analysis. No ArcGIS Pro tools were used during this partner-led phase.

1.3 Data Processing

1.3.1 Generation of Unique Identifiers

Unique internal identifiers were assigned to the reconciled Air District records and the LMA/ITS records to ensure consistent tracking throughout spatial and temporal processing. Because the reporting systems use different identifier formats, a standardized internal ID was required.

Identifiers were created using Excel's RAND() function, which generates random decimal values between 0 and 1. These values were scaled and converted into large

³ This workflow is done by CARB's Agricultural and Prescribed Burning Support Section (APBSS), which provides a reconciled AD dataset to CARB's Fire Emission Inventory team for incorporating into the emission inventory.

integers to produce distinct, non-sequential identifiers. Separate numeric ranges were used for each dataset to avoid overlap.

LMA (ITS) identifiers: approximately 1.1×10^{10} to 9.1×10^{10}

Air District identifiers: approximately 6.6×10^{10} to 9.1×10^{10}

These 11-digit identifiers functioned as stable keys for linking records during Spatial Join operations, VIIRS summarization, and temporal reconciliation. This step standardized IDs across datasets that originally used different naming conventions or event structures.

(Performed outside ArcGIS Pro.)

1.3.2 Spatial Processing

1.3.2.1 Importing XY Coordinates for PFIRS/Air District Records

PFIRS and Air District records with latitude-longitude fields were converted into spatial point features using the XY Table to Point tool in ArcGIS Pro.

This tool created point geometries that served as the spatial basis for matching with buffered ITS features.

ArcGIS Pro tool:

XY Table to Point (Data Management → Features)

1.3.2.2 Buffering ITS Features to Address Spatial Misalignment

ITS spatial data (points, lines, and polygons) were buffered by 500 meters to account for positional inaccuracies in both agency-reported coordinates and ITS spatial representations. The 500-meter distance was selected to capture valid matches where PFIRS or Air District coordinates were offset, while limiting unintended matches.

This distance also aligns reasonably well with the approximate spatial scale of VIIRS observations, which have a native pixel size on the order of several hundred meters. VIIRS geolocation accuracy decreases with increasing off-nadir angle, causing detected hotspots to shift laterally relative to their true ground position. Using a 500-meter buffer helps absorb both agency coordinate misalignment and satellite off-nadir displacement, ensuring that satellite detections and ITS features are compared within a realistic spatial tolerance.

The resulting buffered ITS geometry provided a more flexible spatial envelope for determining whether datasets referred to the same fire activity.

ArcGIS Pro tool:

Buffer (Analysis → Proximity)

The 500-meter buffer distance was selected to include valid but misaligned matches while limiting false positives,

1.3.2.3 Spatial Join: Many-to-One Evaluation

PFIRS/Air District point features were spatially compared to the buffered ITS features using the Spatial Join tool in ArcGIS Pro.

This operation determined:

1. Whether a PFIRS/Air District record fell within an ITS buffer
2. Whether multiple PFIRS/Air District records matched a single ITS feature (many-to-one).
3. Whether a single PFIRS/Air District record intersected multiple ITS features.
4. Whether a record had no spatial match with ITS.
5. Many-to-one and one-to-many intersections were flagged as ambiguous and routed for further evaluation during temporal reconciliation.

ArcGIS Pro tool:

Spatial Join (Analysis → Overlay)

1.3.2.4 Summarizing VIIRS Detections Within Joined Features

VIIRS fire detection data were integrated using the Summarize Within tool in ArcGIS Pro. This tool aggregates all VIIRS detections that fall inside each buffered ITS feature created during the spatial join. Rather than treating each VIIRS detection as an independent event, the tool compiles:

- Counts of detections occurring within the buffered polygon
- Dates and values associated with those detections grouped by record

A consolidated summary of satellite activity linked to each spatial unit

Importantly, VIIRS detections were compared only against ITS data. No spatial comparison was performed between VIIRS detections and Air District records. As a

result, the summarized VIIRS information reflects satellite activity relative strictly to the ITS-defined burn areas.

This approach differs from the U.S. EPA's methodology, in which each VIIRS detection is treated as a unique, standalone event. Instead, the Summarize Within method produces polygon-based summaries, allowing all detections associated with the same burn area to be evaluated collectively. This provides a more context-aware understanding of satellite-observed fire activity and supports downstream temporal reconciliation by linking multiple VIIRS detections to a single reported event.

ArcGIS Pro tool:

Summarize Within (Analysis → Summarize Data)

1.3.2.5 Air District Records with No Spatial Match to ITS

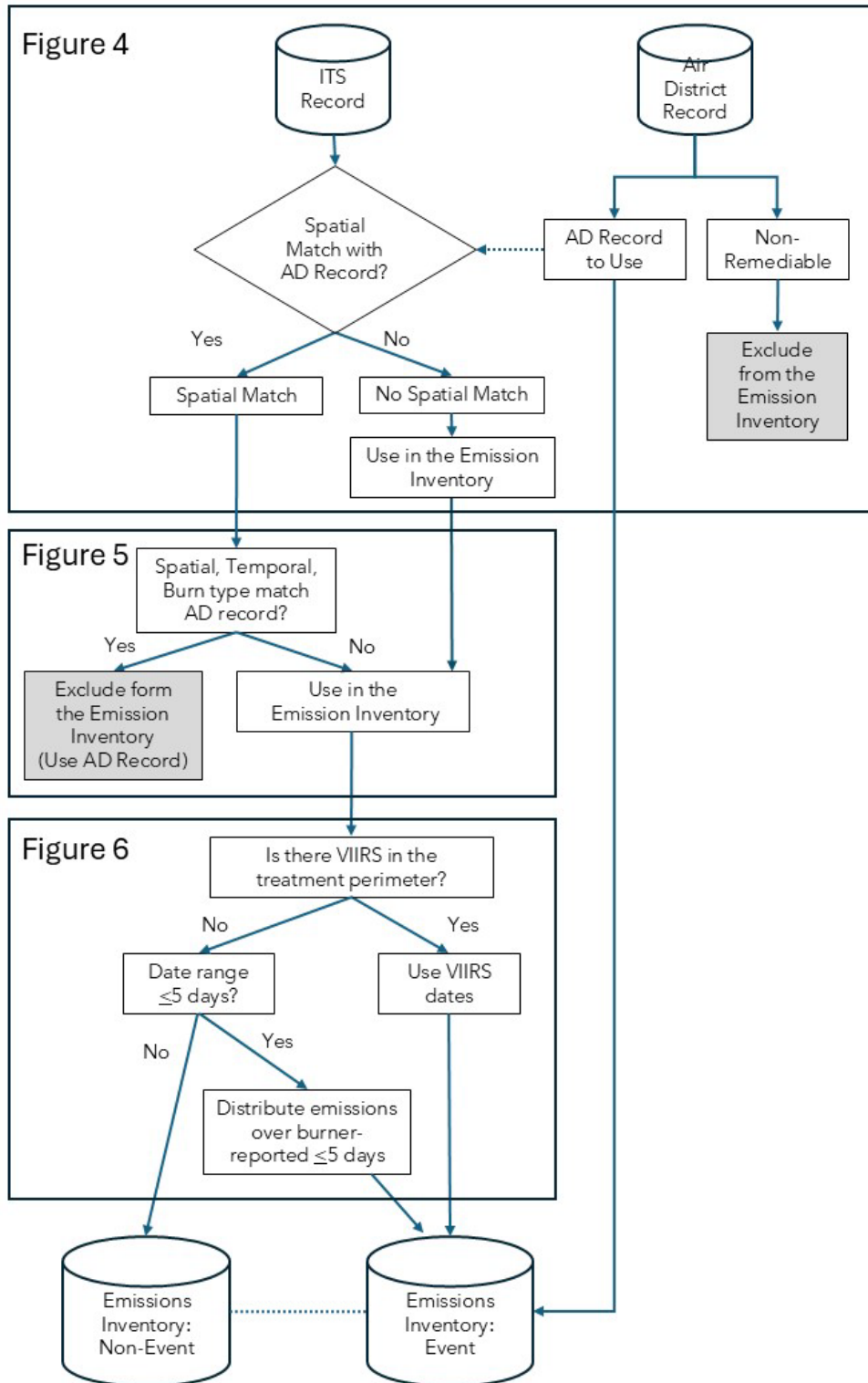
Air District records that did not intersect any buffered ITS feature were retained and categorized separately. Because these records may represent valid burn activities not captured within the ITS system—or may reflect district-level reporting processes independent of PFIRS—they were not removed from the dataset.

All non-matched Air District records were placed into the A1 category: Air District Included bin, which serves as the entry point for the temporal reconciliation process described in Section 2. These records undergo additional evaluation based on timing, reporting context, and available VIIRS detections to determine whether they correspond to known activity or represent distinct events.

Section 2. Decision Framework and Data Reconciliation Methods

The California Rx Fire Inventory integrates activity data from multiple reporting systems to build a comprehensive and non-duplicative record of prescribed fire activity statewide. Data sources include PFIRS, CAPCOA Data, ITS spatial data (LMA records), and VIIRS satellite detections. A multi-stage decision framework was developed to evaluate data completeness, resolve spatial and temporal inconsistencies in activity records, and avoid potential double-/triple-counting between overlapping datasets. Each stage assigns records to a specific Bin, indicating inclusion, exclusion, or further review status. Figure 2 graphically presents the overall process steps that are described in Sections 2.1 to 2.3. Figures 3 to 6 are flow charts that graphically depict the decision logics used in data reconciliation. Reader may wish to refer to Figures 2-6 while reading Sections 2.1 to 2.5.

Figure 2. Workflow diagram demonstrating the temporal reconciliation between the Air District and ITS data.



2.1 Initial Data Screening: Air District Records

The first decision tree ensures only valid AD records enter the reconciliation process.

- Records with Acres Burned equal to zero, blank, or irremediable are omitted from the inventory and categorized as Bin CD (cancelled/denied) or Bin O (non-remediable).
- For PFIRS records, PFIRS administrator⁴ considers a record with timestamps in the Patrol On or Out On fields as a complete record that has been closed out in the system. Such record is retained and passed to subsequent decision trees; otherwise, it is omitted from the inventory and assigned to Bin CD.
- This screening step removes records that are incomplete, cancelled, or incorrectly reported while retaining those with verifiable activity data.

2.2 Reconciliation Between Air District and ITS Records

Next, AD records are cross-checked with the ITS dataset to identify spatial and temporal matches.

- Non-remediable, cancelled, or denied AD records (Bins O, CD) are not included in this step.
- Spatial matching is performed within a 500-meter buffer to capture slight geolocation discrepancies between datasets.
- For AD and ITS records that have both spatial and temporal match, if burn types (pile vs. broadcast) agree, the records are considered matched; if they differ, the record is flagged for additional review.
- Records appearing only in ITS or only in AD are separately classified for further analysis (e.g., Bin A1 for usable AD records).

This step reconciles overlapping activity reports while identifying potential duplicates for follow-up verification.

2.3 Managing LMA Records and Preventing Double Counting

ITS data are then compared with reconciled Air District records to prevent duplicate representation of the same burn.

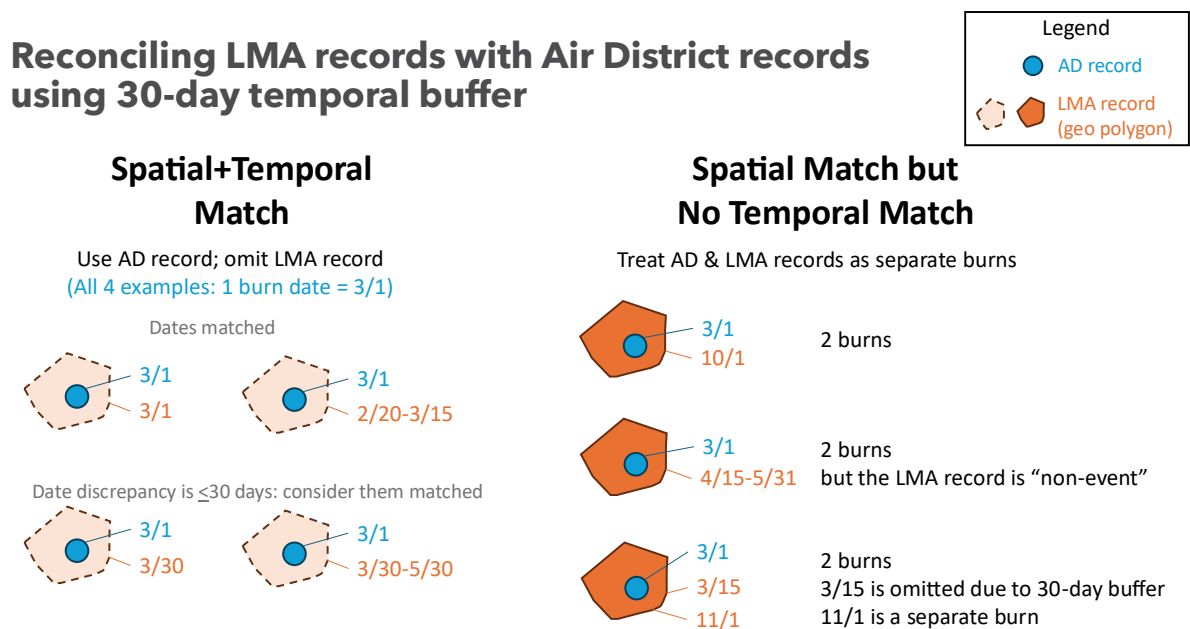
⁴ PFIRS is developed and maintained by CARB's Agricultural and Prescribed Burning Support Section.

- Spatial location and burn type between Air District and ITS data must match to assess temporal matches. If burn type does not match, then the Air District and ITS records are treated as two independent events.
- If an ITS record forms a valid spatial 'pair' with an AD record and the burn dates match temporally, it is excluded to prevent double counting (Bin Y1).
- LMA record and AD record may contain imprecise burn date information, and there is no alternative information available to verify actual burn date. (E.g., an AD record may indicate that burn authorization was requested on March 1, but the corresponding LMA record indicates that the burn took place sometime between March 2 and March 9, thus the actual burn date is uncertain.) To further minimize potential double-counting, the remaining records that have not yet been excluded are screened again with an additional temporal buffer: a spatial 'pair' where reported AD and LMA burn dates are within ≤ 7 days of each other is assigned to Bin Y2 and excluded from the inventory.⁵
- Furthermore, many LMA records contain only an end date but not a start date. It is unknown whether the end date indicates that the entire treatment area was burned on that one day, or that it was the last day of a multi-day burn (where the multiple ignition dates were not reported), or whether it was the date when burner logged the activity into their database thus it does not reflect the actual burn date. Likewise, there is no alternative information available to verify actual burn date. To further minimize potential double-counting, the LMA records without a reported start date (and that have not yet been excluded in previous steps) are screened again with one more temporal buffer: if the LMA forms a spatial 'pair' with an AD record, and the LMA end date falls within ≤ 30 days of a AD record date, it is assigned to Bin Y3 and excluded from the inventory.
- Only ITS records that fall outside a 30-day buffer with an Air District counterpart advance for further analysis (see Section 2.3).

Assumptions in this step prioritize the Air District dataset when temporal or spatial ambiguity exists, because the date info in AD datasets is expected to reflect actual burn date.

⁵ Note: Applying a temporal buffer can minimize potential double-counting, but in some cases, it can also result in exclusion of LMA burn record that is not actually duplicative of its "paired" AD record. Further advancement in data reporting and collection process and enhancement in interagency coordination between AD and LMA could be beneficial for addressing these data issues in the future. Until then, potential exclusion of unique LMA burn records—that should not be excluded but there is not a way for the reconciliation process to distinguish them from true duplicates—may continue to exist. For the purpose of this inventory compilation, in this trade-off, CARB staff has opted for a more conservative approach of prioritizing minimization of potential double-counting over saving unidentified unique LMA records from exclusion.

Figure 3. Illustrative Examples of reconciliation logic between Land Management Agency and Air District records spatially and temporally.



2.4 ITS-Only Records and VIIRS Integration

For records that exist only in ITS (no AD match), VIIRS detections are used to allocate emissions in time. If VIIRS detections match spatially and temporally, the LMA record is included, using VIIRS dates as the burn period. If detections match spatially but not temporally, the LMA record and VIIRS detect are treated as separate burns (where VIIRS detect is as assumed to be pile burn). If no VIIRS detections fall within 500 meters, the LMA record is retained as-is.

- If VIIRS detections occur within the ITS polygon buffer and date range, emissions are anchored to VIIRS dates (Bin V).
- If no detections occur but the reported date range is ≤ 5 days, emissions are distributed evenly across those dates (Bin R).
- ITS records with date range > 5 days and lack VIIRS confirmation are sent to a Non-Event Bin (N).

This ensures all emissions are assigned either from government records or satellite-supplemented dates. This cross-referencing strengthens the temporal fidelity of the emissions dataset and identifies unreported or misdated activity.

2.5 Bin Summary

This integrated decision framework creates a hierarchically confirmed prescribed fire dataset by combining spatial, temporal, and categorical logic across multiple data sources. At each stage, decision trees identify which records represent unique prescribed fire activity versus duplicates, cancelled burns, or “non-events” (a term that was created for this inventory to refer to burn records that do not have specific burn date and have no corresponding satellite fire detection). The result is a statewide emission inventory that avoids double-/triple- counting, maximizes spatial and temporal accuracy, and provides a transparent record of how inclusion and exclusion decisions were made.

Table 1. Summary of bin classifications for AD and ITS records based on spatial, temporal, and burn type relationships.

Bin	Description	Action
O	Non-remediable or invalid AD record	Excluded
CD	Cancelled or denied AD record	Excluded
A1	Valid AD record (no overlap with ITS)	Included
Y1-Y3	LMA records overlapping with AD (potential duplicates)	Excluded
V1	ITS-only records with VIIRS confirmation, where there are both spatial and temporal matches using a 1-day buffer (i.e., VIIRS detect outside of the reported date range, but is within 1 day of either the reported start or the end date, is considered matched)	Included
V2	VIIRS detect within an ITS treatment area polygon that has a unique date outside of the reported date range even after applying a 1-day buffer (assumed to be pile burn)	Included
R	ITS-only records with a date range of ≤ 5 -day, no VIIRS	Included
N	ITS-only records with a date range of > 5 -day and no matching VIIRS detects	Included / Non-event

Figure 4. Decision tree logic for determining omitted (O), cancelled or denied (CD), and included (A1) status for Air District records.

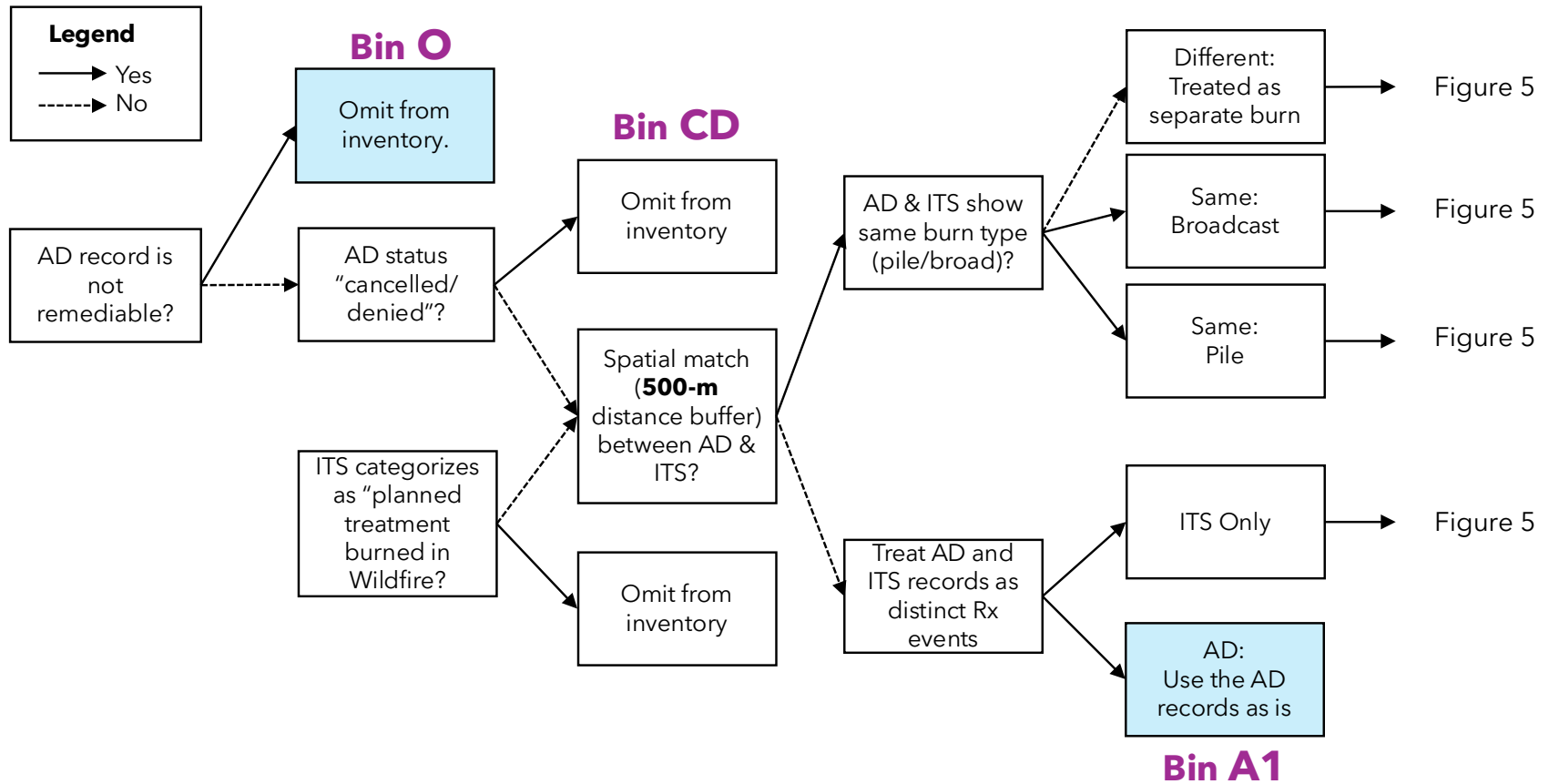
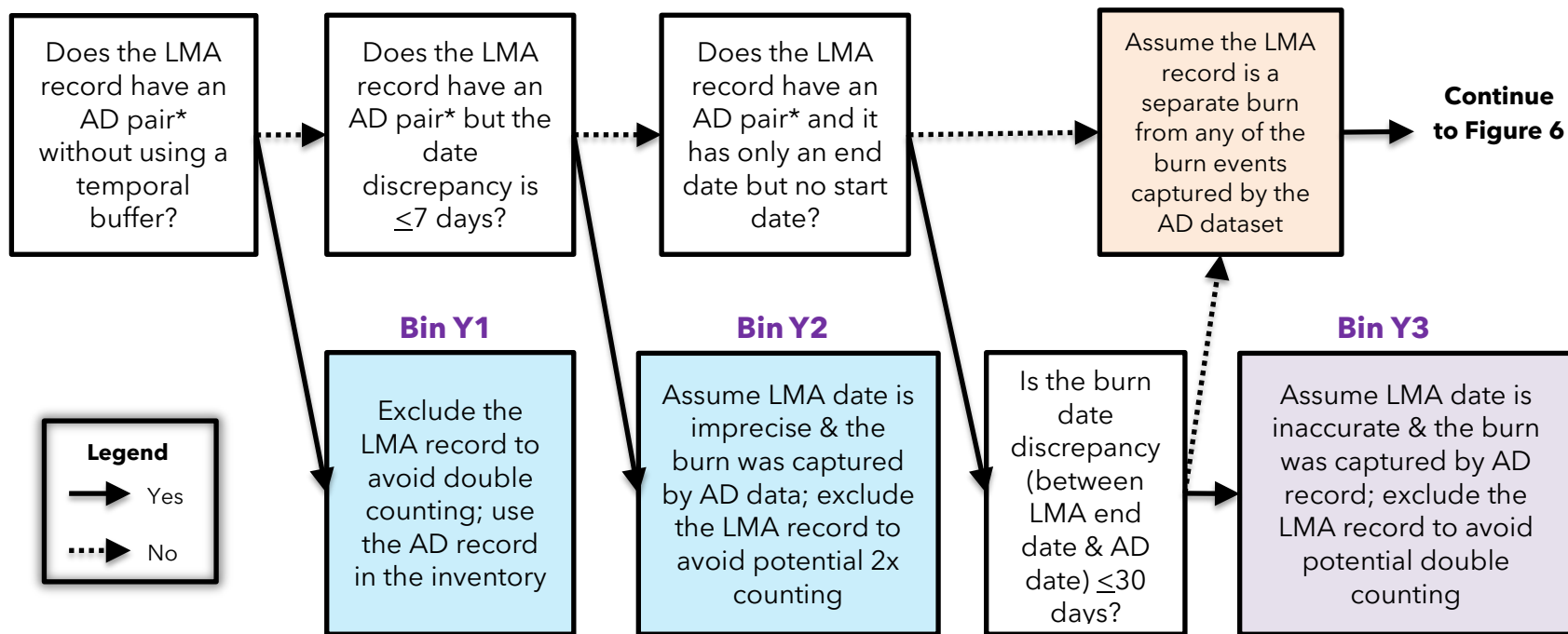
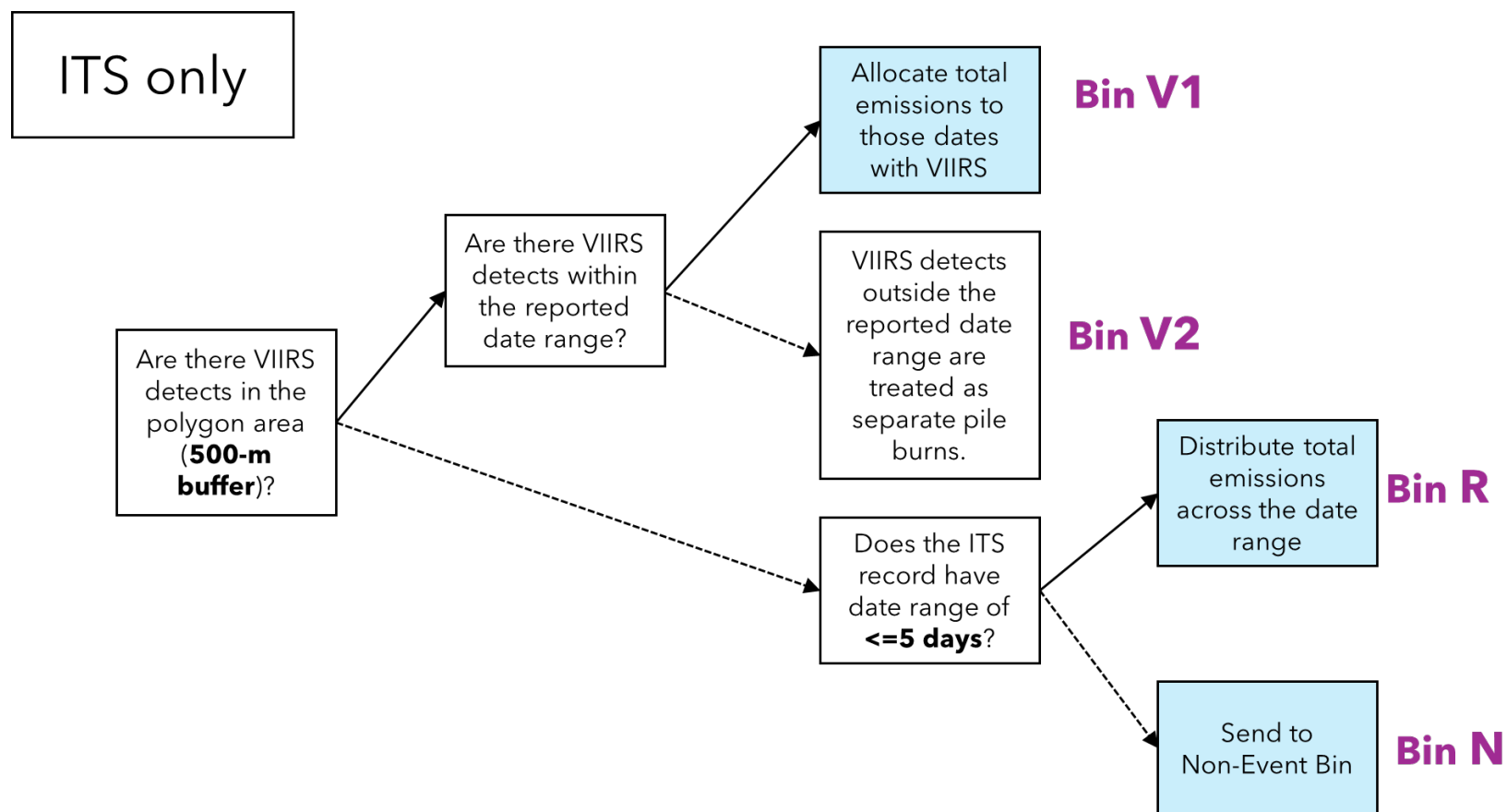


Figure 5. Decision tree logic for determining if an LMA matches an AD record based on spatial, temporal, and burn type criteria. Bin Y1 represents an LMA record that matches spatially, temporally (LMA date matches the AD recorded burn date), and burn type. Bin Y2 represents an LMA record that matches spatially, temporally with a 7-day buffer (LMA date is within 7 days of the AD recorded burn date), and burn type. Bin Y3 represents an LMA record that only has an end date (and missing a start date) and matches spatially, temporally with a 30-day buffer (LMA date is within 30 days of the AD recorded burn date), and burn type.



*A "pair" refers to a case of spatial association between a LMA record and an AD record (a 500-m distance buffer is used). One LMA record could have many AD records spatially associated to it, and each of those spatial association cases is considered a "pair." It is common for a LMA record to have multiple "pairs" with AD records.

Figure 6. ITS records without corresponding Air District records are assigned to bins based on VIIRS detections and burn date duration. Bin V1 occurs when VIIRS detections fall within the ITS date range, and emissions are distributed on those detection dates (a 1-day buffer is used to accommodate imprecision in LMA-reported burn date). Bin V2 occurs when VIIRS detections fall outside the ITS date range and are treated as separate pile burn events. Bin R is assigned when no VIIRS detections exist and the ITS date range is ≤ 5 days, and emissions are distributed across those days. Bin N is assigned when the ITS date range is > 5 days, and the record is treated as a “non-event” record.



2.6 Manual Adjustments Resulting from Discussions with Data Partners

During the process of revamping the inventory, CARB staff engaged with AD and LMA data partners to collect their input on how their prescribed burn activity data are utilized in the inventory. These discussions resulted in several manual adjustments outside of the activity data reconciliation described in Sections 2.1-2.5. The adjustments for 2023 are summarized below.

CARB staff discussed adjustments to known LMA data issues with ITS staff leads who oversaw the compilation of LMA databases into the ITS database. A number of LMA records indicated larger "activity" acreage than "treatment" acreage, while under normal circumstances, "activity" is a smaller subset of "treatment" and should have acreage smaller than or equal to "treatment" acreage. CARB staff used the smaller of the two acreages as the burn acreage in the emission inventory. Additionally, some LMA records have end date preceding start date. CARB staff corrected these cases by switching the 2 dates before feeding the records into the data reconciliation process described in Section 2.1-2.5.

There were several large-acreage burn records from the US Fish and Wildlife Service (FWS) with October 1 as the record date. The San Joaquin Valley Unified Air Pollution Control District (SJVUAPCD) cross-compared the information in their permitting system with the five October 1 FWS records in SJVUAPCD boundaries and found no record of those burns. SJVUAPCD concluded that the October 1 date most likely represented the beginning of the federal fiscal year rather than actual burn date. CARB staff also consulted with ITS staff on this known data issue and arrived at a consensus that these October 1 FWS records should be moved to the Non-Event bin to avoid over-representation of emissions on October 1. Seventeen October 1 FWS records across 9 air districts were re-assigned to the Non-Event bin (and remained part of the emission inventory).

SJVUAPCD did a detailed review of the activity data by cross-comparing the information in their permitting system with the PFIRS records used in the Inventory. They identified 102 PFIRS records that are replications from repeated requests for the same burns over the identified burn window, and 1 beneficial fire record in SJVUAPCD's CAPCOA Data among the AD records used in the emission inventory. Per SJVUAPCD's request, these 103 PFIRS records were excluded from the Inventory.

Other air districts also reviewed the activity records that have been incorporated into the Inventory for their respective districts. They identified some minor data corrections (e.g., pile burn acreage, project name, ACI categorization, burn date) that

did not result in material change to the data, and the Inventory was updated accordingly.

2.7 Manual Corrections of Location Information

In CARB staff's review of the county, air basin, and air district information (collectively referred to as "CoABDis" in the California emission inventory) in the PFIRS and CAPCOA Data, 49 records were found to have incongruous CoABDis combination. The types of incongruous cases and how CARB staff handled the correction are described below:

Case 1: a record indicated that the burn occurred in a specific air basin, but the county and/or the air district are not part of that air basin. In this case, if the county and the air district corroborated, CARB staff corrected the air basin information to match the county and the air district in the record. The rationale was that burners typically would know which county they were in, and if they had been coordinating with the local air district on burn planning, they were also expected to know the name of the air district. Whereas air basin information is not common knowledge outside of the air quality planning and emission inventory community of practitioners.

Case 2: a record indicated a county name and an air district name, but the air district did not encompass the county indicated in the record, and vice versa. In this case, it was not clear which of the two was correct. CARB staff manually reviewed additional contextual information in the original source record (e.g., the name of the burner or Land Management Agency, Smoke Management Plan name, burn unit name, etc. that were supplied by the burner or the air district) to determine the correct county and air district. If the contextual information suggested a county and/or air district that was different from the location indicated in latitude/longitude, contextual information took precedence. If there was insufficient contextual information in the original record to pinpoint the county and/or air district, latitude/longitude was used to correct the county and air district information.

2.8 Temporal Distribution of Non-Event Records by Month

Sections 2.4 to 2.6 discuss burn records where the burner did not provide precise burn date(s) (although there might be a date range that spans weeks, months, or the whole year) and there was no satellite fire detection to fill in the date information. Those sections also describe how the inventory handles these records by classifying them as "non-event" records (burn records without specific burn date). In the Rx Fire Inventory spreadsheet published in CARB's Fire Emission Inventory program

webpage, “non-event” records are presented separately from records that have specific date (“event” records)– this is to maintain consistency with the original government record when there is no additional corroborating data to fill in the details. However, the State’s official emission inventory database, California Emission Inventory Data Analysis and Reporting System (CEIDARS), does not have an established mechanism to house “non-event” activity data and emissions. All activity and emissions must be assigned to specific calendar months in CEIDARS. Because of this, additional temporal assumption must be implemented to ensure that all the prescribed burn activity and emissions are accounted for in CEIDARS. Disaggregation of “non-event” burn data to monthly values for the purpose of inclusion in CEIDARS is described below.

Case 1: If the burn range of a “non-event” record fell entirely within a single calendar month, all the fuel consumption and emissions were assigned to that month.

Case 2: For “non-event” records spanning multiple calendar months, CARB staff used the corresponding “event” records as surrogate for temporal allocation into specific months. The fuel consumption and emissions of “non-event” records were distributed according to the month-specific burn data in the “event” records for the same CoABDiS and Emission Inventory Classification codes (Forest Management and Range Improvement). Disaggregation was based on CoABDiS when possible. If month-specific data were unavailable at the CoABDiS level, data from the broader air district were used. If broader air district data were unavailable, air basin data were used.

For example: There was a “non-event” Forest Management burn record with a date range spanning September through December. Staff calculated the monthly distribution (fractions) of fuel consumption and pollutant-specific emissions of the month-specific “event” records in the same CoABDiS that occurred in September through December. These fractions were applied to the “non-event” burn totals for fuel consumption and pollutant-specific emissions to allocate them across those months.

Section 3. Prescribed Fire Emissions Estimation Methods

3.1 Overview

The purpose of this section is to document updates to California's Rx Fire Inventory that addresses known limitations in previous inventory approaches. Earlier CARB prescribed fire inventories relied primarily on the activity polygons in the fire history geo-database compiled by CAL FIRE Fire and Resource Assessment Program (FRAP), applied default broadcast burn emission factors, and did not incorporate activity data oversight or maintained by local air districts (e.g., PFIRS and CAPCOA Data). As a result, important variation in prescribed fire implementation, fuel consumption pathways, and combustion phase-specific emissions were not explicitly represented.

The updated Rx Fire Inventory expands upon prior methods by incorporating multiple prescribed fire emissions pathways, including broadcast burns, pile burns, and ACI/carbonizer operations. The inventory applies an expanded set of emission factors that explicitly include smoldering-phase emissions, enabling more complete accounting of particulate matter and trace gas production. In addition, the updated framework integrates activity data from the air districts alongside statewide spatial datasets, improving completeness, representativeness, and consistency across jurisdictions. Collectively, these updates provide a more robust and transparent accounting of prescribed fire emissions in California and better support air quality planning, interagency coordination, and evaluation of prescribed fire as a risk-reduction strategy.

The following sections describe the methodology used to estimate emissions from prescribed fire activities in California. The approach integrates (1) fuel consumption assumptions derived from the First Order Fire Effects Model (FOFEM) framework and (2) combustion-phase-specific emission factors developed for broadcast burns, pile burning, and ACI/carbonizer operations.

3.2 Scope

3.2.1 Activity Categories

The methods described in this appendix apply to the following prescribed fire-related activity categories:

- Broadcast burning

- Pile burning
- ACI or carbonizer

3.2.2 Geographic and Temporal Scope

These methods are intended for statewide application within California and support estimation of prescribed fire emissions at both the individual event level and the annual inventory scale. To the extent practicable, fuel characterization is informed by the best available data sources. For pile burning activities, fuel information reported in local Air District records is incorporated where available. For broadcast prescribed burns, the most current LANDFIRE Fuel Characteristic Classification System (FCCS) fuelbed estimates are used to represent fuel loading and composition. The approach is designed to maintain internal consistency across reporting years and prescribed fire activity datasets while allowing incorporation of improved or site-specific fuel information as it becomes available.

3.3 Pollutants and Units

3.3.1 Pollutant Definitions

This inventory estimates emissions for a set of criteria pollutants and associated compounds relevant to prescribed fire combustion processes. Brief descriptions of each pollutant are provided below to clarify terminology and reporting conventions used in this appendix.

Particulate Matter ≤ 10 microns (PM₁₀)

PM₁₀ refers to airborne particulate matter with an aerodynamic diameter less than or equal to 10 micrometers. PM₁₀ includes both fine and coarse particles generated during combustion, including ash, char, and condensed organic material. PM₁₀ is associated with respiratory health impacts and reduced visibility.

Particulate Matter ≤ 2.5 microns (PM_{2.5})

PM_{2.5} is the subset of particulate matter with an aerodynamic diameter less than or equal to 2.5 micrometers. PM_{2.5} is primarily formed from incomplete combustion and condensation of organic vapors and is a dominant component of smoke from prescribed fire. PM_{2.5} is closely associated with public health impacts and air quality standards.

Carbon Monoxide (CO)

CO is a colorless, odorless gas produced by incomplete combustion of carbon-containing fuels. CO emissions increase under low-temperature or oxygen-limited combustion conditions and are strongly associated with smoldering combustion phases in prescribed fires.

Carbon Dioxide (CO₂)

CO₂ is the primary product of complete combustion of biomass. CO₂ emissions are directly related to the amount of carbon oxidized during combustion and are commonly estimated using energy- or carbon-based relationships when direct measurements are unavailable.

Methane (CH₄)

CH₄ is a hydrocarbon gas produced during incomplete combustion and pyrolysis of biomass. Methane emissions are typically higher during smoldering combustion and contribute to greenhouse gas impacts.

Nitrogen Oxides (NO_x)

NO_x represents the sum of nitrogen oxides formed during combustion, primarily nitric oxide (NO) and nitrogen dioxide (NO₂). NO_x formation is influenced by combustion temperature and nitrogen content of the fuel. For inventory consistency, NO_x is reported as NO₂.

Sulfur Dioxide (SO₂)

SO₂ is produced from the oxidation of sulfur contained in biomass fuels. Emissions are generally low for prescribed fire but vary with fuel sulfur content and combustion conditions.

Ammonia (NH₃)

NH₃ is a reduced nitrogen compound emitted during biomass combustion, particularly under smoldering conditions. NH₃ contributes to secondary particulate matter formation in the atmosphere and is often estimated using literature-based default emission factors when measurements are unavailable.

Non-Methane Organic Compounds (NMOC)

NMOC represents the group of organic gases emitted during combustion excluding methane. NMOC includes a wide range of volatile and semi-volatile organic

compounds that contribute to ozone formation and secondary organic aerosol production. Measurement and reporting conventions vary across datasets.

Non-Methane Hydrocarbons (NMHC)

NMHC is a subset of NMOC consisting primarily of hydrocarbon compounds excluding methane. NMHC is commonly measured using flame ionization detection in source testing and is often used as a surrogate for NMOC in emissions inventories when NMOC is not directly reported.

Total Organic Gases (TOG)

TOG refers to the total mass of organic gases emitted during combustion, typically reported as total hydrocarbons (THC). In this inventory, TOG is generally approximated as the sum of methane and non-methane hydrocarbons ($\text{CH}_4 + \text{NMHC}$) where required for reporting consistency.

Nitrous Oxide (N_2O)

N_2O is a greenhouse gas formed during combustion through nitrogen-related chemical pathways. Emissions from prescribed fire are typically low and are often estimated using default emission factors due to limited direct measurements.

3.3.2 Units and Reporting Conventions

Emission factors are expressed in pounds pollutant per ton of fuel consumed (lb/ton). Emissions totals are computed in pounds and may be converted to short tons for reporting, aggregation, and inventory comparison.

3.4 General Calculation Framework

3.4.1 Emissions Calculation

Prescribed fire emissions are calculated as the product of fuel consumption and pollutant-specific emission factors:

$$E_p = FC \times EF_p$$

where:

E_p = emissions of pollutant p (lb)

FC = fuel consumed (tons)

EF_p = emission factor for pollutant p (lb/ton)

3.4.2 Treatment of Combustion Phase

Prescribed fire emissions vary systematically across activity categories as a function of combustion efficiency, fuel structure, and fuel load, which collectively influence the relative contribution of flaming and smoldering combustion. Accordingly, this inventory differentiates combustion phase treatment across broadcast prescribed burning, pile burning, and air curtain incineration to better reflect expected emissions behavior.

Broadcast burning typically exhibits lower overall combustion efficiency than pile burning or air curtain incineration due to heterogeneous fuelbeds, variable fuel moisture, and limited control over oxygen availability at the fuel surface. As a result, broadcast burns generally produce a higher proportion of smoldering combustion relative to total fuel consumed. This elevated smoldering fraction increases emissions of incomplete combustion products, including particulate matter (PM), carbon monoxide (CO), methane (CH₄), and other organic gases, relative to fuels burned under more concentrated or engineered combustion conditions.

Within broadcast prescribed burning, expected emissions characteristics vary by cover type due to differences in fuel loading, fuel continuity, and fuel “flashiness”:

- **Western forest prescribed burns** typically involve deeper litter and duff layers, greater woody fuel loading, and a higher proportion of larger diameter fuels. These conditions promote extended smoldering, particularly in duff and coarse woody debris, and contribute to relatively higher emissions of PM, CO, and CH₄ per unit area treated compared to more flashy fuel types.
- **Shrub and hardwood-dominated systems** generally exhibit intermediate fuel loads and combustion characteristics. While surface fuels often ignite readily and sustain flaming combustion, residual smoldering can persist in heavier shrub bases and downed woody material, producing emissions that fall between forested and grassland systems on a per-area basis.
- **Grassland prescribed burns** are characterized by fine, continuous, and highly “flashy” fuels with low bulk density and minimal duff or coarse woody material. These conditions favor rapid flaming combustion with limited smoldering duration, resulting in comparatively lower emissions of smoldering-associated pollutants per unit area, despite high flame spread rates.

Pile burning generally exhibits higher combustion efficiency than broadcast burning because fuels are concentrated, better aerated, and more uniformly dry. These conditions promote sustained flaming combustion and reduce the relative

contribution of smoldering emissions. Consequently, pile burns typically produce lower emissions of PM, CO, and CH₄ per ton of fuel consumed compared to broadcast burns, although localized high emissions may occur during periods of pile collapse or oxygen limitation.

Air curtain incinerators (ACI) or carbonizer represent the highest combustion efficiency among the prescribed fire pathways considered in this inventory. The forced airflow and controlled combustion environment substantially reduce smoldering combustion and enhance oxidation of organic gases and particulates. As a result, ACI/carbonizer emissions are expected to be dominated by flaming-phase characteristics, with comparatively lower emissions of PM, CO, and CH₄ per ton of fuel processed relative to open burning methods.

By explicitly accounting for combustion phase and fuel-type differences across prescribed fire activity categories, this inventory framework improves representation of expected emissions behavior while maintaining consistency with available emission factor datasets and established fire effects modeling concepts.

For prescribed fire categories in which emission factors are available by combustion phase (e.g., broadcast and pile burning), emissions are calculated separately for flaming and smoldering phases and subsequently summed:

$$E_p = FC_{flaming} \times EF_{flaming,p} + FC_{smoldering} \times EF_{smoldering,p}$$

For ACI/carbonizer operations, emission factors are applied without explicit flaming/smoldering partitioning when source test do not have phase-resolved data.

3.5 Fuel Consumption

3.5.1 Overview

Fuel consumption is a primary driver of prescribed fire emissions. This inventory applies simplified consumption assumptions based on the conceptual framework of FOFEM, which estimates consumption by fuelbed component considering fuel loads, moisture, cover type, and region. Due to inconsistencies between statewide prescribed fire records and the pyFOFEM⁶ pipeline, representative consumption fractions were adopted to reflect typical prescribed fire conditions in western U.S. fuelbeds.

⁶ pyFOFEM is a python-based library that ingests spatial LMA polygons, extracts fuels from FCCS, and calculates fuel consumption by integrating gridded fuel moisture in the FOFEM environment.

In addition to broadcast burns, this framework incorporates pile burns and ACI/carbonizer operations, which were not previously included.

Pile burns assume near-complete consumption of piled fuels, reflecting concentrated arrangements and higher combustion efficiency.

ACI/carbonizer treatments represent mechanical incineration of woody material in air curtain systems, which achieve high combustion efficiency and minimal residual fuel.

These assumptions provide a standardized approach for estimating emissions across diverse prescribed fire and biomass disposal activities in California.

3.5.2 Broadcast Burn

Fuel consumption is a primary driver of estimated prescribed fire emissions. Consumption assumptions used in this framework are grounded in the conceptual structure of FOFEM, which estimates consumption by fuelbed component as a function of fuel loads, moisture, cover type, and region. Because statewide prescribed fire records often lack complete information required to run site-specific FOFEM simulations, this inventory applies a simplified set of representative consumption fractions consistent with typical prescribed fire conditions in western U.S. fuelbeds.

$$FC = BA \times FL \times FF$$

where:

BA = prescribed burn acreage (acres) as reported in government record (if this information is missing in the government record, the record is excluded from the inventory)

FL = fuel loading (tons of fuels per acre)

FF = fraction of fuel consumed (%)

Prescribed Burn Acreage (BA)

Prescribed burn acreage is as reported in government records. If this information is missing from the government record, the record is excluded from the inventory.

Fuel Loading (FL)

Fuel characterization was derived by sampling Fuel Characteristic Classification System (FCCS) fuelbeds using multiple spatial frameworks, including ITS⁷ spatial data, Potential Prescribed Fire Burn Units (PRBU) polygons, and buffered point representations where polygon geometry was unavailable. FCCS fuelbeds intersecting these spatial features were identified and assigned to each prescribed fire record.

For each FCCS fuelbed class, total fuel loading was attributed using FCCS component definitions. These fuel loads were then proportionally distributed across standardized fuel components (litter, duff, shrubs, herbaceous fuels, and 1-, 10-, 100-, and 1000-hour woody fuels) based on the average prescribed fire consumption assumptions summarized in Table 2. Selected consumption percentages represent mid-range values consistent with typical prescribed fire conditions in western U.S. fuelbeds and align with default FOFEM burn behavior under moderate fuel moisture scenarios.

The Potential Prescribed Fire Burn Unit (PRBU) product is a geospatial framework developed by CARB staff that delineates operationally meaningful units for planning, implementing, and tracking prescribed fire. PRBUs represent how land managers realistically organize burns on the landscape, integrating topography, fuels (e.g., LANDFIRE FCCS), ownership boundaries, and planning frameworks such as Potential Operational Delineations (PODs) into spatial units that are both ecologically relevant and operationally actionable.

Within the emission inventory workflow, PRBUs provide a consistent spatial unit for linking activity data (PFIRS, CAPCOA Data, ITS) with fuels and consumption estimates. This enables proportional allocation of fuel loading and emissions at the event level, supports integration with remote sensing (e.g., VIIRS), and allows for repeated treatments to be tracked over time.

⁷ ITS = Interagency Treatment Tracking System database compiled by the California Governor's Wildfire and Forest Resilience Task Force. <https://wildfiretaskforce.org/treatment-dashboard/> The October 2024 version of the ITS database is used for the 2023 Prescribed Fire Emission Inventory.

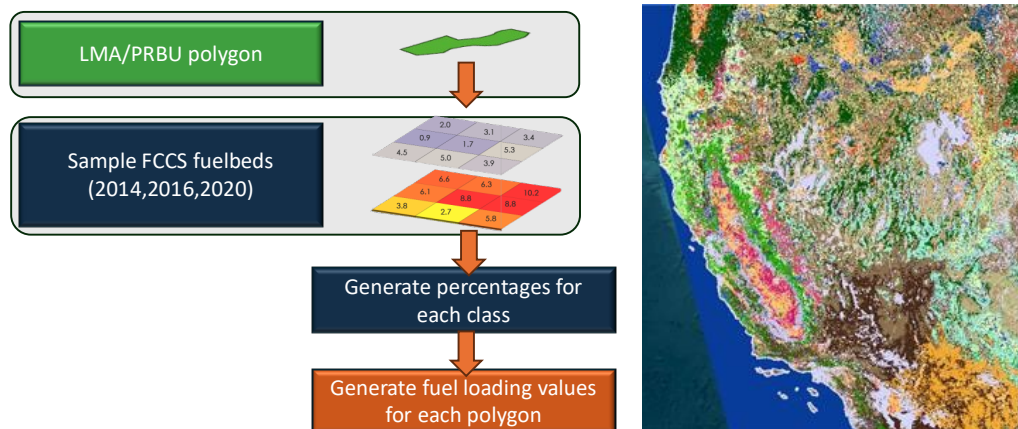
Fuel Loading for Different Vegetation Cover Type

For polygon activities, FCCS attributes were summarized over the intersected area (e.g., area-weighted dominant fuelbed and/or mean component loads). For line and point activities, fuels were attributed using the FCCS fuelbed at the feature location or within a standardized buffer to approximate the treated footprint. For points, we generated a circular buffer from the treatment acres to produce a footprint to sample the FCCS spatial data. The resulting dataset provides a common, repeatable basis for estimating fuel loading and consumption inputs for emissions calculations, improves comparability across disparate activity reporting formats, and supports stratified analyses by vegetation/fuelbed type, geography, and treatment pathway.

Figure 7. Fuel loading for broadcast prescribed burns is derived using the FCCS (Prichard et al., 2019). LMA and PRBU polygons are used as the spatial framework. FCCS fuelbed layers (2014, 2016, and 2020 versions) are sampled within each polygon to determine the proportional representation of FCCS fuel classes. These class percentages are then used to generate representative fuel loading values for each polygon, which are subsequently used to estimate fuel consumption and emissions.

Broadcast Burn: Fuel Loading Assumptions

Fuels Characteristic Classification System (Prichard et al. 2019; General Technical Report PNW-GTR-972)



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To characterize fuels for prescribed fire activity records, CARB intersected LANDFIRE-derived FCCS fuelbeds with the spatial footprints of ITS and PRBU features, including polygons, lines, and points. This spatial overlay assigns a representative fuelbed (and associated FCCS component loads) to each activity record so that fuel strata–litter, duff, 1-hr, 10-hr, 100-hr, and 1000-hr woody fuels, along with shrubs, herbaceous, and other surface fuel components that can be summarized consistently across the state.

Fraction of Fuel Consumed for Each Fuel Compartment (FF)

FOFEM applies default fuel consumption percentages by fuelbed component (litter, duff, woody fuels, herbs, shrubs, etc.) based on inputs like fuel moisture, fuel load, cover type, and region. This synthesis is drawn from published FOFEM documentation, validation studies, and general model defaults. Table 2 provides the default consumption fractions used by fuel components. These values are intended to represent mid-range prescribed fire consumption under moderate moisture conditions and to support consistency across statewide inventory calculations.

Table 2. Average Consumption Percents (Prescribed fire, typical Western US fuelbeds in moderate fuel moisture)

Fuel Component	Avg. Consumption (%)	Notes	Selected Consumption (%)
Litter	75-90%	Usually nearly fully consumed unless moisture is high.	82.5
Duff	20-40%	Duff smolders, highly sensitive to duff moisture; often little consumption in Rx burns.	30
Shrub	70-90%	High consumption if shrubs are cured or dead; live moisture reduces this.	80
Herbaceous	80-95%	Usually consumed completely if cured; <50% if green.	87.5
1-hr fuels	90-100%	Nearly all fine fuels consumed.	95
10-hr fuels	60-80%	Partial; depends on moisture, flame length.	70
100-hr fuels	20-50%	Often only surface-charred or partially consumed in Rx burns	35
1000-hr (3-9" sound, 3-9" rotten)	Sound: 10-20%. Rotten: 30-60%	Rotten wood burns more readily; sound wood rarely consumed in prescribed conditions.	15% and 45%

Partition of Fuel Consumed by Flaming and Smoldering Phases

Consumption by fuel component was subsequently partitioned into flaming and smoldering combustion phases using FOFEM's internal combustion phase allocation logic. Fine fuels and herbaceous components were primarily assigned to the flaming phase, while duff and larger woody fuels contributed a greater proportion to smoldering combustion. This approach ensures that phase-specific emissions (e.g., CO, CH₄, NH₃, and PM_{2.5}) are attributed consistently with the emission factor structure implemented in FOFEM.

Assumptions and Implications

Fine dead fuel moisture is assumed to be consistent with moderate prescribed fire conditions (approximately 12-16 percent). Duff and large woody fuel consumption exhibit substantial sensitivity to fuel moisture and ignition patterns and are recognized as key sources of uncertainty. These assumptions were necessary because the existing FOFEM workflow developed for the wildfire emission inventory must be reparameterized to accept prescribed fire input data. In future iterations, satellite-derived fuel moisture may be incorporated to directly refine fuel consumption within FOFEM for the Rx Fire Inventory.

3.5.3 Pile Burn and ACI/Carbonizer

Fuel consumption for pile burn and ACI/carbonizer are calculated as follows:

$$FC = BA \times BFL$$

where:

BA = prescribed burn acreage (acres) as reported in government record

BFL = burner reported fuel loading (tons/acre)

If BA is missing in the government record, the record is excluded from the inventory. If BFL is missing in the government record, a default assumption of 6.74 tons/acre is used. 6.74 tons/acre is the median of reported tons/acre from Air District records.

3.6 Emission Factor Development and Assignment

3.6.1 Overview

FOFEM emission factors for prescribed fire are available for three primary cover type categories: western forest prescribed burns, shrub-dominated systems, and grassland systems. Although the Smoke Emissions Reference Application (SERA) repository contains a broader set of emission factors for pile burning, this inventory retains only those pile burn emission factors that explicitly include smoldering-phase emissions. This selection criterion is applied to ensure consistency with the combustion phase treatment described in this appendix and to reduce the potential for underestimation of pollutants associated with incomplete combustion.

Emission factors are assigned by prescribed fire activity category and, where applicable, by cover type, fuel type, and combustion phase. Selection of emission factors prioritizes the following, in order of preference:

- Use of established national reference datasets where available and applicable;
- Use of source test data for ACI/carbonizer operations where available; and
- Explicit documentation of derived emission factors and literature-based defaults where direct measurements are unavailable.

3.6.2 Broadcast Burning

Broadcast prescribed burn emission factors are assigned by cover type (western forest Rx, shrubland, and grassland) and are based on FOFEM emission factor documentation. Where available, emission factors are applied separately by flaming and smoldering phases.

Table 3. Emissions Factors for Broadcast Burns (reported in pounds per ton)

Group	Cover Type	PM ₁₀	PM _{2.5}	CH ₄	CO	CO ₂	SO ₂	NH ₃	NMOC	N ₂ O	NO _x as NO ₂
Flaming	Western Forest - Rx	45.5	38.7	10.7	231.0	3515.6	2.3	3.4	59.3	1.1	4.5
Flaming	Shrubland	18.3	15.5	8.1	162.8	3682.8	1.5	3.3	38.5	0.3	4.8
Flaming	Grassland	22.0	18.7	4.3	134.2	3751.0	1.5	3.3	38.8	0.2	4.8
Smoldering	Western Forest - Rx	96.8	72.6	48.4	682.0	7546.0	2.4	96.8	5.5	7.3	2.4
Smoldering	Shrubland	35.2	26.4	15.4	220.0	3476.0	0.9	33.0	3.3	3.3	0.7
Smoldering	Grassland	26.4	17.6	11.0	176.0	3520.0	0.7	22.0	2.2	2.2	0.4

Source: FOFEM 2020.

3.6.3 Pile Burning

Pile burn emission factors are assigned separately for conifer and hardwood pile burns. Emission factors (Table 4) are primarily based on the Smoke Emissions Reference Application (SERA) dataset and include phase-resolved flaming and smoldering values when available. Classification of pile burning records into conifer and hardwood types relies on vegetation attribution using the CAL FIRE FRAP vegetation (FVEG) spatial data layer.

Table 4. Emissions Factors for Pile Burns (reported in pounds per ton)

Group	Cover Type	PM ₁₀	PM _{2.5}	CH ₄	CO	CO ₂	SO ₂	NH ₃	NMOC	N ₂ O	NO _x as NO ₂
Flaming	Conifer	12.6	11.7	5.6	103.8	3403.0	0.1	1.1	39.5	0.3	2.3
Flaming	Hardwood	7.8	7.3	2.8	80.0	3369.9	0.4	0.6	13.4	0.3	4.3
Smoldering	Conifer	30.2	18.1	20.3	247.8	3101.9	0.1	57.3	1.1	3.8	0.3
Smoldering	Hardwood	18.8	17.4	10.3	191.1	3070.9	0.4	19.5	1.1	7.1	0.3

Source: SERA (Smoke Emissions Reference Application) datasets for conifer & hardwood flaming, conifer smoldering.

3.6.4 Air Curtain Incinerators (ACI) and Carbonizer

ACI/carbonizer emission factors are based on source testing of a mobile ACI unit and supporting assumptions required to develop a complete pollutant set for inventory application. CARB staff consulted with the CAPCOA Engineering Working Group for ACI permitting and is using the source test that the working group is using for consistency. To date, emission characterization studies of carbonizer are still limited. For the purpose of the current edition of the inventory, carbonizer uses the same emission factors and methodology as ACI since they share similar technological features, and their combustion conditions are expected to produce similar range of emissions.

Table 5. Emissions Factors for ACI/Carbonizer (reported in pounds per ton)

Group	Cover Type	PM ₁₀	PM _{2.5}	CH ₄	CO	CO ₂	SO ₂	NH ₃	NMOC	N ₂ O	NO _x as NO ₂
ACI/Carbonizer	Hardwood	12.6	11.7	5.6	104	3403	0.1	1.1	39.5	0.3	2.3

Source: *Source Test Report for 2023 Emission Factor Testing - Mobile Air Curtain Incinerator (BurnBoss T24)*. Prepared by Montrose Air Quality Services, LLC for Oregon DEQ (May 23-25, 2023). Document No. W006AS-021372-RT-2857

2.6.4.1 ACI/Carbonizer Pollutants Measured vs. Derived

CO, NO_x, SO₂, CH₄, THC, and NMHC are treated as measured based on direct analyzer observations. Total organic gases (TOG) are estimated as THC (CH₄ + NMHC) and treated as derived.

Particulate matter was reported only as total particulate matter (TPM), without size-resolved methods. PM₁₀ and PM_{2.5} are therefore derived from TPM using published size-fraction assumptions consistent with EPA AP-42⁸ open burning guidance and CARB biomass speciation information:

- PM_{2.5} ≈ 0.90 × TPM
- PM₁₀ ≈ 0.96 × TPM

⁸ U.S. Environmental Protection Agency (EPA). AP-42: Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources, Chapter 1 (External Combustion Sources), Section 1.6 (Wood Residue Combustion in Boilers) and Chapter 2 (Solid Waste Disposal).

PM₁₀ and PM_{2.5} estimates for ACI/carbonizer are treated as derived.

CO₂ was not measured and is estimated using an energy-based emission rate (209 lb/MMBtu) and assumed biomass Higher Heating Value (HHV). HHV is the total amount of energy released during complete combustion of a fuel, including the energy recovered from condensation of water vapor formed during combustion. HHV represents the maximum theoretical energy content of a fuel and is typically expressed in million British thermal units per ton (MMBtu/ton). CO₂ values assigned in this manner are treated as derived and scale linearly with HHV assumptions.

N₂O and NH₃ were not measured and are assigned using published default values (IPCC Tier 1 for N₂O; literature NH₃ default⁹). These values are treated as default and are expected to be conservative for ACI/carbonizer operations relative to open burning due to higher combustion efficiency.

3.7 Calculation Procedures by Activity Category

3.7.1 Broadcast Prescribed Burns

Broadcast burn emissions are computed by assigning cover type, estimating fuel consumption using defaults where required, allocating consumption by combustion phase, and applying phase-specific emission factors for each pollutant.

3.7.2 Pile Burns

Pile burn emissions are computed by classifying piles as conifer or hardwood, estimating fuel consumed, and applying phase-resolved SERA emission factors. Hardwood smoldering factors are derived where necessary using scaling methods described in Section 3.6.3.

3.7.3 Air Curtain Incinerators and Carbonizer

ACI/carbonizer emissions are computed by applying ACI/carbonizer emission factors to estimated tons processed. Derived pollutants (PM size fractions and CO₂) and defaults (NH₃ and N₂O) are applied as documented in Section 3.6.4.

⁹ Intergovernmental Panel on Climate Change (IPCC). 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4: Agriculture, Forestry and Other Land Use, Chapter 2: Generic Methodologies Applicable to Multiple Land-Use Categories. Tier 1 default emission factor for N₂O from biomass burning. Tier 1 default emission factor for NH₃ from biomass burning (0.26 g kg⁻¹ dry matter burned).

3.8 Limitations and Uncertainty Considerations

Key uncertainties include:

- variability in fuel estimates and consumption (especially duff and large woody fuels),
- sensitivity of emissions to assumed phase partitioning,
- reliance on derived/default pollutant estimates for ACI/carbonizer due to incomplete source test pollutant coverage.

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