DEASCO3
2008 Emissions Inventory Methodology

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EXECUTIVE SUMMARY

This document details the methodology used to build a comprehensive, daily fire emissions inventory for the conterminous United States for the year 2008. It relies on several sources of data with the goal of maximizing captured activity while preserving crucial information necessary for planning applications and SIP development.

The document is organized sequentially, with necessary steps listed in the order they must occur for the inventory to be prepared and built. Much of the focus is on data preparation, as the data sources used overlap in some ways and are interconnected in others. In addition, crucial meta-data are missing from a large portion of the data set that must be derived with supporting information to make it useful for estimating emissions and source apportionment.

1.0 DATA SOURCES

There are four primary sources of fire activity data available for the emissions inventory: ground-based reporting from the Fire Emissions Tracking System (FETS), other ground-based reporting including daily reports and monthly/annual summaries, Monitoring Trends in Burn Severity (MTBS)[1] fire perimeters, and satellite-detected activity from the Hazard Mapping System (HMS)[2]. Because there is overlap between all of the data sources, preparation, processing, and validation is required to create a seamless, non-redundant data set. In addition, several supporting spatial layers will aid the classification, reconciliation, and evaluation of data.

1.1 FETS Fire Reports

Accomplished fire data reported to the FETS for the year 2008 will provide prescribed and agricultural burn information for the WRAP region. Planned burns not subsequently reported as accomplished will be used to aid classification of HMS activity data.

1.2 Other Ground-based Reporting

Accomplished fire reports for other states were added to the FETS and used in the same manner as data from WRAP states. In addition, planned burn information helped classify HMS activity data.

1.3 MTBS Fire Data

MTBS data include fire perimeter and burn severity information for wildfires in the United States greater than approximately 500 acres, derived from Landsat scenes before and after the burn. The data were used in conjunction with HMS satellite detections to create daily fire growth for large, multi-day fires, constrained in size by the perimeter information, as well as daily, composite severity for each burned area identified by HMS (on a detect-by-detect basis).

1.4 HMS Fire Detections

HMS activity data include the date, time, and location of the detection. The dataset covers all of North America, and allowed for inclusion of many fires from Canada and Mexico that were otherwise unobtainable.

HMS data were used in two ways in the 2008 emissions inventory: to create daily fire growth patterns for large wildfires included in the MTBS dataset, and gap-fill areas of the modeling domain where ground-based reporting was lacking. All HMS detections were classified as wildfire, prescribed, or agricultural burning for use in the inventory.

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[1] http://www.mtbs.gov

[2] http://www.ospo.noaa.gov/Products/land/hms.html

1.5 2008 National Emissions Inventory Version 2

This dataset included classified fire data for wildfire, prescribed fire, and agricultural fire for the year 2008. Documentation of the methods used to calculate emissions and classify fires was not available when this inventory was developed, however, and the data will therefore not be used as a supplementary data source. The dataset was used for a comparative analysis as part of the QA/QC process.

1.6 Fuelbed Datasets for North America

The Fire Characteristics Classification System (FCCS)[3] 30m fuelbed layer was available for the conterminous United States, providing fuel loading information for multiple strata in 300+ fuel beds. However, the modeling domain encompassed an area including Canada, south of Hudson Bay, and Mexico, north of the Yucatan Peninsula. A cross-walk exercise integrated the three datasets into a seamless fuel layer for the modeling domain. The layers to be integrated are:

- FCCS 30m fuelbed layer
- Canadian Forest Fire Behavior Prediction System (CFFBPS) 1km layer.
- The MODIS General Land Cover (GLC) 2000 1km layer (for Mexico).

1.7 Supporting Spatial Layers

There were several GIS datasets that supported data preparation and emissions calculations:

- FCCS 30m fuelbed layer for the conterminous United States, providing fuel-loading information for multiple strata in 250+ fuel beds.
- Crop Data Layer (CDL) for 2010. This 30m fuelbed layer was developed by Michigan Tech Research Institute and combined data from the FCCS later above and National Agricultural Statistics Service annual state-by-state crop layers for 2010, assigning new FCCS codes (starting with 1201) for 30 different crop types.
- Custom-built land ownership maps for the WRAP region and select states outside the WRAP to support fire classification analysis.
- A map of UTM zones for projecting data, used when calculating distance and area.
- Various boundary maps, including states, counties, tribal areas, and PLSS grids.
- Daily, gridded, multi-sensor (radar and rain gauge) precipitation estimates obtained from the National Weather Service[4], used as an input into the fire consumption model.
- A map of Weather Information Management System (WIMS) fire weather station locations paired with daily fuel moisture and meteorological data[5] were used as inputs to the fire consumption model.

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[3] http://www.fs.fed.us/pnw/fera/fccs/

[4] http://water.weather.gov/precip/download.php

- A map of the Bailey Eco-regions for North America[6] was used as an input to the fire consumption model. The map contains hierarchical classes of eco-regions, the broadest being western, southern, and boreal; these three were used by the consumption model. The next level, domain, was used to match fire locations with the "best-fit" WIMS fire weather station. There are four domains in North America.

[5] http://www.wfas.net/index.php/fire-weather-weather-35

[6] http://www.fs.fed.us/rm/ecoregions/products/map-ecoregions-north-america/

2.0 DATA PREPARATION

2.1 Preparing the Database

- The existing FETS database was copied and migrated to a separate GIS-enabled database running PostgreSQL 9.3/PostGIS 1.5.3 architecture.
- Multiple schemas were created, and the original FETS schema modified, to support new spatial capabilities and allow for incorporation of and efficient comparison between multiple inventories in their native formats (e.g. EPAFIRE, FINN).
- Support was added for all states (lookup tables, etc.) beyond the WRAP region.
- Support was added for vector spatial data layers (RASTER data must live external to the database due to processing overhead costs).
- Functions were written to support use of vector spatial data layers for routine database operations and calculations beyond the core PostGIS distribution.

2.1.1 Fuel-Area Relationship

The method for assigning and storing fuelbed information for each daily fire event in the FETS was modified. Previously, a single FCCS fuelbed type was assigned to each daily event. A new table was created to store an arbitrary number of fuelbed types for each daily event along with the number of acres for that fuelbed. For small, single day fires that only included a point location, a circular buffer the size of the fire was overlaid on the fuelbed layer, and the frequency of each fuelbed within that buffer multiplied by the total acres was stored for the event. For larger events where polygon information was available, the polygon replaced the circular buffer to obtain the frequency information. When calculating emissions, all FCCS|Acres pairs for that event were sent to CONSUME3.

2.2 Ground-based Data

There are several known and suspected sources of ground-based, accomplished activity data for regions outside the WRAP. A modest data-gathering effort was conducted, after which all data was assessed for quality, completeness, and utility with respect to the emissions inventory.

2.2.1 Data Gathering

A letter was drafted to representatives of CENSARA (Central) and SESARM (Southeast) RPOs requesting help gathering fire data within their respective membership regions. In addition, Tom Moore (WRAP) participated in a conference call with CENSARA representatives to introduce the project and request fire data from member states. Datasets received in response to that letter and conference call are listed in Table 1.

Table 1. Additional ground-based datasets to include in the 2008 inventory

Received From	State(s)	Agencies	Burn Types	Coverage	Year(s)	Used in EI?	Location	Notes
FAM-WEB	All	All Federal	Rx, WF	Federal lands	1972 - 2010	Yes	http://fam.nwcg.gov/fam-web/weatherfirecd/state_data.htm	
Marnie Stein	Iowa	State/ local	Rx, WF	State, Private lands	2008	Yes	via email	
Daniel Chan	Georgia	State, Local	Rx, WF	Private lands	2008	No	ftp://gfc.state.ga.us User: epd Pass: epd	No accomplishment reports, only monthly totals.
Ben Webster	West Virginia	All	WF	All	2008	Yes	via email	
Carla Bedenbaugh	South Carolina	All	WF, Rx, Ag	Most (some fed data may be missing)	2008	Yes	via email	
Sue Leverette	Florida	Federal	WF, Rx	Federal lands	2008 - 2010	WF Only	ftp://ftp.nifc.gov/Incident_Specific_Data/SOUTHERN/Florida/Fire_History/	Files for "Prescribed Fire" and Open Burning" for 2008. Rx files do not include accomplishment reports.

2.2.2 Data Processing

Data received from individual states were assessed with respect to data fields necessary for inclusion in the FETS, including burn date, fire size, and source type. Data that included these elements were loaded and processed using the FETS. Data were received that did not include burn dates and were consequently not used in the inventory.

The federal lands prescribed and wildfire data received require extensive QA/QC. This process is described in detail in Appendix D.

2.2.3 Data Reconciliation

Wildfire data were reported from several sources: ICS-209 reports, MTBS fire perimeters, and FAM-WEB (see Table 1, row 1). Therefore, reconciliation was required to avoid reporting the same fire multiple times. The following hierarchical steps were followed:

- "Point" wildfires (reported to FETS with a single location and start/end dates from ICS-209 or FAM-WEB) within 5km of MTBS burn perimeters in the within 3 days of the MTBS start date, or with the same name occurring in the same year, were flagged and not included in the inventory.
- For remaining "point" wildfires, other wildfire records with the same name in the same year, or in the same year and within 0.5km, were queried and examined as a group. The record with the shortest reported time period (in days) was kept and all others flagged for removal from the inventory.

Prescribed burn data were reported directly to FETS from individual state and tribal agencies, and a small number of additional burns on federal lands were included from FAM-WEB. Directly reported data from agencies superseded FAM-WEB data with the following exceptions:

- If a duplicate prescribed burn record was found and the agency-reported data were still marked as "planned" (i.e. no accomplishment report was sent), the planned report was marked "accomplished" given the acres value of the FAM-WEB record.
- If a duplicate prescribed burn record was found and the agency reported zero accomplished acres, the accomplished acres were set to the non-zero value reported by FAM-WEB.

All other FAM-WEB prescribed fires that matched an existing FETS burn (based on proximity [0.5km] and date) were flagged and removed from the inventory.

2.3 MTBS Data

There were two components to the MTBS dataset: burn severity mosaics for each fire event using an ordinal scale of 0 (unburned) to 5 (extreme burn), and perimeter shapefiles outlining the final extent of each burn event. The perimeter data were used to determine daily fire growth of multi-day fires with the following steps:

- Data were loaded into the FETS database.
- Daily growth patterns were created using HMS data (see Section 2.4.1).
- For perimeters with no associated HMS data, a daily growth table of acres/day was built using [total acres]/[total days]. A single value was calculated for burn severity, and one set of FCCS|Acres pairs developed for the entire perimeter.

Burn severity data were applied to the daily growth patterns to determine a composite burn severity on a continuous scale (0-5). The process was similar to that described in section 2.1.1 for assigning FCCS values, but instead of the FCCS layer the burn severity mosaic was used, and a single, composite value—the average of all severity values within the area—was assigned to the total area.

2.4 HMS Fire Detections

A schema was created in the FETS database to store HMS data. Initial processing determined local time zone, flagged duplicates (i.e., two detects at the same location on the same day), and removed detects outside of the modeling domain or in the ocean. Then, a series of scripts processed the data to determine the burn type and size of each detect.

2.4.1 Process Detects Associated with MTBS Data

Daily growth for wildfires in the MTBS dataset was calculated by adding up the number and location of HMS fire detections within or nearby each perimeter on a given day. There were two steps to this process: identifying all fire detections associated with a perimeter, and calculating daily acres burned.

The following steps associated detections with a perimeter:

- For each MTBS record, detects contained by the perimeter were identified. If detects were earlier than the reported start date of the fire, an "HMS start date" of the earliest detect was added. For fires with an HMS start date earlier than three weeks before the reported start date, starting with the earliest detect record, detects were removed that were more than 14 days apart. If four or more detects occurred within two days, subsequent detects were removed only if they were more than 30 days apart. If nine subsequent detects occurred within two days, no more detects were removed. The official start date of the fire was then set to the earliest retained detection.
- After the start date was determined, detects within 6km of the perimeter were identified. Detects within 0.5km of the fire were retained.
- Detects were further filtered by date and/or distance: if a detect was more than two weeks away from any other detect after the start date of the fire, or was more than 2km away from any other detect associated with the fire, the detect was disassociated from the fire. Remaining detects were flagged as "associated but outside the perimeter threshold". This ensured the detects were not double-counted as additional fires.

The following steps calculated daily growth for each perimeter:

- A size algorithm was applied using the intersection of the MTBS burn perimeter and a 0.564 km buffer around each detect to determine the acres burned per detect, *AD*. For buffers completely within the perimeter, the size was always 247 acres.
- The number of days of burning at each detect location, *ND,* was calculated and stored. This number was used when determining total acres burned per day within the perimeter (see Equation 1).
- Calculate a size scalar, *SS*, for the MTBS burn using the perimeter acres divided by the sum of the detect acres. The scalar was used to determine the total acres per day burned within the perimeter: detect acres for a given day were summed and then multiplied by the scalar. Together with the number of days of burning at each detect location, *ND*, this scalar ensured that each burn day matched the total size of the perimeter (see Equation 1).
- FCCS and severity values were assigned as described in section 2.1.1, with a single, composite value for severity.

Equation 1. Algorithm to determine the acres burned per day within an MTBS perimeter using HMS fire detections

$$Acres/Day = SS \times \sum {}^{AD}/_{ND}$$

2.4.2 Process Detects Associated with Ground-based Reports

A simple process was developed to reconcile fires reported by states, and other reported fire point locations, with HMS fire detections. All HMS detections directly associated with reported fires were flagged and removed from the inventory. However, a number of fire detects associated in space, but not occurring on the same day, were retained following the rules below:

- For single-detect fires, association was determined by proximity: if a circle the size of the reported burn overlaps a circle with a radius twice that of the detect's sensor pixel (~1km^2 or ~16km^2), the detect is associated with the report.
- If a fire detection was associated with a reported fire marked as "planned" (i.e. no accomplishment report was submitted), the reported fire was marked "accomplished."
- If a fire detection was flagged as associated with a reported burn (day 1), and a detection occurred on the following day (day 2) in the same location with no associated report, the fire detection was marked as "smoldering" and the source type for the detection was assigned to that of day 1. For detections in the same location on subsequent days (day 3+) the source type was assigned to that of day 1.

2.4.3 Process "Unknown" Detects

HMS fire detections remaining after reconciliation with MTBS and FETS data were retained in the inventory and assigned a size and source type (wildfire, prescribed, or agricultural). The process was as follows:

- Agricultural fires were assigned using by overlaying fire detections on the 2010 CDL (see section 1.7). Detections returning a code between 1201 and 1299 were classified as agricultural. Fire size was assigned following the scheme in Table 2.

- After assigning agricultural fire, wildland (prescribed and wildfire) fires were classified and given a size using a three-step approach:

    - For each fire detection, FETS data were queried within 50km and within 2 weeks before and after the date of the detection.

    - *If one or more reported burns were found*, the accomplished acres of those fires were averaged. Then the lesser of two values, 125 acres and the average accomplished acres, was assigned to the detection. The source type was then determined by the most frequently occurring source type among the queried reported fires.

    - *If no reported burns were found*, the ecoregion domain and whether or not the detection occurred on federal land were determined. Fire size was assigned using the values in Table 2. If the detection occurred on federal land, it was classified a wildfire; if not, prescribed.

Table 2. Fire size assignments for fire detections not associated with reported burns

Source type	HMS Sensor	Ecoregion domain / States	Fire Size (acres)	References
WF; RX	ALL	DRY; POLAR	20	Average size of one-day wildland fires in the FETS database in ecoregion
WF; RX	ALL	HUMID TROPICAL	11.6	Average size of one-day wildland fires in the FETS database in ecoregion
WF; RX	ALL	HUMID TEMPERATE	14.4	Average size of one-day fires in the FETS database in ecoregion
AG	ALL	NV; AZ; CO; WY; NM	10	Average size of one-day agricultural burns in the FETS database for chosen states; McCarty 2008[7]; Giglio 2003[8]; Zhang 2008[9]
AG	ALL	KS; NE; ND; SD; OK; TX; IA	40	McCarty 2008
AG	MODIS	CA; OR; WA; ID; MT	25	Average size of one-day agricultural burns in the FETS database for chosen states; McCarty 2008; Giglio 2003; Zhang 2008
AG	GOES	CA; OR; WA; ID; MT	50	Average size of one-day agricultural burns in the FETS database for chosen states; McCarty 2008; Giglio 2003; Zhang 2008
AG	MODIS	All other states not listed	10	Average size of one-day agricultural burns in the FETS database for chosen states (largely based on data from SC); McCarty 2008; Giglio 2003; Zhang 2008
AG	GOES	All other states not listed	20	Average size of one-day agricultural burns in the FETS database for chosen states (largely based on data from SC); McCarty 2008; Giglio 2003; Zhang 2008

2.5 Integrated FCCS fuelbed layer for the Modeling Domain

The emissions model, CONSUME3, requires fuels information in the form of FCCS fuelbeds. Therefore, an integrated spatial layer containing FCCS classes must be created for the entire modeling domain. This was done in a 4-step process:

1. Fuel layers were obtained for Canada and Mexico.
2. FCCS classes along the borders between the US and Canada as well as the US and Mexico were identified.

[7] McCarty, J.L., T. Loboda, S. Trigg. 2008. A hybrid remote sensing approach to quantifying crop residue burning in the United States. *Applied Engineering in Agriculture* 24(4): 515-527.

[8] Giglio, L., J. Descloitres, C. O. Justice, and Y. J. Kaufman. 2003. An enhanced contextual fire detection algorithm for MODIS. *Remote Sensing of Environment* 87(2-3): 273-282.

[9] Zhang, X., S. Kondragunta. 2008. Temporal and spatial variability in biomass burned areas across the USA derived from the GOES fire product. *Remote Sensing of Environment* 112: 2886-2897.

3. Fuel classes were cross-walked to FCCS.
4. The Canadian and Mexican fuel layers were re-classified and merged with the FCCS fuelbed layer.

2.5.1 Layer Processing to Prepare Crosswalks

There are three separate raster datasets that comprise the modeling domain: The Fuel Characterization Classification System (FCCS), which covers the United States at a 30m x 30m resolution; The Canadian Forest Fire Behavior Prediction System (CFFBPS) raster, which covers the Canadian portion of the modeling domain at a 1km x 1km resolution; and the General Land Cover (GLC) raster of North America clipped to include the portion of Mexico in the model domain at a 1km x 1km resolution. To prepare for the crosswalk, FCCS values along the borders of Canada and Mexico were identified.

- A polygon shape of the conterminous United States, which is also the extent of the FCCS, was divided into two "strips" of area. The strips are where the US shares a border with Mexico or Canada.
    - The strips are approximately 110 miles from the border towards the interior of the US.
    - These two sections are further subdivided into approximately 5500 $mile^2$ blocks.
- The blocks are used as defined areas to sample from the FCCS layer.
- The program R is used to sample the FCCS values within the blocks.
    - The FCCS raster and the strip of block polygons are brought into the R environment.
    - All objects are projected to the same coordinate system.
    - Because of memory constraints, values within each block are aggregated to a factor of 9 to 1, to the value of highest frequency.
    - Aggregated values have water and N/A's removed.
    - Values are tallied and put into a table for each block.
- Aggregated values within each border block are compared to spatially similar values in the GLC and CFFBPS datasets.

2.5.2 Crosswalk between Canadian and FCCS Fuel Beds

In order to characterize the fuel beds present in the region north of the United States border the spatial GIS of the Canadian Forest Fire Behavior Prediction System (CFFBPS) was used. This spatial layer has a 1km resolution, and consists of 16 unique fuel beds. The GIS layer provided by the Canadian contains four additional fuel beds, specifically, water, non-fuel, cropland and tundra. For each of the CFFBPS fuel beds a representative FCCS fuel bed was determined. The crosswalk of these fuel beds was based on a comparison of the available qualitative and quantitative information on the CFFBPS fuel beds with those in the most-recent version desktop FCCS software. A comparison of the FCCS fuel beds with the LandFire fuel beds was conducted as an additional source of information.

2.5.3 Crosswalk between Mexican and FCCS Fuel Beds

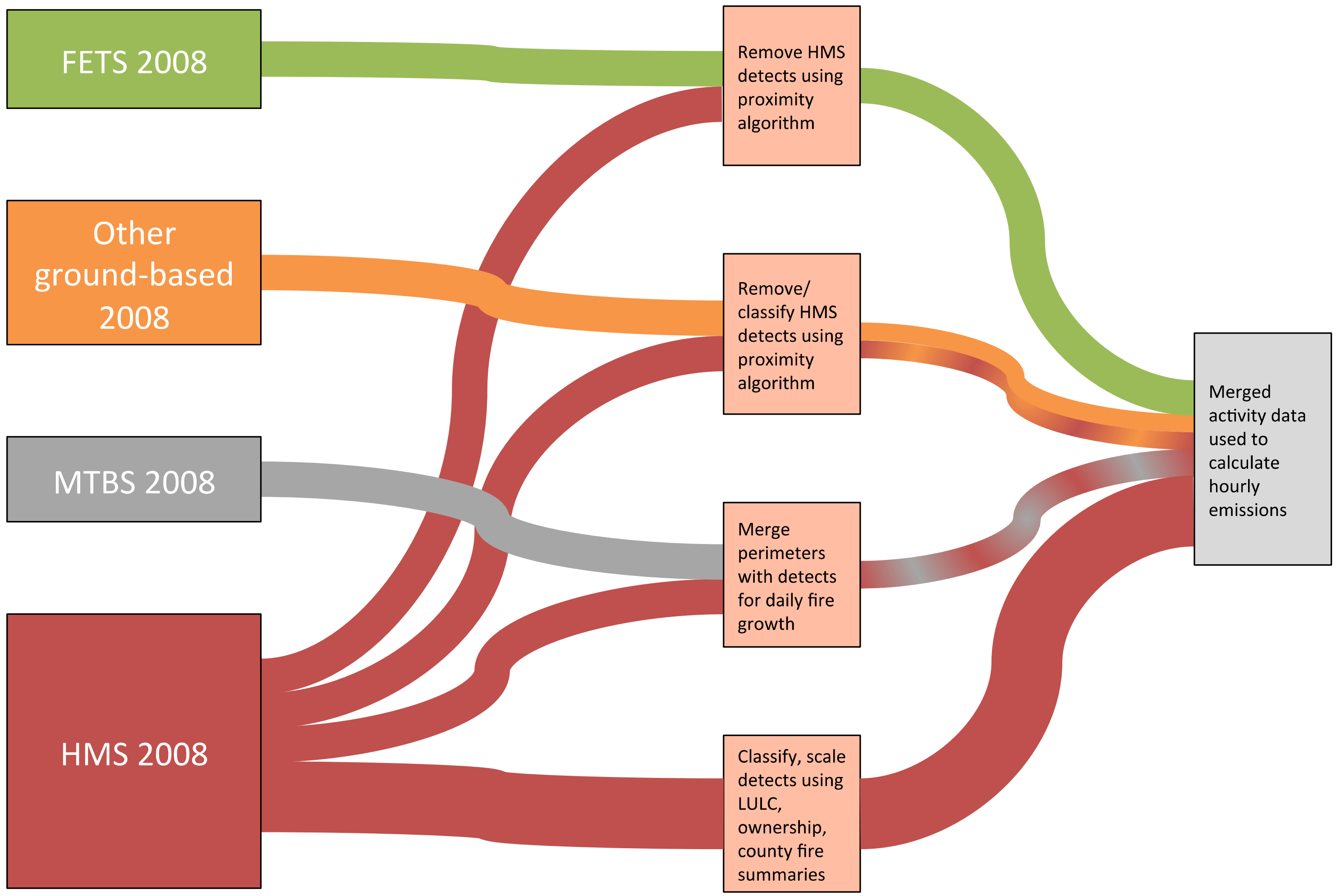
In order to characterize the fuel beds present in the region south of the United States border the spatial GIS of the General Land Cover (GLC) map of North America was used. This spatial layer has a 1km resolution, and consists of 13 unique cover classes. The crosswalk of this GLC layer was performed quantitatively by developing a spatial overlay of the GLC classes in the southern United States with the 30m resolution FCCS layer. For each GLC class the FCCS fuel beds mapped to these classes were evaluated to determine the most appropriate FCCS fuel bed to represent each class[10].

2.6 Final Activity Data Quality Control

The steps defined above resulted in an integrated database of fire activity data in space and time. To assure that only valid records were brought forward for emissions calculations, several checks were performed on the data to ensure completeness and accuracy. Because certain geographic attributes were supplied with the raw data, any inconsistencies were identified. Only records with a valid start and end date, location (latitude and longitude coordinate), non-zero fire size in acres, and valid FCCS classification will be used in the final inventory. "Fatal" flaws were flagged and not carried forward for the final emissions inventory.

[10] A more refined extension of the FCCS fuel beds into Mexico is under development by the US Forest Service Pacific Wildland Fire Sciences Laboratory. Adoption of the FCCS layer for Mexico, which will have 30m resolution, is recommended in the future, as it will be a considerably more accurate approach than the crosswalk based on the GLC classes. However, at the time this work is still in progress (due to limited funding). A complete FCCS layer for Mexico is anticipated to be completed by the end of 2012.

Figure 1. Flow diagram of data processing for the 2008 Emission Inventory



3.0 EMISSIONS CALCULATIONS

3.1 Initial Processing and Preparation

In preparing for the final emissions calculations after the activity data were processed and reviewed, several decisions and preparation steps were made:

- Python-CONSUME (CONSUME3) was integrated into the FETS system. This version of CONSUME3 allowed for extraction of emissions and heat release by burn phase, application of multiple fuelbeds for a single event, and assignment of customized emission factor profiles.
- CONSUME3 reported emissions in three phases (flaming, smoldering, residual). These phases were combined into two (flaming, smoldering) as required by the PGM. This required careful review of the emissions results to decide how to allocate emissions.
- Defaults used in FETS-CONSUME were reviewed and updated. There are several parameters required by CONSUME3 that are not available for the majority of activity data. The original list of parameters and methods used in the FETS to assign values is included in Appendix A: .
- CONSUME3 included emission factors for PM, PM_{10}, $PM_{2.5}$, CO, CO_2, CH_4, and NMHC. Emission factors for additional pollutants were compiled. These emissions were calculated by multiplying by the consumption calculated by CONSUME3. Separate emission factors *were not* used for flaming and smoldering phase consumption.
- The plume rise algorithm used for the 2002 WRAP EI[11] was reviewed and updated. The same parameters were supplied with the final EI, but the calculation methods were revised.

3.2 Calculating Emissions

The basic emissions calculation process for wildland fires is outlined in . Agricultural burns could not be processed through CONSUME3, so the basic method from the WRAP 2002 EI—acres X fuel loading X emission factor—was employed instead. The result of the activity data processing outlined in Section 2 was a database of daily fire events that included the following attributes: date, location, fuel moisture, date of last precipitation, total acres, acres partitioned by FCCS class, eco-region, MTBS composite burn severity (for large wildfires), burn type (e.g. piled), and source type (wildfire, prescribed). With the exception of date and location, all attributes were used to process each daily event in CONSUME3. The result from CONSUME3 consisted of,

- Total consumption, by combustion phase (flaming, smoldering, residual)
- Emissions, by pollutant and combustion phase

The outputs were stored in the database. After CONSUME3 was run, there were several post-processing steps:

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[11] WRAP, Western Regional Air Partnership, 2005. 2002 Fire emission inventory for the WRAP region—Phase II. Prepared by Air Sciences, Inc. Project No. 178, July 22, 2005. Available at http://www.wrapair.org/forums/fejf/tasks/FEJFtask7PhaseII.html

- Additional emissions, for pollutants not in CONSUME3, were calculated 'on-the-fly' based on consumption using functions stored in the database when formatted files were exported for the model.

- Emissions for agricultural fires, since CONSUME3 could not accommodate those fuelbeds, were calculated 'on-the-fly' as outlined above using functions stored in the database when formatted files were exported for the model.

- Hourly plume rise and diurnal consumption parameters were calculated. Similar to the additional emissions calculations, these were calculated 'on-the-fly' during export using functions stored in the database.

3.2.1 Defining Input Parameters for CONSUME3

The batch version of CONSUME currently used by the FETS requires many input parameters, outlined in Appendix A: . CONSUME3 requires many of the same inputs but does *not* include the ability to describe piled activity burns. In addition, clarification was added to the CONSUME3 documentation that separated the inputs that apply only to activity burns (Table 2).

There are significant differences between the methods outlined in Appendix A: and the new methods in Table 2. Default values supplied by CONSUME3 were used for the emissions inventory whenever specific information was missing. Because there were no inputs available for piled fuels, all burns in the FETS identified as "piled" were converted to acres using Equation 6 in Appendix A: .

The MTBS burn severity data set provided additional information for large wildfires in the 2008 inventory that enabled two parameters to be scaled more precisely: percent of shrubland blackened and percent of canopy consumed. A composite burn severity on a scale of 0-5 was determined for each daily burn area identified using the process in Section 2.4.1. The severity parameter was then scaled to percent of shrubland blackened and percent of canopy consumed. The scale used for both parameters is outlined in Equation 2.

Equation 2. Method to calculate percent shrubland blackened (PSB) and percent canopy consumption (PCC). The maximum value for each parameter is 90.

$$PSB, PCC = Severity \times 18.0$$

Table 3. Assignment of CONSUME3 Parameters in the 2008 emissions inventory

Parameter	Scope	Description	Application
Burn Type	--	Natural or Activity	WF, WFU are natural
Ecoregion	All	Western, Southern, or Boreal	Determined from Bailey Eco-region layer
Percent shrubland blackened	All		For MTBS burns, scaled based on severity, remainder use CONSUME default (50%)
Percent canopy consumption	All		For MTBS burns, scaled based on severity, remainder use value defined by FCCS class (varies for natural vs activity burns)
Duff moisture	All		**50%**
1000-hour fuel moisture	All		Determined from WIMS data; nearest station in the same eco-region domain is used
Ignition Timing (minutes)	Activity	Determines intensity of activity burn, 10-hour fuel consumption	Calculated as max time for "high intensity" See Appendix A
Slope	Activity		CONSUME default (5 degrees)
Wind speed	Activity		CONSUME default (5 mph)
10-hour fuel moisture	Activity		Determined from WIMS data; nearest station in the same eco-region domain is used
Days Since Last Rainfall	Activity	Number of days since the last significant rainfall (0.25 in or more)	

3.2.2 Consumption Phase Partitioning

CONSUME3 partitions combustion and emissions into three phases: flaming, smoldering, and residual. Since the PGM accommodates only two phases of combustion/emissions (flaming and smoldering), emissions needed to be re-distributed. In the context of the PGM, flaming emissions occur on the date of the fire event, and smoldering emissions are allocated to the day after. Below are definitions of smoldering combustion and residual smoke found on the National Wildfire Coordinating Group website:[12]

- Residual Smoke. Smoke produced by smoldering material. The flux of smoke originating well after the active flaming combustion period with little or no vertical buoyancy and, therefore, most susceptible to subsidence inversions and down-valley flows.
- Smoldering Combustion Phase. Phase of combustion immediately following flaming combustion. Emissions are at twice that of the flaming combustion phase.

In addition, Table 4 summarizes the percent of total consumption, by phase, for all wildland fires in the 2008 emissions inventory (agricultural fires are assumed to have no smoldering emissions, and were not processed with CONSUME3). Combining the smoldering and residual phases in to one phase for the PGM would allocate, on average, 59% of the total emissions to the non-flaming phase of the fire, a

[12] http://www.nwcg.gov/var/glossary/

significant departure from the methods used in the WRAP 2002 EI (in that inventory, smoldering emissions were estimated to be 18% of flaming emissions). Based on the definitions above and the results in Table 4, flaming and smoldering emissions from CONSUME3 were combined to create "PGM flaming," and residual emissions were assigned to "PGM smoldering," for data export to the PGM.

Table 4. Percent of total consumption by phase for all wildland fires in the 2008 emissions inventory

Flaming	Smoldering	Residual
41%	23%	36%

3.2.3 Emission Factors

Emissions are calculated in CONSUME3 by multiplying the estimated consumption and a set of emission factors for PM, PM_{10}, $PM_{2.5}$, CO, CO_2, CH_4, and NMHC. There are multiple sets of emission factors, mapped to fuelbeds and eco-region domains. This structure was used, unaltered, to calculate wildland fire emissions for the seven pollutants listed above. See Appendix C for a detailed list of all emission factors used in CONSUME3.

Emissions were also calculated for nitrogen oxides (NO_x), sulfur dioxide (SO_2), (NH_3), black (elemental) carbon (BC), and organic carbon (OC). Emission factors were taken from Tables 1 and 2 in Akagi, et al. (2011)[13] and stored in the database; FCCS codes were mapped to the basic biomass types presented there (see Appendix B). Emission factors were then pulled for each fire event based on the dominant biomass type (since many events had more than one FCCS code associated with them). For black carbon and organic carbon, the emissions were calculated based on the ratio with the PM emission factor presented in Akagi, then multiplied by the emissions of PM calculated by CONSUME3. This way, there is never a situation where the emissions of BC or OC are greater than total PM.

3.3 Plume Rise

The plume rise method from the WRAP 2002 EI was evaluated and modified to take advantage of refinements to consumption and emissions calculations used in this inventory. Three parameters are required as hourly inputs to the PGM: Height of plume top (P_{top}), Height of plume bottom (P_{bot}), and the Layer 1 fraction (Lay1F). Each daily fire event is assigned a "plume class" that, combined with the hour of the day, is used with look-up tables to calculate the input parameters. The modification to the plume rise method focused on two parts:

- Assigning a fire to a plume class "bin"
- Defining Layer 1 and distributing emissions between Layer 1 and P_{bot}

Previously, fires were assigned to a plume class bin based on acres normalized to the pre-burn fuel loading defined for that fire. This method was modified to consider actual fuel consumed and the intensity of the fire (see Equation 3). By using the actual flaming-phase fuel consumed, the Flaming

[13] Akagi, S. K., et al. "Emission factors for open and domestic biomass burning for use in atmospheric models." *Atmospheric Chemistry and Physics* 11.9 (2011): 4039-4072.

Phase Consumption Index (FPCI) looks at the *actual* heat released instead of *potential* heat release. In addition, dividing by the square root of the acres burned attempts to capture the intensity of the burn: 1,000,000 BTUs released over 100,000 acres is not equivalent, in terms of plume production, to the same amount of heat released over 10,000 acres.

Equation 3. Flaming Phase Consumption Index calculation used to determine plume height bins.

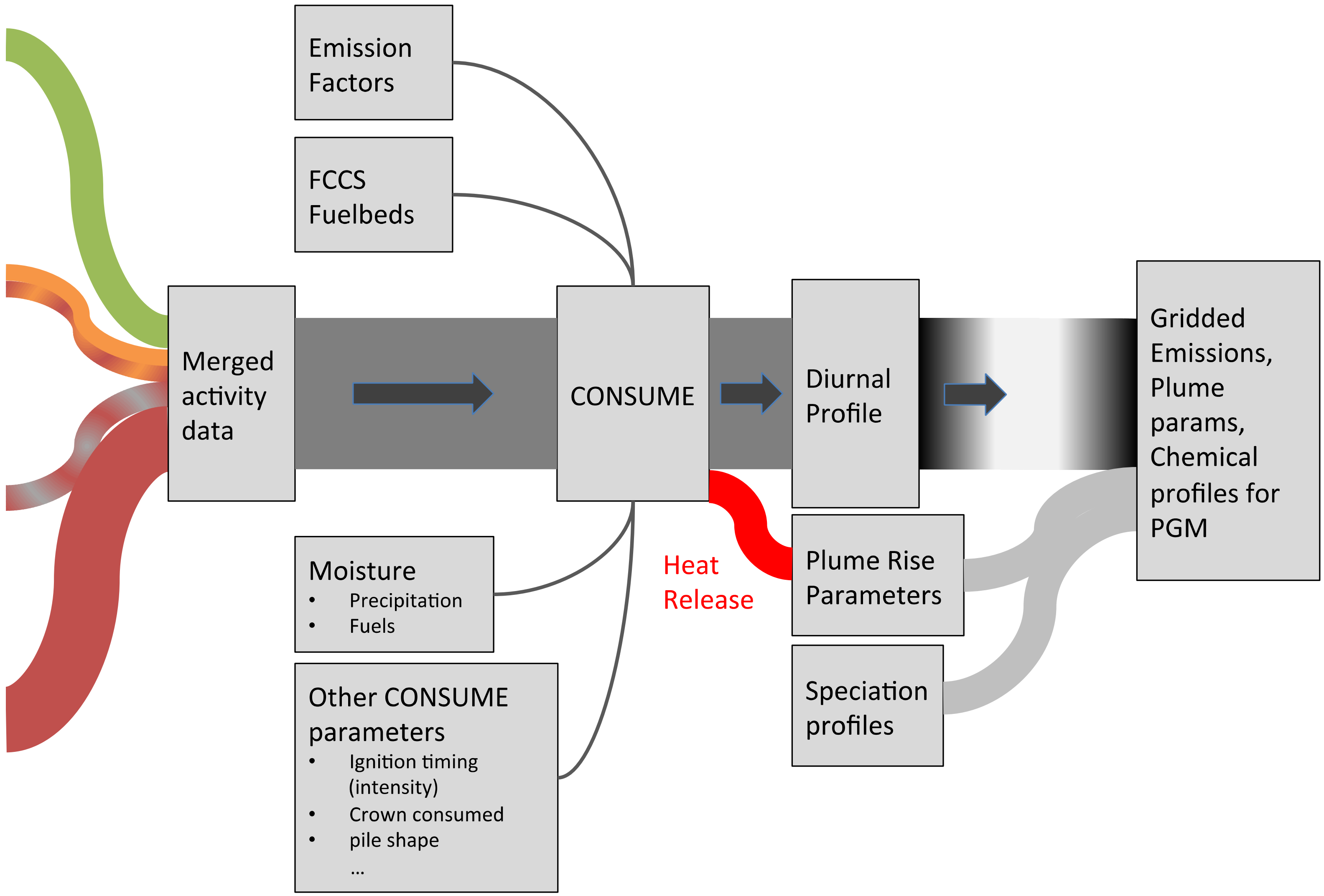
$$FPCI = \frac{Flaming\ Phase\ Consumption}{\sqrt{acres}}$$

FPCI was calculated for every fire *in the WRAP Region* and bins were calibrated with help from the distribution found in the WRAP 2002 EI (see Table 4), keeping in mind that the total coverage of (especially small) fires was greater in 2008.

Table 5. Plume height bins calculated using FPCI using fire activity in the WRAP region in 2008.

Plume Class *FPCI*	1 *0-75*	2 *75-300*	3 *300-675*	4 *675-1250*	5 *>1250*	Total
Events, FETS 2008	48,725	9,912	1,167	366	96	60,266
Bin frequency, FETS 2008	81%	17%	1.9%	0.61%	0.16%	
Bin frequency, WRAP 2002	62%	33%	4.5%	0.2%	0.02%	

Figure 2. Flow diagram of emissions processing for the 2008 emissions inventory.



Appendix A: CONSUME Input Parameters

This memorandum presents the Strawman approaches for obtaining supplementary information required to execute emissions calculations using CONSUME 3.0 in the Fire Emissions Tracking System (FETS). It was originally presented to the FETS Task Team during the initial development of the FETS.

CONSUME Input Parameters: Background

A Strawman technical memorandum distributed on April 23, 2007 identified CONSUME 3.0 as the best candidate to calculate emissions in the FETS. The FETS Task Team agreed upon an approach of incorporating CONSUME 3.0 into the FETS system, called the "Technical Node," that exists on a stand-alone Linux machine and performs emissions and GIS calculations without the need or ability for user input.

The FETS Emissions Strawman noted that CONSUME requires certain ancillary information to calculate emissions for a fire event. Some of these data elements are available directly from data providers, while others must be obtained from other sources or through established defaults. Air Sciences has attempted to account for each of the additional required elements with accuracy while not deviating significantly from the scope of the workplan.

Methods to Obtain CONSUME Parameters

Data sources for each of the additional required elements for CONSUME emissions calculations were compiled and evaluated based on several criteria, including:

- Ease of incorporation into the FETS;
- Consistency of the data source;
- Accuracy gained (or lost) when using a particular method.

For most of the additional required data, the FETS cannot expect data providers to be a primary source of information. The CONSUME 3.0 User's Guide (User's Guide) provides defaults and/or equations to estimate values for several of the additional elements. For other parameters, other solutions were sought. The CONSUME defaults, as well as the proposed parameter sources for the FETS, are shown in Table A-1. Further explanation for each parameter, if deemed necessary, is provided below. It should be noted that while the FETS cannot rely on data providers to consistently submit these additional data, user-supplied information for any of the parameters discussed here will always supersede default or derived values.

Table A-1. Summary of Ancillary Data Required by CONSUME

Parameter	CONSUME default	FETS default
10 hr Fuel Moisture	None	GIS/WIMS data[1]
1000 hr Fuel Moisture	None	GIS/WIMS data[1]
Duff Fuel Moisture	None	See "Days Since Rain"
% crown consumed	RX - 0% ; WFU - 40% ; WF - 60%	Use CONSUME default
Shrubland % Blackened	Equation based on wind, slope, 10-hr FM	Use CONSUME default[1]

Parameter	CONSUME default	FETS default
Ignition duration	Equation based on acres and "intensity"	Use equation, but "intensity" is always the same[1]
Wind Speed (mph)	Max 35 mph	10 mph
Slope (%)	20	Use CONSUME default
Days Since Rain	None	GIS/WIMS data[1]
Harvest?	None	FALSE
Snow off?	None	FALSE
Number of piles	None	(V x 0.0057) / Acres[1]
Pile Shape	None	Half-ellipsoid[1]
Pile Dimensions	None	10'W x 6'H x 9.5'L [1]
Packing Ratio	10% ; 20% ; 30%	20%
Percent of pile that is soil	None	10%
Primary wood density	None	Lookup based on FCC code
Percent Primary Species	None	100%
Secondary wood density	None	0
Percent Secondary Species	None	0
Pile Quality	1 - clean ; 2 - dirty ; 3 - Really dirty	Hand Piles = 1 ; Machine Piles = 2 ; Piles = 2

[1]Explained in detail below

10- and 1000-hr Fuel Moisture

The United States Forest Service Wildland Fire Assessment System (WFAS) reports daily fire weather observations from the Weather Information Management System (WIMS). 10-, 100- and 1000-hour fuel moistures are reported at each of several hundred stations throughout the WRAP region.

The Technical Node of the FETS has already incorporated a GIS to perform spatial overlay operations. Fuel moisture data from WFAS may be downloaded and interpolated into RASTER surface moisture maps by the Technical Node on a daily basis for use in the FETS. Maps for each day of the calendar year can be stored in the Technical Node; fire events queried by date may then be overlaid onto the appropriate moisture maps to derive 10- and 1000-hour fuel moisture. Occasionally WIMS data are not available for a particular day; in these cases, the moisture map for the previous day may be used to derive moisture values for relevant fire events. Fire events submitted by a data provider that include 10- and 1000-hour fuel moisture values will supersede the GIS-interpolated WIMS observations.

10- and 1000-hour moisture maps created using a similar technique are posted daily on the WFAS website, and are presumably used by fire managers to report fuel moisture. The above technique has already been implemented in the technical node for the FETS since it follows an existing method for estimating fuel moisture used by the fire community.

Duff Fuel Moisture and Number of Days since Rain

Although duff fuel moisture is a required input to CONSUME 3.0, the parameter is not utilized in subsequent algorithms. Instead, the "Days since Rain" parameter is used to determine one of three moisture regimes – wet, moist, or dry – which then determines the extent of duff layer consumption (duff layer parameters, such as depth, are stored internally in CONSUME by FCC code).

The number of days since the last significant rain is not tracked by any smoke management program. Therefore, the FETS, if it is to obtain such values, must seek them elsewhere. The FETS project team recommends one of two approaches.

Approach 1: WIMS Precipitation Interpolation

The daily WIMS dataset, described above, reports precipitation at each station in the WRAP region, and may be useful to determine "Days Since Rain" for any given fire event. Similar to fuel moisture, precipitation values may be interpolated into a surface RASTER map to estimate precipitation throughout the WRAP region. Then, the map may be recoded such that RASTER cell values greater than 0.25 (representing >0.25 inches of rain in 24 hours) are set to 0.0; values 0.0 – 0.24 are set to 1. If two or more maps are created in this manner, they may be combined together successively to obtain a cumulative "Days Since Rain" map for anywhere in the WRAP region. The map combination equation is as follows:

$$\text{DSRmap1} = (\text{mapDay1} \times \text{mapDay2}) + \text{mapDay2} \qquad (1)$$

$$\text{DSRmap2} = (\text{DSRmap1} \text{ X } \text{mapDay3}) + \text{mapDay3}$$

…

Since some areas of the WRAP region receive very little precipitation each year, the initial cumulative "Days Since Rain" map (DSRmap) should have its start date several months in the past to establish an accurate baseline. On the occasion that WIMS data are not available for a particular day, the previous day's map will be used.

The method above, although it includes some additional processing, is essentially the same technique as for estimating fuel moisture and therefore carries a similar level of accuracy. The estimated time to implement this approach is 4 hours.

Approach 2: Default Parameter

The alternative to Approach 1 is assigning a default value to every fire to ensure the CONSUME algorithm always falls into the "dry" duff moisture regime. This approach requires no additional development time.

Shrubland Percent Blackened

The CONSUME 3.0 User's Guide offers the following equation to estimate percent of the shrub layer burned (%SB):

$$\%SB = e^{(y)} / (1+e^{(y)}) \qquad (2)$$

$$y = [-1.5693 - (0.2453 \times \text{10-hr FM}) + (0.1697 \times \text{Wind} \times [\text{Slope Category}])] \quad (3)$$

Table A-2. Slope Categories

Slope Category	**Slope range (%)**
1	0 ≤ Slope < 5
2	5 ≤ Slope < 16
3	16 ≤ Slope < 26
4	26 ≤ Slope < 36
5	Slope ≥ 36

Reporting of wind and slope for fires in the FETS is expected to be sporadic, and therefore %SB in Equation 2 will most often depend only on fuel moisture, with Wind = 10 and [Slope Category] = 3 according to the defaults outlined in Table A-1.

Ignition Duration

CONSUME 3.0 uses ignition duration as part of an algorithm to estimate fire intensity and therefore the approximate diameter reduction (DRED) of woody fuels (i.e., the extent to which the diameter of woody fuel is reduced by burning). CONSUME makes no distinction between wildfires and prescribed fires in this regard, and therefore estimates must be made for both fire types. Table A-3 outlines the approximate DRED for four possible fire intensities.

Table A-3. Diameter reduction for varying fire intensities

Fire Intensity	Approx. DRED
Extreme	33 %
Very High	22
High	11
Medium	Not Reduced

The User's Guide provides estimates for maximum ignition times that would still be considered "mass ignition" for three fire intensities: "Extreme", "Very-High", and "High". For "High" intensity fires, the maximum ignition time is expressed as:

≤ 20 acres: $\text{Ignition Duration (minutes)} = 4 \times \text{acres}$ (4)

> 20 acres: $\text{Ignition Duration (minutes)} = (2 \times \text{acres}) + 40$ (5)

For ignition times greater than those derived from Equations 4 and 5, the CONSUME algorithm assumes no diameter reduction of woody fuels. The FETS project team recommends using the maximum ignition time for high-intensity fires. This will allow for consumption of woody fuels while assuming a lower intensity burn, although realistically the extent (if any) to which woody fuels are burned during a prescribed fire will vary depending on the particular prescription. For wildfires, the default Ignition Duration will be calculated using equations from the User's Guide similar to Equations 4 and 5 such that the fire intensity will fall into the "Very High" regime.

Number of Piles, Pile Shape, Pile Dimensions

In the process of coordinating data acquisition by the FETS, it appears that several state Smoke Management Programs track information regarding piles, including dimensions and number of piles. Thus, it is anticipated for many pile-burning events sufficient data will be available to supply to CONSUME. For events without any pile information, however, defaults must be established.

Median pile sizes reported in 2006 for Arizona (AZDEQ, 2007) are reported below. These dimensions will be used for Piles and Hand Piles when no other information is given. Piles reported as Machine Piles will have double the default hand pile dimensions, shown below.

Table A-4. Default Pile Dimensions

Dimension	Piles/Hand Piles	Machine Piles
H	6 ft	12 ft
W	10	20
L	9.5	19

Pile shape will default to a half-ellipsoid. If no information on number of piles is provided, it will be estimated using the default volume, V, and reported acres:

$$\# \text{ of piles} = \text{Acres}/(V \times 0.0057) \qquad (6)$$

Equation 6 is adapted from *Wyoming 2005 Emissions Inventory: Section 3- Fire Data Sources and Inventory Development* (Air Sciences, 2007), and is based on the smoke management plan (SMP) guidelines developed by the states of Wyoming and New Mexico. If a burn is reported as a pile burn and no information is given, including acres, the number of piles will default to one and default dimensions and shape will be used.

References

Arizona Department of Environmental Quality (2007). Personal Communication with Mark Fitch. Phone Call, 5/2/2007.

Air Sciences Inc. 2007. Wyoming 2005 Emissions Inventory: Section 3- Fire Data Sources and Inventory Development (Draft, April 2007). Golden, CO.

Prichard, SJ., RD Ottmar, and GK Anderson (2006). *Consume 3.0 User's Guide*. Pacific Wildland Fire Sciences Laboratory; USDA Forest Service, Pacific Northwest Research Station. Seattle, WA.

Appendix B: FCCS Codes and Biomass Types

Emission factors presented in Akagi, et al. (2011) were distinguished by basic biomass types. In order to choose a set of emission factors for a given fire event, each FCCS code in the FETS database was mapped to a biomass type, and the dominant type (since more than on FCCS code could be associated with a fire event—see section 2.1.1) for the fire event was chosen.

Table B-1. FCCS codes mapped to biomass types from Akagi, et al. (2011)

Code	Fuelbed Name	Biomass Type
0	Non-fuel area	Non-fuel area
1	Black cottonwood - Douglas-fir - Quaking aspen	Temperate Forest
2	Western hemlock - Western redcedar - Douglas-fir forest	Temperate Forest
3	Douglas fir forest	Temperate Forest
4	Douglas fir / Ceanothus forest	Temperate Forest
5	Douglas-fir - White fir forest	Temperate Forest
6	Oregon white oak - Douglas-fir forest	Temperate Forest
7	Douglas-fir - Sugar pine - Tanoak forest	Temperate Forest
8	Western hemlock - Douglas-fir - Western redcedar / Vine maple	Temperate Forest
9	Douglas fir - Western hemlock - Western redcedar / Vine maple forest	Temperate Forest
10	Western hemlock - Douglas-fir - Sitka spruce forest	Temperate Forest
11	Douglas fir / Western hemlock - Sitka spruce forest	Temperate Forest
12	Red fir - Mountain hemlock - Lodgepole pine - White pine forest	Temperate Forest
13	Mountain hemlock - Pacific silver fir forest	Temperate Forest
14	Black oak woodland	Temperate Forest
15	Jeffrey pine - Red fir - White fir / Greenleaf manzanita - Snowbrush forest	Temperate Forest
16	Jeffrey pine - Ponderosa pine - Douglas-fir - Black oak fore	Temperate Forest
17	Red fir forest	Temperate Forest
18	Douglas-fir / Oceanspray forest	Temperate Forest
19	White fir - Giant sequoia - Sugar pine forest	Temperate Forest
20	Western juniper / Huckleberry oak forest	Temperate Forest
21	Lodgepole pine forest	Temperate Forest
22	Lodgepole pine forest	Temperate Forest
24	Pacific ponderosa pine - Douglas-fir forest	Temperate Forest
25	Pinyon - Juniper forest	Temperate Forest
26	Interior Ponderosa pine - Limber pine forest	Temperate Forest
27	Ponderosa pine - Two-needle pine - Juniper forest	Temperate Forest
28	Ponderosa pine savanna	Temperate Forest
29	Interior Ponderosa pine - Engelmann spruce - Douglas fir forest	Temperate Forest
30	Turbinella oak - Ceanothus - Mountain mahogany shrubland	Temperate Forest
32	Ponderosa pine / Pinyon pine - Juniper forest	Temperate Forest
33	Gambel oak / Sagebrush shrubland	Temperate Forest
34	Interior Douglas-fir - Ponderosa pine / Gambel oak forest	Temperate Forest
36	Live oak - Blue oak woodland	Temperate Forest
37	Ponderosa pine - Jeffrey pine forest	Temperate Forest

Code	Fuelbed Name	Biomass Type
38	Douglas-fir - Madrone / Tanoak forest	Temperate Forest
39	Sugar pine - Douglas-fir - Ponderosa pine - Oak forest	Temperate Forest
40	Tobosa - Grama grassland	Savanna
41	Idaho fescue - Bluebunch wheatgrass grassland	Savanna
42	Trembling aspen / Engelmann spruce forest	Temperate Forest
43	Arizona white oak - Silverleaf oak - Emory oak woodland	Extratropical Forest
44	Scrub oak - Chaparral shrubland	Chaparral
45	Pine - Oak forest	Temperate Forest
46	Chamise chaparral shrubland	Chaparral
47	Redwood - Tanoak forest	Temperate Forest
48	Tanoak - California bay - Madrone forest	Extratropical Forest
49	Creosote bush shrubland	Chaparral
51	Coastal sage shrubland	Chaparral
52	Douglas-fir - ponderosa pine forest	Temperate Forest
53	Pacific ponderosa pine forest	Temperate Forest
54	Douglas-fir - White fir - Interior ponderosa pine forest	Temperate Forest
55	Western juniper / Sagebrush savanna	Chaparral
56	Sagebrush shrubland	Chaparral
57	Wheatgrass - Cheatgrass grassland	Savanna
58	Western juniper / Sagebrush savanna	Chaparral
59	Subalpine fir - Engelmann spruce - Douglas-fir - Lodgepole pine	Temperate Forest
60	Sagebrush shrubland	Chaparral
61	Whitebark pine / Subalpine fir forest	Boreal Forest
62	Vaccinium - Heather shrublands	Chaparral
63	Showy sedge - Alpine black sedge grassland	Savanna
65	Red fescue - Oatgrass grassland	Savanna
66	Bluebunch wheatgrass - Bluegrass grassland	Savanna
67	Interior Ponderosa pine - Douglas fir forest	Temperate Forest
69	Western Juniper / Sagebrush - Bitterbrush shrubland	Chaparral
70	Subalpine fir - Lodgepole pine - Whitebark pine - Engelmann Spruce	Boreal Forest
71	Ohia / Florida hopbush - Kupaoa forest	Extratropical Forest
72	Ohia / Uluhe forest	Extratropical Forest
73	Koa / Pukiawe forest	Extratropical Forest
74	Mamane - Naio savanna	Extratropical Forest
75	Slash pine / New Caledonia pine forest	Extratropical Forest
76	Slash pine / Molasses grass forest	Extratropical Forest
77	Eucalyptus plantation forest	Extratropical Forest
78	Florida hopbush - Mauna Loa beggarticks shrubland	Extratropical Forest
79	Pili grass - Broomsedge bluestem grassland	Savanna
80	Fountain grass grassland	Savanna
81	Columbia bluestem / Pukiawe grassland	Savanna
82	White leadtree / Guinea grass shrubland	Chaparral

Code	Fuelbed Name	Biomass Type
83	Molasses grass grassland	Savanna
84	Ohia / Broomsedge bluestem savanna	Savanna
85	Black spruce / Lichen forest	Boreal Forest
86	Black spruce / Feathermoss forest	Boreal Forest
87	Black spruce / Feathermoss forest	Boreal Forest
88	Black spruce / Sphagnum moss forest	Boreal Forest
89	Black spruce / Sheathed cottonsedge forest	Boreal Forest
90	White oak - Northern red oak forest	Boreal Forest
91	White spruce / Prickly rose forest	Boreal Forest
92	Aspen - Paper birch - White spruce - Black spruce forest	Boreal Forest
93	Paper birch - Trembling aspen forest	Boreal Forest
94	Balsam poplar - Trembling aspen forest	Boreal Forest
95	Willow - Alder shrubland	Temperate Forest
97	Cottongrass grassland	Savanna
98	Marsh Labrador tea - Lingonberry tundra shrubland	Chaparral
99	Bluejoint reedgrass grassland	Savanna
100	Altai fescue grassland	Savanna
101	White spruce forest	Boreal Forest
102	White spruce forest	Boreal Forest
103	White spruce - Paper birch forest	Boreal Forest
104	White spruce - Paper birch forest	Boreal Forest
105	Paper birch - Aspen forest - White spruce	Boreal Forest
106	Red spruce - Balsam fir forest	Boreal Forest
107	Pitch pine / Scrub oak forest	Temperate Forest
109	Eastern white pine - Northern red oak - Red maple forest	Temperate Forest
110	American beech - Yellow birch - Sugar maple forest	Temperate Forest
114	Virginia pine - Pitch pine - Shortleaf pine forest	Temperate Forest
115	Rhododendron - Blueberry - Mountain laurel shrubland	Chaparral
120	Oak - Pine / Mountain laurel forest	Extratropical Forest
121	Oak - Pine / Mountain laurel forest	Extratropical Forest
123	White oak - Northern red oak - Black oak - Hickory forest	Extratropical Forest
124	Pitch pine - Oak forest	Extratropical Forest
125	Oak - Hickory - Pine - Eastern hemlock forest	Extratropical Forest
129	Green ash - American elm forest	Extratropical Forest
131	Bluestem - Indian grass - Switchgrass grassland	Savanna
133	Tall fescue - Foxtail - Purple bluestem grassland	Savanna
134	White oak - Northern red oak - Hickory forest	Temperate Forest
135	Eastern redcedar - Oak / Bluestem savanna	Temperate Forest
138	Red pine - White pine forest	Temperate Forest
140	Jack pine / Black spruce forest	Boreal Forest
142	Trembling aspen - Paper birch forest	Boreal Forest
143	Trembling aspen - Paper birch - White spruce - Balsam fir forest	Boreal Forest

Code	Fuelbed Name	Biomass Type
146	Jack pine forest	Temperate Forest
147	Jack pine savanna	Temperate Forest
148	Jack pine forest	Temperate Forest
152	Red pine - White pine forest	Temperate Forest
154	Bur oak savanna	Chaparral
155	Red spruce - Balsam fir forest	Temperate Forest
156	Slash pine plantation forest	Extratropical Forest
157	Loblolly pine - Shortleaf pine - Mixed hardwoods forest	Extratropical Forest
158	Loblolly pine - Shortleaf pine - Mixed hardwoods forest	Extratropical Forest
161	Loblolly pine - Slash pine forest	Extratropical Forest
162	Loblolly pine - Slash pine forest	Extratropical Forest
164	Sand pine forest	Extratropical Forest
165	Longleaf pine / Three-awned grass - Pitcher plant savanna	Extratropical Forest
166	Longleaf pine / Three-awned grass - Pitcher plant savanna	Extratropical Forest
168	Little gallberry - Fetterbush shrubland	Chaparral
170	Pond pine / Little gallberry - Fetterbush shrubland	Chaparral
173	Live oak / Sea oats savanna	Extratropical Forest
174	Live oak - Sabal palm forest	Extratropical Forest
175	Smooth cordgrass - Black needlerush grassland	Savanna
176	Smooth cordgrass - Black needlerush grassland	Savanna
178	Loblolly pine - Shortleaf pine forest	Extratropical Forest
180	Red maple - Oak - Hickory - Sweetgum forest	Extratropical Forest
181	Pond pine forest	Extratropical Forest
182	Longleaf pine - Slash pine / Saw palmetto - Gallberry forest	Extratropical Forest
183	Loblolly pine - Shortleaf pine forest	Extratropical Forest
184	Longleaf pine / Turkey oak forest	Extratropical Forest
185	Longleaf pine / Turkey oak forest	Extratropical Forest
186	Turkey oak - Bluejack oak forest	Extratropical Forest
187	Longleaf pine / Yaupon forest	Extratropical Forest
188	Sand pine - Oak forest	Extratropical Forest
189	Sand pine - Oak forest	Extratropical Forest
190	Slash pine - Longleaf pine / Gallberry forest	Extratropical Forest
191	Longleaf pine - Slash pine / Gallberry forest	Extratropical Forest
196	Loblolly pine / Bluestem forest	Extratropical Forest
203	Sawgrass - Muhlenbergia grassland	Savanna
208	Grand fir - Douglas-fir forest	Temperate Forest
210	Pinyon - Juniper forest	Temperate Forest
211	Interior ponderosa pine forest	Temperate Forest
212	Pacific ponderosa pine forest	Temperate Forest
213	Wheatgrass - Cheatgrass grassland	Savanna
214	Giant sequoia - White fir - Sugar pine forest	Temperate Forest
215	Douglas fir - Madrone / Tanoak forest	Temperate Forest

Code	Fuelbed Name	Biomass Type
216	Gambel oak - Bigtooth maple forest	Temperate Forest
217	Gambel oak - Bigtooth maple forest	Temperate Forest
218	Gambel oak / Sagebrush shrubland	Chaparral
219	Ponderosa pine - White fir / Trembling aspen forest	Temperate Forest
220	Ponderosa pine - White fir / Trembling aspen forest	Temperate Forest
221	Wheatgrass - Ryegrass grassland	Savanna
222	Interior ponderosa pine forest	Temperate Forest
223	Douglas-fir - White fir - Interior ponderosa pine forest	Temperate Forest
224	Trembling aspen forest	Temperate Forest
225	Trembling aspen forest	Temperate Forest
226	White fir - Gambel oak forest	Temperate Forest
227	White fir forest	Temperate Forest
228	Interior Ponderosa pine - Limber pine forest	Temperate Forest
229	Ponderosa pine / Juniper forest	Temperate Forest
230	Pinyon - Juniper forest	Temperate Forest
231	Gambel oak - Juniper - Ponderosa pine forest	Temperate Forest
232	Mesquite savanna	Chaparral
233	Sagebrush shrubland	Chaparral
234	Sagebrush shrubland	Chaparral
235	Idaho fescue - Bluebunch wheatgrass grassland	Savanna
236	Tobosa - Grama grassland	Savanna
237	Vaccinium - Heather shrublands	Chaparral
238	Pacific silver fir - Mountain hemlock forest	Temperate Forest
239	Douglas fir - Sugar pine - Tanoak forest	Temperate Forest
240	Saw palmetto / Three-awned grass shrubland	Chaparral
241	Longleaf pine - Loblolly pine forest	Extratropical Forest
242	Longleaf pine - Loblolly pine forest	Extratropical Forest
243	Pitch pine / Scrub oak shrubland	Chaparral
260	Ohia / Uluhe Forest	Extratropical Forest
261	Pili grass - Broomsedge bluestem grassland	Savanna
262	Molasses grass grassland	Savanna
263	Ohia / Broomsedge bluestem savanna	Savanna
264	Post oak - Blackjack oak forest	Temperate Forest
265	Balsam fir - White spruce - Mixed Hardwoods forest	Extratropical Forest
266	Sugar maple - Basswood forest	Extratropical Forest
267	American beech - Yellow birch - Sugar maple - Red spruce forest	Temperate Forest
268	American beech - Yellow birch - Sugar maple - Eastern hemlock forest	Temperate Forest
269	Sugar maple - Yellow poplar - American beech - Oak forest	Extratropical Forest
270	Red spruce - Fraser fir / Rhododendron forest	Temperate Forest
272	Red mangrove - Black mangrove forest	Extratropical Forest
273	Engelmann spruce - Douglas-fir - White fir - Interior ponderosa	Temperate Forest
274	American beech - Sugar maple forest	Extratropical Forest

Code	Fuelbed Name	Biomass Type
275	Chestnut oak - White oak - Red oak forest	Extratropical Forest
276	Oak - Pine - Magnolia forest	Temperate Forest
279	Black spruce - Northern white cedar - Larch forest	Boreal Forest
280	Bluestem - Gulf cordgrass grassland	Savanna
281	Shortleaf pine - Post oak - Black oak forest	Extratropical Forest
282	Loblolly pine forest	Extratropical Forest
283	Willow oak - Laurel oak - Water oak forest	Extratropical Forest
284	Green ash - American elm - Silver maple - Cottonwood forest	Temperate Forest
286	Interior Ponderosa pine - Limber pine forest	Temperate Forest
287	Eastern white pine - Eastern hemlock forest	Temperate Forest
288	Bald-cypress - Water tupelo forest	Extratropical Forest
289	Pond-cypress / Muhlenbergia - Sawgrass savanna	Savanna
291	Longleaf pine - Slash pine / Saw palmetto forest	Temperate Forest
301	California central valley riparian	Temperate Forest
302	Intermountain montane subalpine riparian	Temperate Forest
303	Warm desert riparian	Extratropical Forest
304	Conifer swamp	Temperate Forest
305	Red alder	Temperate Forest
306	Knobcone pine forest	Temperate Forest
307	Palo verde shrubland	Chaparral
308	Low sagebrush	Chaparral
309	Blackbrush	Chaparral
310	Greasewood	Chaparral
311	Salt-desert shrub	Chaparral
312	Gambel oak	Temperate Forest
313	Mountain Mahogany	Temperate Forest
314	Limber-bristlecone pine	Temperate Forest
315	Interior alpine forb-grass	Savanna
316	Northern California coastal shrub	Chaparral
317	Rocky Mountain Maple	Temperate Forest
318	Bluejoint reedgrass -- water sedge grassland	Savanna
319	North Pacific avalanche chute shrubland	Chaparral
320	Western Larch Forest Alliance	Temperate Forest
401	Recently Logged Timerland-Shrubland Cover	Temperate Forest
402	Recently Logged Timberland-Woodland Cover	Temperate Forest
403	Ouachita Montane Oak Forest	Temperate Forest
404	Southern and Central Appalachian Cove Forest	Temperate Forest
405	Central and Southern Appalachian Montane Oak Forest	Temperate Forest
406	West Gulf Coastal Plain Mesic Hardwood Forest	Temperate Forest
407	Southern Coastal Plain Dry Upland Hardwood Forest	Temperate Forest
408	Eastern Great Plains Tallgrass Aspen Parkland	Temperate Forest
409	Appalachian Shale Barrens	Temperate Forest

Code	Fuelbed Name	Biomass Type
410	Southern Appalachian Montane Pine Forest and Woodland	Temperate Forest
411	Edwards Plateau Limestone Savanna and Woodland	Extratropical Forest
412	Acadian -- Appalachian Alpine and Subalpine Woodlands and Barrens	Temperate Forest
413	Northern Oak Barrens	Temperate Forest
414	Nashville Basin Limestone Glade and Woodland	Extratropical Forest
415	Cumberland Sandstone Glade and Barrens	Savanna
416	Calcareous Glade and Woodland	Extratropical Forest
417	West Gulf Coastal Plain Glade and Barrens	Savanna
418	Great Lakes Alvar	Extratropical Forest
419	Llano Uplift Acidic Woodland and Glade	Extratropical Forest
420	Great Lakes Wet-Mesic Lakeplain Prairie	Savanna
421	Bluegrass Savanna and Woodland	Extratropical Forest
422	Arkansas Valley Prairie and Woodland	Extratropical Forest
423	Highland Rim Prairie and Barrens	Savanna
424	Southern Coastal Plain Nonriverine Cypress Dome	Extratropical Forest
425	Southern Coastal Plain Nonriverine Cypress Dome	Extratropical Forest
426	Tamaulipan Riparian Forest	Extratropical Forest
427	Laurentian-Acadian Alkaline Conifer-Hardwood Swamp	Extratropical Forest
428	Melaleuca forest	Extratropical Forest
429	Introduced Upland Vegetation - Treed	Temperate Forest
430	Mississippi River Alluvial Plain Loess Slope Forest	Extratropical Forest
431	East Gulf Coastal Plain Limestone Forest	Extratropical Forest
432	South Florida Hardwood Hammock	Extratropical Forest
433	Atlantic Coastal Plain Maritime Grassland and Woodland	Temperate Forest
434	Mississippi River Dune Woodland	Extratropical Forest
435	Tamaulipan Clay Grassland	Savanna
436	South Texas Sand Sheet Grassland	Savanna
437	South Texas Coastal Grassland	Savanna
438	South Florida Cypress Dome	Extratropical Forest
439	Carolina Bay savanna	Savanna
440	Caribbean Swamp Forest	Extratropical Forest
441	Central Interior and Appalachian Swamp Forest	Extratropical Forest
442	Great Plains Prairie Pothole	Savanna
443	Eastern Great Plains Marsh	Peatland
444	Great Lakes Coastal Marsh	Peatland
445	Central Interior and Appalachian Wetland	Peatland
446	Laurentian-Acadian Wetland	Peatland
447	Atlantic Coastal Plain Nonriverine Swamp Forest	Temperate Forest
448	Atlantic Coastal Plain Nonriverine Swamp Forest	Temperate Forest
449	North-Central Interior Wet Flatwoods	Temperate Forest
450	Edwards Plateau Slope Forest and Woodland	Extratropical Forest
451	Edwards Plateau Slope Forest and Woodland	Extratropical Forest

Code	Fuelbed Name	Biomass Type
452	Edwards Plateau Riparian	Extratropical Forest
453	Ruderal Upland-Old Field	Savanna
454	Ruderal Forest-Northern and Central Hardwood and Conifer	Temperate Forest
455	Managed Tree Plantation-Northern and Central Hardwood and Conifer Plantation Group	Temperate Forest
456	Introduced Wetland Vegetation-Tree	Extratropical Forest
457	South Florida Coastal Strand and Maritime Hammock	Peatland
458	South Texas Lomas	Extratropical Forest
500	Agricultural burning	Crop Residue
501	Turf Grass (Kentucky Bluegrass)	Crop Residue
502	Cereal Grains (Wheat,Barley,oats, etc)	Crop Residue
503	Legumes	Crop Residue
504	Conservation Reserve Program	Pasture Maintenance
505	almonds	Crop Residue
506	apples	Crop Residue
507	apricots	Crop Residue
508	asparagus	Crop Residue
509	avocado	Crop Residue
510	barley	Crop Residue
511	beans dry edible	Crop Residue
512	blueberries	Crop Residue
513	bushberry	Crop Residue
514	canola	Crop Residue
515	cherries	Crop Residue
516	citrus	Crop Residue
517	coffee	Crop Residue
518	corn grain	Crop Residue
519	corn silage	Crop Residue
520	cotton pima	Crop Residue
521	cotton upland	Crop Residue
522	CRP	Pasture Maintenance
523	dates	Crop Residue
524	ditches and ditch banks	Crop Residue
525	ditches and fenceline	Crop Residue
526	figs	Crop Residue
527	filberts	Crop Residue
528	flaxseed	Crop Residue
529	fruits and vegetables other	Crop Residue
530	grapes	Crop Residue
531	hay alfalfa	Crop Residue
532	hay	Crop Residue
533	hops	Crop Residue

Code	Fuelbed Name	Biomass Type
534	kiwi	Crop Residue
535	lentils	Crop Residue
536	macadamia nuts	Crop Residue
537	mint	Crop Residue
538	nectarines	Crop Residue
539	oats	Crop Residue
540	olives	Crop Residue
541	onion seeds	Crop Residue
542	orchard pruning	Crop Residue
543	orchard removal	Crop Residue
544	peaches	Crop Residue
545	Peanuts	Crop Residue
546	Pears	Crop Residue
547	peas; dry edible	Crop Residue
548	Pecans	Crop Residue
549	Persimmons	Crop Residue
550	Pistachio	Crop Residue
551	plums and prunes	Crop Residue
552	pomegranates	Crop Residue
553	Potatoes	Crop Residue
554	proso millet	Crop Residue
555	quinces	Crop Residue
556	rice	Crop Residue
557	rye	Crop Residue
558	safflower	Crop Residue
559	seeds alfalfa	Crop Residue
560	seeds KBG	Crop Residue
561	seeds other	Crop Residue
562	sorghum	Crop Residue
563	soybeans	Crop Residue
564	sudan	Crop Residue
565	sugarbeets	Crop Residue
566	sugarcane	Crop Residue
567	sunflower	Crop Residue
568	weeds	Crop Residue
569	walnuts	Crop Residue
570	wheat	Crop Residue
571	wheat durum	Crop Residue
572	wheat spring	Crop Residue
573	wheat spring irrigated	Crop Residue
574	wheat winter	Crop Residue
575	berries other	Crop Residue

Code	Fuelbed Name	Biomass Type
801	Short grass FBPS NFFL Model 1	Savanna
802	Timber (grass and understory) FBPS NFFL Model 2	Temperate Forest
803	Tallgrass FBPS NFFL Model 3	Savanna
810	Timber (litter and understory) FBPS NFFL Model 10	Temperate Forest
813	Heavy Slash FBPS NFFL Model 13	Temperate Forest
821	Short sparse dry climate grass Finney Model 101 100	Savanna
822	Short sparse dry climate grass Finney Model 101 75	Savanna
823	Short sparse dry climate grass Finney Model 101 50	Savanna
824	Short sparse dry climate grass Finney Model 101 0	Savanna
888	Bare Ground	Non-fuel area
911	Open Water	Non-fuel area
912	Snow/Ice	Non-fuel area
920	Developed-General	Non-fuel area
921	Developed-Open Space	Non-fuel area
922	Developed-Low Intensity	Non-fuel area
923	Developed-Medium Intensity	Non-fuel area
924	Developed-High Intensity	Non-fuel area
931	Barren	Non-fuel area
932	Quarries/Strip Mines/Gravel Pits	Non-fuel area
933	Sparsely Vegetated	Non-fuel area
952	Introduced Upland Vegetation - Shrub	Chaparral
954	Introduced Upland Vegetation - Annual and Perennial Grassland and Forbland	Savanna
958	Introduced Riparian Vegetation	Temperate Forest
999	Out of Bounds	Non-fuel area
1000	Derive from 1km FCCS fuel map	Non-fuel area
1201	Corn	Crop Residue
1202	Cotton	Crop Residue
1203	Rice	Crop Residue
1205	Soybeans	Crop Residue
1223	Wheat	Crop Residue
1225	Other Small Grains	Crop Residue
1241	Sugarbeets	Crop Residue
1242	Beans	Crop Residue
1243	Potatoes	Crop Residue
1244	Other Crops	Crop Residue
1245	Sugarcane	Crop Residue
1247	Misc. Veg. & Fruits	Crop Residue
1252	Lentils	Crop Residue
1260	Biofuels	Crop Residue
1261	Fallow	Crop Residue
1262	Pasture/Grass	Crop Residue
1271	Other Tree Nuts	Crop Residue

Code	Fuelbed Name	Biomass Type
1273	Other Tree Fruits	Crop Residue
1280	Bluegrass/Grass Seed	Crop Residue
1281	Pasture/Hay/Alfalfa	Pasture Maintenance
1290	Dbl. Crop Win Wht/Corn	Crop Residue
1291	Dbl. Crop Wheat/Soy	Crop Residue
1292	Dbl. Crop Other Grain/Corn	Crop Residue
1293	Dbl. Crop Lettuce/Durum Wheat	Crop Residue
1294	Dbl. Crop Lettuce/Upland Cotton	Crop Residue
1295	Dbl. Crop Wht/Sorghum	Crop Residue
1296	Dbl. Crop Wheat/Cotton	Crop Residue
1297	Dbl. Crop Soybeans/Cotton	Crop Residue
1298	Dbl. Crop Soybeans/Other Grains	Crop Residue
1299	Dbl. Crop Corn/Soybeans	Crop Residue

Appendix C: CONSUME3 Emission Factors

Table C-1. Emission factor groups used by CONSUME3 (extracted from source code)

ID	fuel_type	references	Flaming							Smoldering/Residual						
			PM	PM_{10}	$PM_{2.5}$	CO	CO_2	CH_4	VOC	PM	PM_{10}	$PM_{2.5}$	CO	CO_2	CH_4	VOC
0	Default - Source Code	CONSUME3 documentation	24.0	16.0	13.0	96.0	3380	4.0	6.0	35.0	26.0	21.0	243.0	3082	14.0	13.0
1	Doug-fir/ hemlock	Ward et al. 1989	24.7	16.6	14.9	143.0	3385	4.6	4.2	35.0	27.6	26.1	463.0	2804	15.2	8.4
2	Hardwoods	Ward et al. 1989	23.0	14.0	12.2	92.0	3389	4.4	5.2	38.0	25.9	23.4	366.0	2851	19.6	14.0
3	Ponderosa/ Lodgepole	Ward et al. 1989	18.8	11.5	10.0	89.0	3401	3.0	3.6	48.6	36.7	34.2	285.0	2971	14.6	9.6
4	Mixed conifer	Ward et al. 1989	22.0	11.7	9.6	53.0	3458	3.0	3.2	33.6	25.3	23.6	273.0	3023	17.6	13.2
5	Juniper	Ward et al. 1989	21.9	15.3	13.9	82.0	3401	3.9	5.5	35.1	25.8	23.8	250.0	3050	20.5	15.5
6	Sagebrush	Hardy et al. 1998	45.0	31.8	29.1	155.0	3197	7.4	6.8	45.3	29.6	26.4	212.0	3118	12.4	14.5
7	Chaparral	Hardy et al. 1998	31.6	16.5	13.5	119.0	3326	3.4	17.2	40.0	24.7	21.6	197.0	3144	9.0	30.6
8	Western Pine	Baker 2005	na	na	13.8	81.7	1663	2.9	2.8	na	na	14.4	141.5	1552	6.3	3.8
9	Minnesota Oak	Baker 2006	na	na	10.0	61.2	1709	1.7	1.9	na	na	10.5	109.1	1609	6.6	3.8
10	Minnesota Pine	Baker 2007	na	na	11.7	64.6	1694	2.0	2.0	na	na	13.4	90.8	1645	3.1	2.6
11	Southern Pine	Baker 2008	na	na	11.4	72.8	1681	2.0	2.5	na	na	9.9	119.3	1602	3.8	4.0
12	Sage	Baker 2009	na	na	12.9	126.4	1590	3.1	4.4	na	na	8.4	184.2	1453	11.9	14.3
13	Minnesota Grass	Baker 2010	na	na	12.2	61.4	1698	2.1	3.8	na	na	10.8	109.4	1630	4.3	4.3
14	Arizona Piles	Baker 2011	na	na	7.7	52.7	1715	3.3	3.6	na	na	21.1	130.4	1545	11.0	6.8
15	Grassland	CONSUME3 documentation	20.0	20.0	6.0	80.0	3400	0.0	0.0	20.0	20.0	6.0	80.0	3400	0.0	0.0
16	Default - Av. of all	Ottmar	26.7	16.8	13.1	89.5	2522	3.3	4.8	39.4	27.9	19.1	209.3	2285	11.1	10.4
17	Default - User's Guide	CONSUME3 documentation	23.0	15.0	13.0	90.0	2522	3.0	5.0	34.0	24.0	19.0	209.0	2285	11.0	10.0

Appendix D: FAMWEB Data Processing

1.0 FAMWEB DATA PROCESSING

This is a description of the pre-database processing of the Fire Emissions Tracking System (FETS) data from the Fire and Aviation Management WEBsite (FAMWEB). Several fire data sets were included in the FAMWEB files. The Wild Fire Management Information (WFMI) dataset is composed of fire data sets from the Bureau of Indian Affairs (BIA), Bureau of Land Management (BLM), Bureau of Reclamation (BOR), and the National Parks Service (NPS). These organizations have their data stored in a similar format on FAMWEB. Other datasets with individually formatted and encoded fire data include sets from the United States Forest Service (USFS), the Fish and Wildlife Service (FWS), and the California Department of Forestry and Fire Protection (CAL FIRE).

Several processes were performed on the FAMWEB data prior to entry into the FETS. The data were garnered via download from the FAMWEB site. The data were then reformatted into comma-separated format for ease of reading into the R and Excel software; additionally, the WFMI datasets were combined into a single comma-delimited file.

Each of the initial fire file formats (WFMI, USFS, FWS, and CALFIRE) was preprocessed individually. For all sets, only entries whose fire started dates fall after the beginning of 2007 were considered; any prior entries were removed. For an entry, if latitude, longitude, date, or area burned data were not present the entry was removed.

In order to determine whether a fire's source type as prescribed burn (Rx), wild fire (WF), or wild fire use (WFU), the various file formats were de-coded individually and then the entries mapped to the appropriate source type. The same information was also used to determine the burn category (natural or anthropological) of the fire. Tables that described the interpretation of the data into source type and burn category are provided under the individual data set descriptions below.

The last step in the pre-database processing was estimating the number of acres burned each day. The database requires burn information on a daily basis. The FAMWEB data, with the exception of the CAL FIRE data, provided a start and end date for a given burn and total acreage; daily specific burn acreage was not available. Several steps gave a reasonable estimation of daily burn acreage:

- Any entry with area greater than 1000 acres was not considered in the pre-processing and was removed; fires greater than this size were added to the database from another source.
- Any wildfire entry with area greater than 500 acres was not considered in the pre-processing and was removed; fires greater than this size were added to the database from another source.
- Any wildfire smaller than or equal to 100 total acres had its end date set to the start date; the assumption was that the majority of the area of small burns occurred on their first days. This compressed small wildfires into a single day. These fires are assigned a revised burn rate equal to their total acres burned.

- A raw burn rate was calculated for large wild fire entries (greater than 100 acres) by dividing the total acreage by the number of days the fire lasted, the fire period.
- Any raw burn rate less than 1 acre/day was increased to 1 acre, the "revised" burn rate, and a revised end date calculated based on the revised burn rate and total acreage. This compressed large wild fires with long fire periods to fewer days.
- For wild fires, any raw burn rates less than 1 acre/day was increased to 1 acre, the "revised" burn rate, and a revised end date calculated based on the revised burn rate and total acreage. This compressed large wild fires with long fire periods into fewer days.
- For prescribed fires, any raw burn rates less than 0.1 acres/day was increased to 0.1 acres, the "revised" burn rate, and a revised end date calculated based on the revised burn rate and total acreage. This compressed prescribed fires with long fire periods into fewer days.
- The revised burn rates were used as the number of acres burned daily, and an entry was constructed for each day of the fires' periods.

1.1 USFS Specific Processing

The USFS data contains entries that have erroneous date information. The first type of erroneous date places events in the wrong centuries. These are easily corrected by changing the first two digits to "19" (for entries in the 70's to 90's) or to "20" (for entries in the 00's and 10's).

The second type of erroneous date is apparently typographical error in some of the start or end date data for wild fires. These are identified by end dates that are entered as being just over a year later than the start dates, which is reasonably unlikely for small fires. In these cases, the end date is either revised backwards one year, or if revising the date backwards one year would place the end date before the start date then the end date is set equal to the start date. To assure that the change in this type of erroneous date entry is reasonable, these data were corrected on an entry-by-entry basis.

For example, in the USFS data set, The Bill's Branch #1 fire was 0.1 acre fire whose fire ignition date was 2009-02-11 and whose fire controlled date was 2010-02-12. Its end date was set to 2009-02-12 (prior to the ending date revisions based on burn rate as described in General Processing).

Assigning a source type to the USFS data involved the use of several of the available fields: statistical cause, specific cause, prescribed (Y/N), and escaped (Y/N). The statistical and specific cause codes were interpreted from the Firestat's User Guide[14]. Additionally, any entry whose fire name field contained "WFU" or "fire use" (or similar) has its source type categorized as WFU. Tables C-1 – C-3 summarize the methodology used.

Table D-1. USFS Statistical Cause Interpretation

14 Firestat User's Guide v5.4, Appendix A

Code	Description	Possible Source Types
1	Lightning	WF, WFU
2	Equipment Use	WF
3	Smoking	WF
4	Campfire	WF
5	Debris Burning	WF, RX
6	Railroad	WF
7	Arson	WF
8	Children	WF
9	Miscellaneous	WF, RX, WFU

Table D-2. USFS Statistical Cause Codes Interpreted as Source Type and Burn Category

	USFS			FETS	
Statistical Cause Code	Prescribed?	Escaped?	Specific Cause Code	Source Type	Burn Category
1	No, Blank	Any	Any	WF	NAT
1	Yes	Any	1	WFU *	NAT
2, 3, 4, 6, 7, 8	Any	Any	Any	WF	NAT
5, 9	No, Blank	Yes	Any	WF	NAT
5, 9	Yes	No, Blank	Any	RX	ANTH
5, 9	No, Blank	No, Blank	See Specific Causes	See Specific Causes	See Specific Causes

* Entries with "WFU" or "fire use" (or something similar) in the fire name are given a FETS source type of WFU, regardless of other fields

Table D-3. USFS Specific Cause Codes Interpreted as Source Type and Burn Category

Code	Description	Source Type	Burn Category	Code	Description	Source Type	Burn Category
1	Lightning	WF	NAT	16	Right-of-way burning	RX	ANTH
2	Aircraft	WF	NAT	17	Resource management burning	RX	ANTH
3	Burning vehicle	WF	NAT	18	Grudge fire	WF	NAT
4	Exhaust-powersaw	WF	NAT	19	Pyromania	WF	NAT
5	Exhaust-other	WF	NAT	20	Smoking out bees or game	RX	ANTH
6	Logging line	WF	NAT	21	Insect/snake control	RX	ANTH
7	Brakeshoe	WF	NAT	22	Job fire	RX	ANTH

Code	Description	Source Type	Burn Category	Code	Description	Source Type	Burn Category
8	Cooking fire	WF	NAT	23	Blasting	WF	NAT
9	Warming fire	WF	NAT	24	Burning building	WF	NAT
10	Smoking	WF	NAT	25	Powerline	WF	NAT
11	Trash burning	WF	NAT	26	Fireworks	WF	NAT
12	Burning dump	WF	NAT	27	Playing with matches	WF	NAT
13	Field burning	RX	ANTH	28	Repel predatory animals	RX	ANTH
14	Land clearing	RX	ANTH	29	Stove fuel sparks	WF	NAT
15	Slash burning	RX	ANTH	30	Other	WF	NAT

1.2 FWS Specific Processing

The codes for the "Fire Type" and "Protection Type" fields were interpreted via the FWS Individual Fire Report Instructions[15]. Tables C-4 and C-5 summarize the methodology used.

Table D-4. FWS Codes Interpreted as Source Type and Burn Category

FWS				FETS	
Fire Type Code	Fire Type Description	Protection Type Code	Protection Type Description	Source Type	Burn Category
1	Suppressed	Any	-	WF	NAT
2	Natural Outs	Any	-	WF	NAT
3	Support Actions	Any	-	WF	NAT
4	Prescribed Fires	8	Prescribed - Planned	RX	ANTH
4	Prescribed Fires	9	Prescribed - Unplanned	WFU*	See General Causes
5	False Alarms	Any	-	WF	NAT
Missing	-	Any	-	WF	NAT

* Entries with "WFU" or "fire use" (or something similar) in the fire name are given a FETS source type of WFU, regardless of other fields

Table D-5. FWS General Cause Codes Interpreted as Burn Category

FWS		FETS
General Cause Code	Description	Burn Category
1	Natural	NAT
2	Camp Fire	ANTH
3	Smoking	ANTH
4	Fire Use	ANTH

15 U.S. FWS, Individual Fire Report Instructions (DI-1202), June 1997

FWS		FETS
General Cause Code	Description	Burn Category
5	Incendiary	ANTH
6	Equipment	ANTH
7	Railroads	ANTH
8	Juveniles	ANTH
9	Miscellaneous	ANTH

1.3 WFMI Specific Processing

The "Fire Type" and "Protection Type" codes were interpreted according to various agencies' User's Guides[16,17,18,19]. However, after reviewing these documents, the associating of those fields with RX, WF, and WFU source types was identical for all WFMI data sets. Table C-6 summarizes the methodology used.

Table D-6. WFMI Codes Interpreted as Source Type and Burn Category

WFMI				FETS	
Fire Type Code	Fire Type Description	Protection Type Code	Protection Type Description	Source Type	Burn Category
1	Wildfires Suppressed	1-6	-	WF	NAT
1	Wildfires Suppressed	9	-	WFU	WFU
2	Natural Outs	Any	-	WF	NAT
3	Support Actions	Any	-	WF	NAT
4	Prescribed Fires	7	-	RX	RX
4	Prescribed Fires	8	Management-ignited prescribed fires.	RX	RX
4	Prescribed Fires	9	Naturally ignited wildland fire managed with a WFIP to accomplish resource objectives.	WFU	WFU
5	False Alarms	Any	-	WF	NAT
Missing	-	Any	-	WF	NAT

16 Bureau of Indian Affairs, Fire Occurrence Reporting System – User's Guide, January 2008

17 Bureau of Land Management, Fire Occurrence Reporting System - User Instructions, 2007

18 Bureau of Reclamation, Fire Occurrence Reporting System – User Instructions, 2008

19 NPS Wildland Fire Report Form, Instructions and Form, October 2007

1.4 CAL FIRE Specific Processing

Within the CAL FIRE data, a section of the data is badly formatted. This section is identified by not having eight characters in the date field. These entries were removed. CAL FIRE formatted data do not have information on the ending date of the fire. Therefore, for all entries, the ending date is set equal to the starting date. The cause codes were deciphered according to a California Dept. of Forestry and Fire Protection (CDF) fire operating plan[20]. It was determined after review that all fires in this dataset were natural wildfires. For reference, the CDF cause codes are included in Table C-7.

Table D-7. CDF Cause Codes

CDF Cause Code	CDF Description
0	Unknown
1	Undetermined
2	Lightning
3	Campfire
4	Smoking
5	Debris Burning
6	Arson
7	Equipment Use
8	Playing/Fire
9	Misc
10	Vehicle
11	Railroad
12	Powerline

[20] National Fire Danger Rating System Operating Plan, Fire Weather Operating Plan, Amador-El Dorado Unit of the California Dept. of Forestry and Fire Protection, Appendix G