FINAL REPORT

Creating a Statewide Spatially and Temporally Allocated Wildfire and Prescribed Burn Emission Inventory Using Consistent Emission Factors

ARB Contract Number: 98-726

Prepared by:
Scarborough, James, Nicolas Clinton, Ruiliang Pu, Peng Gong
Center for the Assessment and Monitoring of Forest and Environmental Resources
College of Natural Resources

Principal Investigators:
Peng Gong – Professor
Center for the Assessment and Monitoring of Forest and Environmental Resources
College of Natural Resources

John Radke – Associate Professor
Geographic Information Science Center

Rick Standiford – Extension Specialist
Center for Foresty
College of Natural Resources

151 Hilgard Hall #3110
University of California
Berkeley, CA 94720-3110

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Disclaimer

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0. Executive Overview

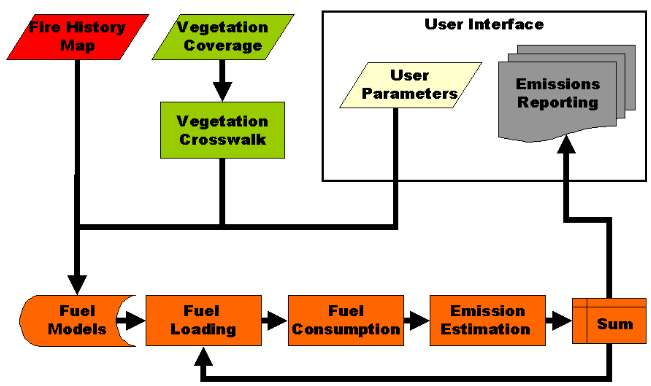
To help better understand factors influencing air quality and visibility degradation, the California Air Resources Board (ARB) requires a method for accurately estimating particulate matter (2.5 and 10 micron particles) and other emissions from controlled and uncontrolled wildland fires. This information can be used not only for evaluating current and past emissions relevant to forest and air quality planning decisions, but, also as a long term planning tool for predicting the potential emissions from proposed burning projects.

The purpose of this study is to develop a spatially and temporally explicit method for quantifying emissions from wildfires and prescribed fires. Through the development of a new Wildland Fire Emissions Estimation System (EES) we have integrated vegetation data, fire history data, emissions estimation methodology, and a user interface into a cohesive model. The system consists of:

- An adaptive architecture that can be readily modified or updated.
- Spatially allocated inputs (GIS layers) to identify what burned, where it burned, and when it burned.
- The application of standard emissions estimation models. (FOFEM)
- Emissions inventory output as tables and maps.
- A flexible interface that can be customized to the needs of the user.

0.1. The Modular Approach

The Emissions Estimation System concept model is based on a modular framework (see right). This model accepts both spatial and non-spatial data inputs and produces estimates based on unique combinations of input parameters. This framework was developed because a *modular* emissions estimation system is flexible. It is capable of being easily updated as new software and data become available. This assures that the overall approach remains practical even if one component becomes obsolete.



0.2. Emissions Estimation Engine (EEE) Module

One component of the Emissions Estimation System is the Emissions Estimation Engine (EEE). The EEE is responsible for calculating emissions based on inputs regarding the type, quantity, and condition of the fuel burned. Several models were evaluated to perform this function as part of our GIS-based emissions system. After comparing the features of the different systems, we selected the USDA – Forest Service's First Order Fire Effects Model (FOFEM) as the Emissions Estimation Engine (EEE) module of the EES. The EEE is formed from combination of FOFEM emissions estimation algorithms, the FOFEM relational tables, and original Avenue (ArcView language) scripts that facilitate input, processing, and output of spatial data. At this time, FOFEM only provides estimates for PM_{10}, $PM_{2.5}$, and carbon monoxide (CO), so only emissions from these pollutants are provided in this report. . The output data are GIS compatible and may be used as inputs for further processing including emissions trajectory modeling.

0.3. Spatial Vegetation Data Module

Vegetation layers are needed as input to the Emissions Estimation Engine. This data module is used to identify fuel loadings from site-specific vegetation. We examined input data in the form of digital vegetation layers from several sources, primarily the CALVEG data set (CDF / USDA-FS collaboration) and the GAP vegetation (California Department of Fish and Game / U.C. Santa Barbara collaboration). We found that CALVEG has a higher resolution and is more consistent in accurately estimating emissions. However, as CALVEG is a work in progress, it is incomplete so we chose to employ the GAP vegetation for its statewide coverage.

0.4. Spatial Fire History Data Module

The fire history layer is used to identify the exact location and extent of wildland fires. The system overlays the fire history layer with the vegetation layer to identify precisely what vegetation burned.

We received a fire history data set from CDF that consists of burn area polygons from the early part of the century to 1998. It is not entirely up to date and various regions of the state have not submitted information on burning history for four or more years. There is also no information about positional accuracy of fire perimeters.

We also identified algorithms, collected raw data and created a prototype fire mapping system using remotely sensed (RS) data. Our remote sensing fire mapping system for California includes four main processing steps: 1) Data preparation, 2) Hotspot detection, 3) Burned area mapping by hotspot detection coupled with burn scar detection, and 4) Post-processing of image data for integration with GIS and the EES. These steps can be used to make a remotely sensed fire history map.

0.5. The User Interface Module

We created user interfaces that facilitate input to and output from the Emissions Estimation system. There are three main types of interfaces created in the GIS software:

- Desktop Emissions Estimation System for PC: Designed for generation of statewide annual emissions inventories.
- Workstation Emissions Estimation System for Unix: Designed to examine the model components including emissions estimation engines and potential data layers.
- Web-GIS: Designed for interactive fire emissions calculations and mapping of pre-computed emissions inventories.

We provide multiple prototype interfaces as an example of system customizations for different potential users.

0.6. How the modules fit together in an emissions estimation system

The EES evaluates each fire in the input and each vegetation type in each fire. This is accomplished through spatial overlay operations in the GIS. The EES employs the following steps:

1. Identify fire location and extent (CDF or RS data fire polygon data),
2. Determine vegetation types (GAP) for the burn using GIS spatial overlays,
3. Determine pre-burn fuel loading, fuel mass consumed by the fire, combustion efficiency and emissions created (FOFEM),
4. Summarize emissions as a table and graphically and
5. Spatially allocate the emissions through a link to the input fire history map.

0.7. Findings

All of the components of the Emission Estimation System were programmed and assembled. Analyses were then performed to evaluate the performance of the model using different inputs. When various vegetation coverages were used, there was about a 20% variation in the emission estimates due to these inputs. However, varying the burning conditions such as fuel moisture and dead fuel loading assumptions created variations of as much as 70% difference from default values. This tells us that the current vegetation coverages we have selected are adequate, however it is important to try to include as much fire specific information into the emissions estimates as possible. These parameters, such as dead fuel loading levels and fuel moisture are not directly available from the vegetation coverages, but must be collected or ascertained through other methods beyond the scope of this project.

To evaluate the overall model functionality, we used GIS based fire history data from CDF to develop emission estimates. For all of California in 1998, we summarized results by emission type (PM_{10}, $PM_{2.5}$, and CO), emission source (prescribed or wild fire), county, airbasin and acres burned (see Table 5 and 5b). By joining these data to the fire input, we can create grids of emissions for inclusion in other modeling programs.

The EES estimates that 113,107 tons of CO emissions were produced statewide from prescribed and wild fires. Previous ARB wildland fire emission estimates using historical tabular data show 144,654 tons of CO. One reason for this difference is that the CDF fire history input layer to the EES documents 88,940 acres burned. Whereas the source of ARB tabular data (CDF and USDA-FS annual reports) indicates 161,412 acres burned. Moreover, the emission estimates will be different because current ARB methods do not use fuel specific emission factors, but instead use only two different fuel classes to characterize all fuels.

The current configuration of the statewide system has limitations in terms of the completeness of the fire history coverage, the resolution of the GAP dataset, and the accuracy of user defined inputs. Our analysis shows that although the new method is much more refined, and fundamentally a better approach, additional work will be needed to validate and improve input data in order to achieve a comprehensive statewide emissions inventory. Per acre estimates produced by the EES are on the same order of magnitude as the conventional system of emissions estimation.

We produced fire history maps using remotely sensed data for the 1999 burn season. These maps can be created as vector or raster data, have one kilometer spatial resolution, and can have daily temporal resolution.

0.8. Conclusions

The EES we created uses spatial data and user defined parameters to create spatially allocated emissions for wildfires and prescribed burns that can be reported as maps or tables in a variety of formats on a variety of platforms. At this point, the main limitation in producing more accurate, spatially and temporally refined emission estimates, is the need for more complete input data. Fortunately, the CDF and other land managers are making great efforts in this area. We expect that within another year or two data will be available to full take advantage of the design of our emissions model. In addition, we are confident that ongoing research in remote sensing technology, in concert with agency data collection and ground based validation, will produce fire history maps that are more accurate, consistent, and provided in a timely manner. More research is needed to validate this output, integrate with emissions estimates from other sources, and facilitate reporting.

1. Introduction

In the interest of improving air quality, the California Air Resources Board (ARB) estimates the emissions of particulate matter and other emissions from wildland fires. In the past, this was done using generic emissions data, generalized vegetation data, and rough approximations of the quantities of materials burned. With the current interest in increasing burning for forest management, as well as the potential for more smoke incursion to populated areas, this level of estimation is no longer adequate.

This project brings substantial improvements to the science of estimating regional and smoke emissions produced by wildlands fires. The goal of this research is to develop a methodology for estimating spatially and temporally explicit wildland fire emissions. Moreover, this project delivers prototype geographic information system (GIS) software that produces spatially resolved annual average statewide and county emissions based on actual burn history data compiled by the land management agencies such as the California Department of Forestry and Fire Protection (CDF) and the U.S. Department of Agriculture – Forest Service (USDA-FS). Using GIS, the emissions are computed for each reported fire based on the vegetation types specific to each burn. The emissions are computed using the First Order Fire Effects Model (FOFEM) developed and maintained by the USDA – Forest Service.

To deliver not only a scientifically sound methodology, but also working software, we set the following objectives:

- Employ a modular approach to building a spatial model. This enables our model to adapt as new data and software become available. It also is flexible with regard to customization of the end user interface.
- Use existing vegetation and other input data in order to minimize time consumptive and expensive forays into data collection and preprocessing.
- Employ an existing fire model that is a widely used and accepted method of estimating the quantity and quality of emissions from wildfires.
- Create a platform neutral process capable of generating information in multiple formats. In an air pollution control context, this results in output that is meaningful to managers, but also spatially allocated for input to other models.

This research provides a Wildland Fire Emissions Estimation System (EES) to integrate vegetation data, fire history data, emissions estimation methodology, and a user interface.

The results of this project provide important tools necessary for better evaluating how wildlands burning can affect air quality. For example, the design of this new system allows emissions to be computed from actual reported burn data, not compiled estimates. The system estimates emissions based on the specific vegetation type that actually was burned, not just a couple of generalized vegetation classes as is done now. The new system now uses fuel specific emission factors, rather than using just two emission factors for the entire state. With the new system, the emissions from wildlands fires can be displayed graphically and in gridded formats on maps, in addition to tables.

This project provides valuable tools that are needed now to help manage the important, but sometimes conflicting, environmental needs of maintaining both forest health and air quality. To provide even more complete information in the future, planned enhancements to the current system will assist in estimating fire-specific emissions, evaluating smoke impacts, evaluating fuel loading, and providing satellite-based emission estimates during the course of fires.

2. Methods

2.1. Conceptual Basis

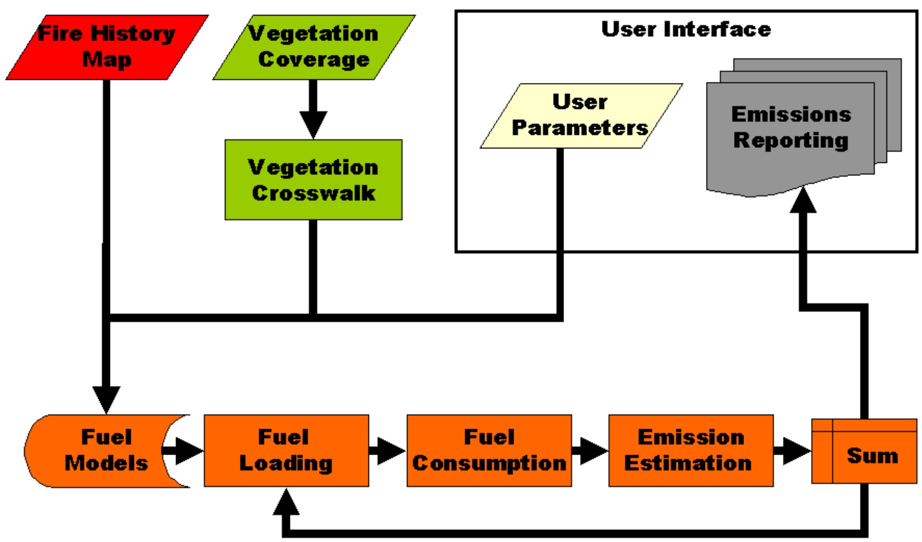
Sound system architecture is central to the creation of a more accurate and detailed method of emissions estimation. We designed a methodology to achieve following qualities:

- An adaptive architecture that can be readily modified or updated.
- Spatially allocated inputs including vegetation and fire polygons.
- The application of standard (non-spatial) emissions estimation models.
- Accurate output as tables and maps.
- A flexible interface that can be customized to the needs of the user.

In order to create a system that meets these objectives, we employed a modular approach. This allows greater utility to test different inputs, interfaces, models and other system components. This section describes the methods we used to achieve the above objectives. The result of this work is the Emissions Estimation System, described in the Results Section.

2.2. Modular approach

The Emissions Estimation System concept model has a modular framework (see below).



This flowchart is a graphic representation of the EES modules. Boxes represent module components. Shading distinguishes modules from each other

These modules consist of:

- An Emissions Estimation Engine (EEE) that quantifies the pollutant masses emitted by wildfires. This model accepts both spatial and non-spatial data inputs and produces estimates based upon unique combinations of input parameters.

- A spatial vegetation data layer as input to the EEE.
- A spatial fire boundary data layer that, overlaid with the vegetation layer, is also input to the EEE.
- An interface that facilitates the specification of spatial and non-spatial inputs to the EEE. The interface is capable of accepting user defined data and reporting the data in multiple formats.

Inputs to each module can be from existing products or published research. There are different emissions estimation methodologies in the literature to implement as an EES in our framework. Likewise, more than one government agency maintains a spatial vegetation data layer. In assembling the system, we selected model components that not only could function in concert, but would be interchangeable with equivalent components of the same type. The EES is a framework for linking existing sub-models and data sources. The EES modularizes each model to ensure that any one can interoperate with any combination of other modules. A combination of particular modules is called a "configuration" of the Emissions Estimation System. This type of system is dynamic and flexible, capable of being easily updated as new software and data become available.

2.2.1. A modular system is dynamic and flexible

To modularize means to segment model components via a standardized interface. Modules are expected only to understand input and produce output of a certain format. How they transform one to the other is internal to the module. The idea is that any EES model will be able to function no matter which other EES components are being used.

A modular system allows:

- The re-use of software encoded models and data,
- the rapid inclusion of new or updated models and
- a test-bed for evaluating and comparing the models themselves.

After a model is encoded into the EES specification it is fully implemented no matter what configuration is run. For instance, once an emissions engine is coded, it will function with any number of vegetation inputs. The EEE does not have to be recoded for each competing data source. Regardless of how many model components are already implemented, adding another is as simple as integrating it to the single interface. Seen another way, the possible configurations of the EES increases exponentially at the expense of coding a single sub-model.

The economy of scale of building modular systems is also an advantage for testing purposes. We recognize that natural systems research such as emissions estimation is obligated to validation. A modularized EES facilitates comparing the effects of the models themselves. Vegetation data layers can be swapped in and out to assess estimation results *vis a vi* different emissions engines, for example.

Lastly, a modularized system accommodates models that are not yet even considered. If a new source for vegetation data, for example, were to become available in the future a new EES configuration could be established and tested. Likewise, the EES can be run on a periodic basis with an evolving fire history database. A modular EES provides a functioning system now while allowing the rapid inclusion of new or updated models at any point in the future. Moreover, the EES framework and module specification we are providing ARB is not wed to any particular model currently implemented.

We created several interfaces to the system, each of which is designed for a particular processing application. All interfaces support the notion of interchangeable modules. Our process for developing and testing an EES configuration addresses the varying output resulting from different configurations of the system. By batch processing multiple system configurations, we are able to evaluate how each "instance" of the system responds to varying inputs and module combinations.

2.3. Emissions estimation engine

2.3.1. What is expected of this module

We evaluated fire simulators and other models capable of producing emissions estimates primarily for ability to estimate particulate emissions. Additionally, we examined EEE's based on their capacity to accept spatial data inputs and create outputs that are compatible with conventional database formats.

The spatial inputs to the model define the burning conditions of the natural environment. Ultimately these conditions are represented by both live and dead fuels, but can be inferred indirectly through spatial vegetation or land cover data and published relationships between species based community classifications and fuel levels. An EEE that relates directly to a vegetation classification system was a preferable model since the assumptions about how fuel levels are related to community types are inherent to the model and facilitate input of existing vegetation data sets.

The EEE output, in addition to describing the pollutants of interest, must be reported in a way that can easily integrate with the relational database structure of a GIS. At the same time, the output data must have the capacity for re-integration with spatial inputs so that emissions estimates can be assigned spatially. This requirement that output data be in a GIS compatible format is essential if the emissions data are to be used as inputs for further processing including emissions trajectory modeling.

2.3.2. The model

We chose the USDA – Forest Service's First Order Fire Effects Model (FOFEM) for conforming to the requirements of our modular EES and because of several additional benefits. FOFEM is readily available, can be downloaded directly from the internet, and is well documented by Forest Service publications. The algorithms are conveniently described in mathematical notation in the FOFEM manual. They are straightforward enough to be readily implemented in ArcView GIS using Avenue, the ArcView scripting language.

The fuel loading input to FOFEM is derived from a list of fuel models, compiled from the available literature by the FOFEM authors. The models are coupled with the Society of American Foresters (SAF) and Forest and Range Environmental Study (FRES) vegetation classification systems (SAF/FRES). The fuel models and classification types are national in scope. The conversion tables between the fuel models and the SAF/FRES vegetation types are packaged with the program and can be imported directly to ArcView.

Only PM_{10}, $PM_{2.5}$ and CO are estimated by FOFEM, but we are ultimately interested in incorporating emission estimates for oxides of nitrogen (NO_x), oxides of sulfur (SO_x), reactive organic gases (ROG), and greenhouse gases such as methane, and ammonia. In fact, the emissions engine may be expanded to incorporate estimates of any pollutant species with a published relationship to current FOFEM output.

FOFEM is widely used by fire scientists in multiple agencies and resource management sectors. The extensive application of FOFEM effectively standardizes our output with respect to the predominant modeling software.

2.3.3. FOFEM methodology implemented in the ArcView environment

The First Order Fire Effects Model is a non-spatial model. It takes inputs of a "covercode" (corresponding to an SAF or FRES classification vegetation type), meteorological parameters, and fire characteristics. Output is in the form of predicted fuel consumption and emissions for a covercode on a per unit area basis. In the ArcView environment, using ESRI's Avenue scripting language, we incorporated the functionality of the FOFEM fuel consumption and smoke calculation subroutines to the spatially explicit environment of the geographic information system. In addition to using the published FOFEM equations, we obtained the FORTRAN source code from the authors in order to verify our interpretation of the computations.

To adapt the computation to handle spatial inputs and to create spatial outputs, we wrote a series of scripts to iterate through multiple cover codes (vegetation types) in a single burn area as well as multiple burn areas. As each burn area is represented by a single polygon composed of multiple vegetation polygons, the iterative process is necessary for processing fire information stored as spatial data. The EES processes each vegetation polygon in the burn area, retaining information about its area. This allows the EES to compute total emissions for each vegetation polygon from the per unit area emissions estimated by the core EEE (the FOFEM algorithms). The EES also retains a unique identifier for each burn area polygon. This allows us to link resultant emissions back to the location from which they originated. The EEE module of the EES is formed from combination of FOFEM emissions estimation algorithms, the FOFEM relational tables, and original scripts that facilitate input, processing, and output of spatial data. The scripts also coordinate user input of non-spatial fire parameters such as default live and dead fuel loadings, moisture conditions and burn characteristics.

We added some additional relationships to the table relating vegetation type to FOFEM fuel model. This was necessary because some vegetation types represented in California had not been assigned a fuel model in the FOFEM table. We assigned fuel models to these vegetation types based on species relationships, where possible. Where there was not a direct species relationship, we relied on genera, families and ecological similarities to couple a vegetation type with a realistic fuel model. The updated fuel model table is shown as **Table 1** in Appendix D. Fuel models that appear in italics were not present in the original table.

2.4. Vegetation data

We examined input data in the form of digital vegetation layers from several sources. We evaluated the data sets by three main criteria: 1) In terms of their scope since we required statewide coverage; 2) their date of creation since we wanted the most current data for ongoing analysis, but not necessarily historic analysis; and 3) their spatial resolution or how well they capture the heterogeneity that is natural in California ecosystems. We also inspected the attribute data (conventional row and column database associated with the map information) in order to determine how the various classification systems would translate to the SAF/FRES system (used as FOFEM input). We also checked whether the attribute information could be used for any FOFEM fuel or environmental parameter input.

We used two vegetation layers in our processing of historical fire data, a CALVEG data set provided to us by the California Department of Forestry and Fire Protection and the Gap Analysis Project (GAP) vegetation data set, available from the California Department of Fish and Game's Natural Heritage Commission. Each layer has its own particular advantages and disadvantages in terms of our evaluation criteria. Each layer functions as input to the EEE according to a "crosswalk" between a vegetation classification and the FOFEM fuel models. These crosswalks, in the form of relational data tables, can be seen as a sub-module, capable of being easily updated or revised. Crosswalks are described in more detail below.

2.4.1. CALVEG

The CALVEG layer, created in a collaborative effort between the U.S. Department of Agriculture – Forest Service and CDF using Landsat Thematic Mapper data, is the highest resolution and most recent vegetation layer we examined. With a 2.5 acre minimum mapping unit and 1994-1997 imagery, the coverage is the most accurate representation of current conditions. A CALVEG coverage for Siskiyou county alone has more than 40,000 polygons, a high amount of complexity which likely reflects the patchy distribution of ecosystems over the landscape.

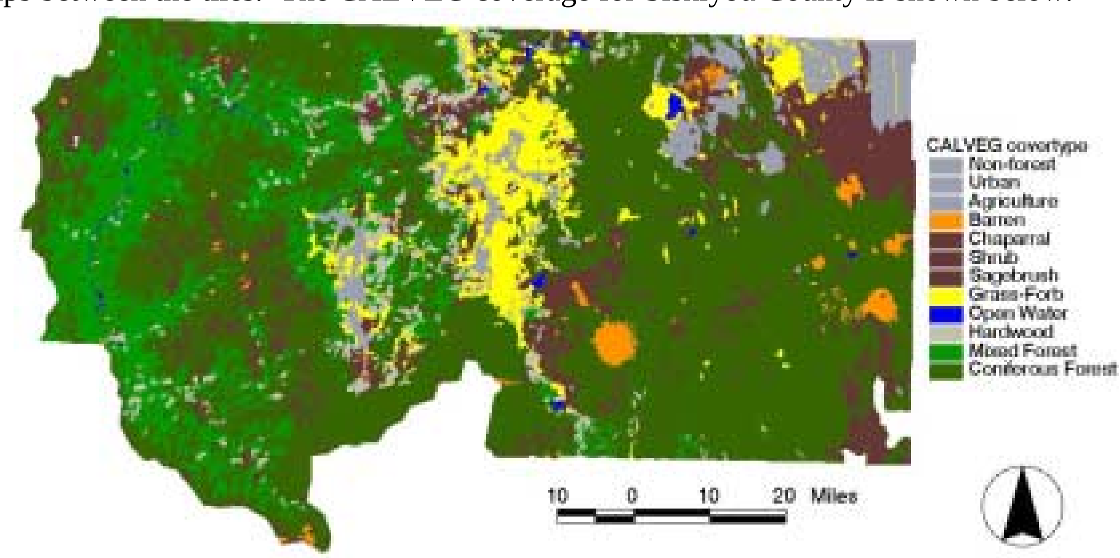
Another advantage of this data set is that CDF has developed a "crosswalk" between the CALVEG classification and the SAF/FRES classification used by FOFEM. Before delivering the data to us, CDF added a field containing the SAF vegetation codes. This service allowed us to input the data directly to FOFEM with only minor pre-processing. The relationship between the two systems is shown as **Table 2** in Appendix D.

Many CALVEG "non-forest" vegetation types had been classified as '000' or '299' in the SAF/FRES system, codes that do not correspond to any vegetation type. Since the FRES system has a more detailed classification system for "non-forest" vegetation type, we crosswalked the '000' and '299' types according to the set of relationships illustrated in **Table 3**.

Table 3: Crosswalk* of CALVEG "non-forest" types to the SAF/FRES system
**created by CAMFER*

CALVEG description	CALVEG code	FOFEM code	SAF/FRES description
Barren/Rock	BA	199	Non-stocked
Water	WA	199	Non-stocked
Snow/Ice	SN	199	Non-stocked
Agriculture	AG	199	Non-stocked
Urban/Developed	UB	199	Non-stocked
Dune	DU	199	Non-stocked
Wet Meadows	HJ	7	Wet Grasslands
Tule-Cattail-Sedge	HT	7	Wet Grasslands
Annual Grass/Forbs	HG	3	Plains Grasslands
Unknown Grass	GR	3	Plains Grasslands
Pickleweed/Cord Grass	HC	3	Plains Grasslands
Perennial Grass	HM	6	Prairie-Tall Grass
Low Sagebrush	BL	9	Sagebrush-Moderate Shrub Cover
Basin Sagebrush	BS	9	Sagebrush-Moderate Shrub Cover
Buckwheat (White Sage)	SB	9	Sagebrush-Moderate Shrub Cover
Sage	SP	9	Sagebrush-Moderate Shrub Cover
Califronia Sage	SS	9	Sagebrush-Moderate Shrub Cover
Bitterbrush	BB	12	Chaparral-Moderate Shrub Cover
Rabbitbrush	BR	12	Chaparral-Moderate Shrub Cover
Saltbush	BC	12	Chaparral-Moderate Shrub Cover
Montane Mixed Chaparral	CX	12	Chaparral-Moderate Shrub Cover
Upper Montane Mixed Shrub	CM	12	Chaparral-Moderate Shrub Cover
Ultra Mafic Mixed Shrub	C1	12	Chaparral-Moderate Shrub Cover
Desert Buckwheat	DB	15	Desert Shrub-Moderate Shrub Cover
Mixed Desert Shrub	DX	15	Desert Shrub-Moderate Shrub Cover

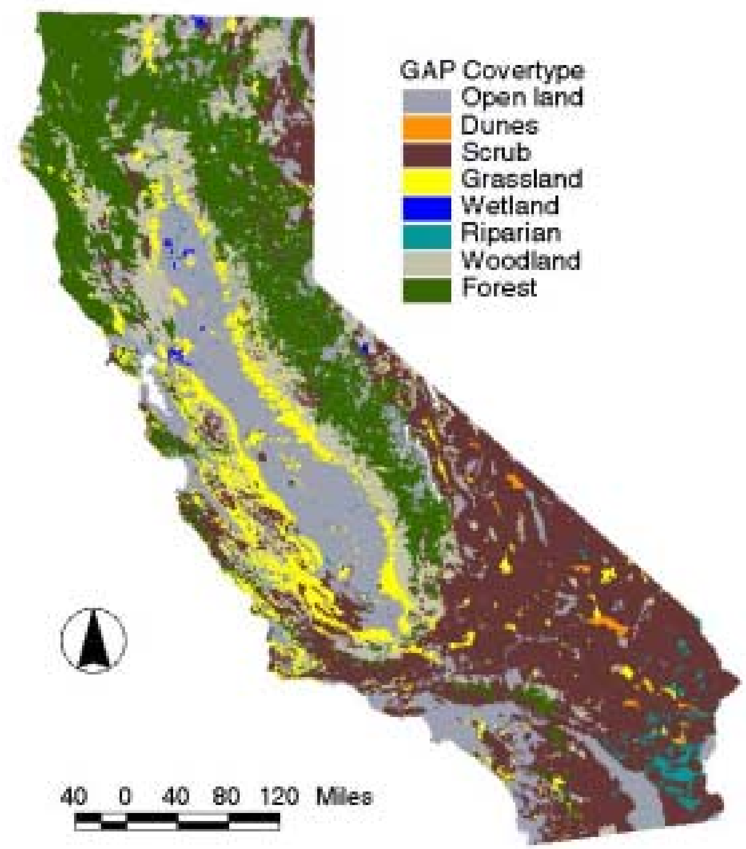
Original CALVEG "tiles" for the Siskiyou county area were provided to us in the UTM Zone 10 projection. We were obliged to conflate the layers into a unified coverage and then reproject to the State standard Teal-Albers projection. Due to imperfect boundary matching of the tiles, resulting in "holes" between the coverages, additional processing was required to assign values to gaps between the tiles. The CALVEG coverage for Siskiyou County is shown below.



This layer may not be appropriate for estimating emissions from a fire that occurred before the source data was collected. In addition, this coverage is not conterminous for the state of California and is therefore incompatible with an EES designed to function consistently statewide. For these reasons, we examined several alternative vegetation sources such as CALVEG77 and the GAP dataset.

2.4.2. GAP

The GAP vegetation dataset was developed by the Geography Department of the University of California at Santa Barbara (UCSB) for the California Department of Fish and Game. It was compiled from multiple sources, primarily relying on 1990 Landsat Thematic Mapper data. Its primary purpose was intended for the evaluation of wildlife habitat and land conservation. The GAP coverage for the State of California is shown below.



We used the GAP data set as the statewide vegetation layer for the EES. The significant advantage of the GAP coverage is that it is conterminous over California. The data set is less spatially heterogeneous than the CALVEG coverage with approximately 21,000 polygons over the entire state. Indeed the published minimum mapping unit is 100 hectares (one square kilometer or 247.1 acres), 100 times that of the CALVEG coverage. However, there is additional information about “secondary” and “tertiary” cover types stored in the attributes of the data set. Each polygon has attribute fields that identify three present vegetation types and a percent cover for each. Thus, a large polygon may be decomposed into simple acreages of constituent vegetation. In order to use this information we developed an alternative GAP processing module that reads primary, secondary and tertiary vegetation types from the attributes. We then computed emissions based on the relative percentages of the three.

This more intricate "alternative GAP processing" was used only in the preliminary vegetation comparison (section 3.2.1). The standard GAP processing module assumes 100% cover of the primary vegetation type in the attributes and is employed in the desktop interface, the web interface and the FOFEM parameter comparison of the workstation interface,.

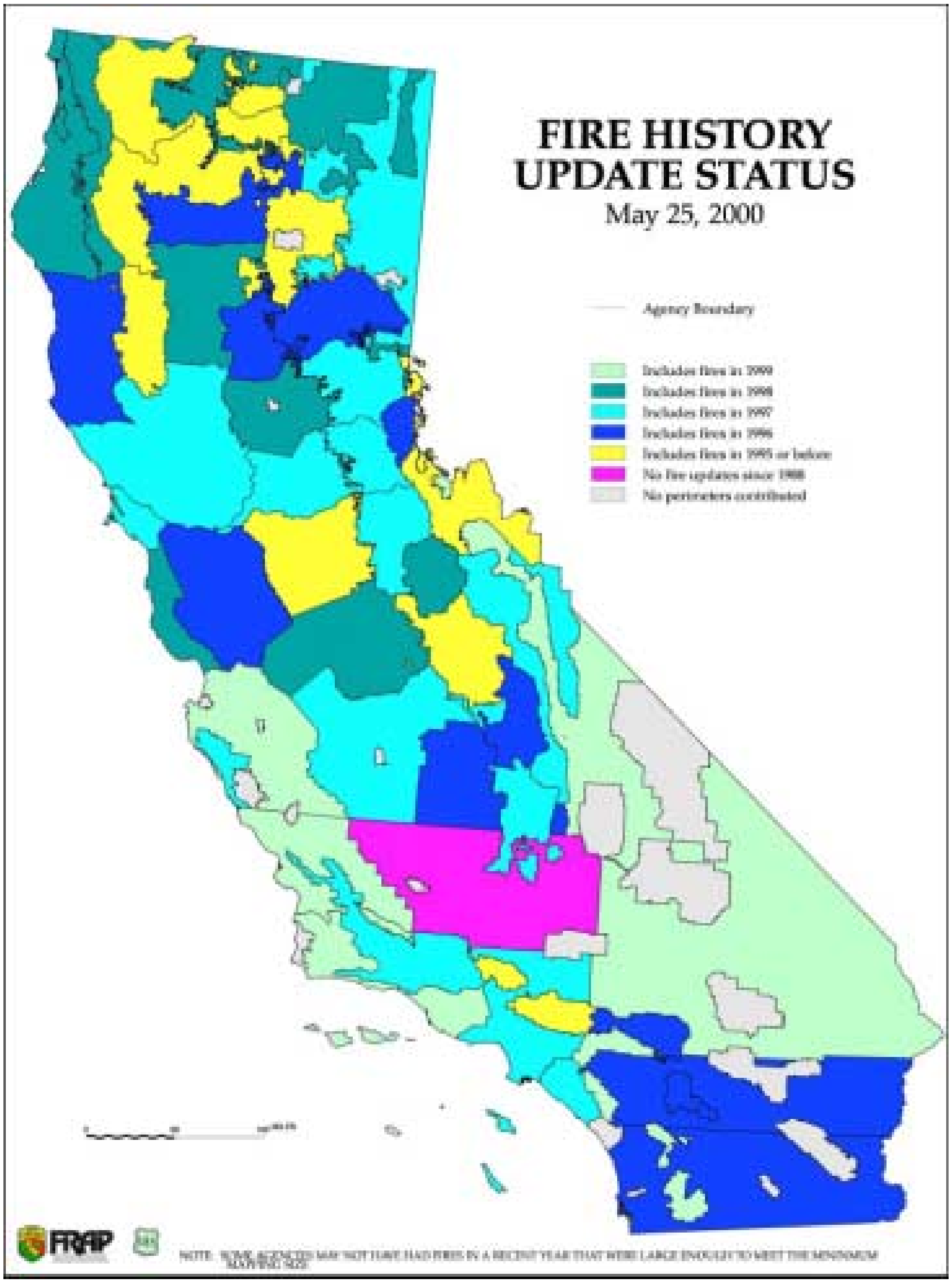
A disadvantage of the GAP vegetation layer, in terms of its input to the EES, is that it classifies vegetation according to the Holland (or California Natural Diversity Database) system. Unlike the CALVEG coverage, there is no direct crosswalk to the SAF/FRES system that is used by FOFEM. Rather than generate a crosswalk from the Holland system to the SAF/FRES system, we simply assigned FOFEM fuel models directly to the Holland vegetation types represented in the GAP dataset. This avoided compounding two new translations, one from Holland SAF/FRES then another from SAF/FRES to the fuel models used by FOFEM.

The new GAP-FOFEM crosswalk is almost entirely species based, though the relationship between Holland and FOFEM fuel models is many to one. For that reason, there was not always a direct species to species relationship and we were obliged to assign a fuel model based on genus, family, or ecological characteristics of the Holland community type. Additionally, we used the existing table of FOFEM fuel model assignments to SAF/FRES system to guide our decisions. This relationship is shown in **Table 4**.

2.5. CDF fire history data

2.5.1. Data product available from CDF

The CDF provided a polygon coverage of fire boundaries from the early 1900’s to 1998. This coverage was compiled from diverse sources including CDF itself, Forest Service, National Park Service, and the Bureau of Land Management (BLM). The dataset is not comprehensive, with very little data from central valley and BLM lands. This dataset is also at varying stages of update. The status of the data by region in California is shown below.



From the original CDF Fire History coverage, we created shapefiles of polygons for specific years or ranges of years. Examination of these subsets of the fire history data revealed that they included polygons outside of California. We spatially amended the fire history data by removing any fire polygons that were not entirely within the boundary of California. This fine-tuning was necessary to avoid run time errors in the GIS software.

2.5.2. Parameters extraction

In the attributes of the CDF fire history dataset is a field that represents the year and date of each fire. We used this field to create smaller data sets by year. We also determined the season of occurrence by parsing the month from the date field. Seasonality is an input to the EEE called "season of burn". The content of the date field is inconsistent, with some fires specifying year only and other fires having values of "0", "99990000" and other non-sensical dates. In the analysis we included only fires that clearly could be classified by year. For fires that included year yet did not have a month specified in the date field, we assumed a burn season of "fall". It is therefore conceivable that some fires mapped in the database were effectively excluded from the analysis. But given the facts that we could not rationally assign them to a specific year and that they may have occurred outside the temporal domain, we assume potential effects on the analysis to be minimal.

The CDF data also includes a field containing an "incident number" (although this field is incomplete for some fires). According to staff at CDF, this field should allow us to link to an "Emergency Activity Database" that may provide additional information about fire characteristics. This supplemental information might provide a way to determine fire parameter inputs to the EEE that reflect actual field conditions at the time of the fire. Currently, the system relies on user input to determine these parameters.

2.6. Remote sensing fire history data

2.6.1. Remote sensing based fire mapping

A major component of this research contract was to produce a method for remotely sensed fire mapping. We identified a method in keeping with the goals of the entire project: consistency and statewide application. We identified algorithms, collected raw data and created a prototype fire mapping system.

Statewide and consistent data is obtained at little or no cost from the National Oceanographic and Atmospheric Administration (NOAA), U.S. Department of Commerce. Their Advanced Very High Resolution Radiometer (AVHRR) sensors are mounted on a handful of polar orbiting satellites. Generally speaking, each AVHRR equipped NOAA satellite visits the same place on the earth once a day. Each satellite image, or "scene", records five spectral bands of information at about a one kilometer horizontal resolution. Fortuitously, raw AVHRR imagery for the last decade and a half are archived at NOAA. Intended for weather observation, several researchers across the world have turned AVHRR data into a resource for fire detection.

The two fundamental strategies for fire mapping are fire hotspot detection and fire burn scar detection. Hotspot detection involves detecting the heat from the fire. The tactic is to utilize the thermal infra-red channels from AVHRR to sense high heat that can be attributed to fire. Burn scar detection is to monitor the greenness of the surface and note the areas that suddenly turn black. Both hotspot detection and burn scar detection are active research topics in the remote sensing community. One of the leaders in the field is Dr. Zhangqing Li of the Canada Centre for Remote Sensing (CCRS). Dr. Li and his researchers are pioneering a method to combine hotspot and burn scar detection for the fire mapping of Canada's boreal forest. The essence of Dr. Li's approach is to do both a hotspot and burn scar detection independently then combine those results. The innovative post-processing algorithms keep burn scar polygons that have a hotspot within them and also edit the perimeter to include any supplementary hotspots.

In our research we have adapted Dr. Li's algorithms for ARB's use over California. The main challenge in doing so lays in the physiographic differences between California and Canada. The land cover of California is considerably more heterogeneous than the Canadian boreal forest. The models were re-calibrated as best as possible for California.

2.6.2. AVHRR based fire mapping methods

What we have achieved is a method for estimating what is burning each day and built that into a fire history map. Our remotely sensed fire mapping system for California has four main steps: 1) AVHRR data preparation, 2) Hotspot detection, 3) Burned area mapping by hotspot detection coupled with burn scar detection, and 4)Post-processing of image data for integration with GIS and the EES. We have scripted all the steps in PCI Geomatics brand image processing software.

The first step of data preparation includes downloading relevant scenes from NOAA's Satellite Active Archive (SAA). PCI Geomatics software can ingest the raw formatted SAA data. A module of PCI automatically performs radiometric correction, radiometric calibration, and initial geometric correction. The coarse geometric correction, or geo-referencing, results with a positional error of approximately five kilometers. We reduced this error using a finer CHIP based geometric registration process. CHIPs are small consistent and distinct areas of an image. They are a conspicuous group of pixels that, save for cloud cover, we would expect to see on every daily scene. Corners of the coast and lakes are examples of natural features that render good image CHIPs. We included a couple dozen of these "points" in a chip database along with their precise coordinates as determined from topo maps. PCI includes a semi-automated interface to match CHIPs in a roughly corrected scene then goes on to fine tune the image position. The successful match of simply ten chips spread across the state achieves a good registration of around one kilometer.

The second step of hotspot detection is defined as the process of identifying and delineating areas that are on fire. There are four models invoked to map these areas. The premise is to identify what pixels could possibly be on fire then eliminate ones deemed to be false hotspots. The fire detection model invokes multiple thresholds to identify a *potential* hotspot pixel. The radiometric thresholds attempt to identify what phenomena the satellite is sensing. For instance can we say there is a fire or is it just a highly reflective cloud? Subsequently, a contextual algorithm is applied to remove lone hotspots. These isolated pixels are unlikely some small burning fire but rather noise in the image. Lastly a boundary mask model clips out the forested areas of the state. The hotspot detection not calibrated for agricultural and urban areas because those areas are not in our study domain.

The final step is to generate a burn scar map and use the prepared hotspot detection to verify it. A burn scar map is based on the normalized difference vegetation index (NDVI). NDVI calculations are well established in the remote sensing literature. NDVI could be called a measure of greenness; that is the higher the NDVI of the remotely sensed pixel the more green the foliage on the ground. A cloud free composite is built from ten daily AVHRR scenes then the average NDVI calculated. Composites were produced for every two weeks. Subtracting one composite for the next yields the NDVI differencing for each two week period. If the differencing reveals an area suddenly changing from green to black, the formation of a burn scar is possible. The potential burn scar map undergoes a thinning much like the hotspots; eliminating pixels that have not changed significantly relative to others. Burn scar patches are ultimately confirmed if they coincide with a hotspot.

This burn scar map is output from the PCI software as a georeferenced image. In order to integrate this information with other data in the GIS, for the purposes of emissions estimation, it is necessary to convert the data. We created an Avenue script for this process. The script converts the image to a grid, projects the grid to Teal Albers coordinates, eliminates redundancy in fire perimeters between months, and converts the data to vector format. The end product is a layer of fire polygons, classified by month of burn, similar to the fire history coverages created by CDF.

We applied this method to California for the months of July through October, 1999. We consequently have a fire history map identifying the perimeter and date of each fire. There is no CDF analog for these data as CDF has not yet produced a fire history coverage for 1999. Ironically, AVHRR data for California is not yet available to us for the 1998 fire season and before. While there is no technical impediment to processing the remotely sensed data with the EES, we did not run the remotely sensed fire polygons through the EES due to lack of validating data from CDF.

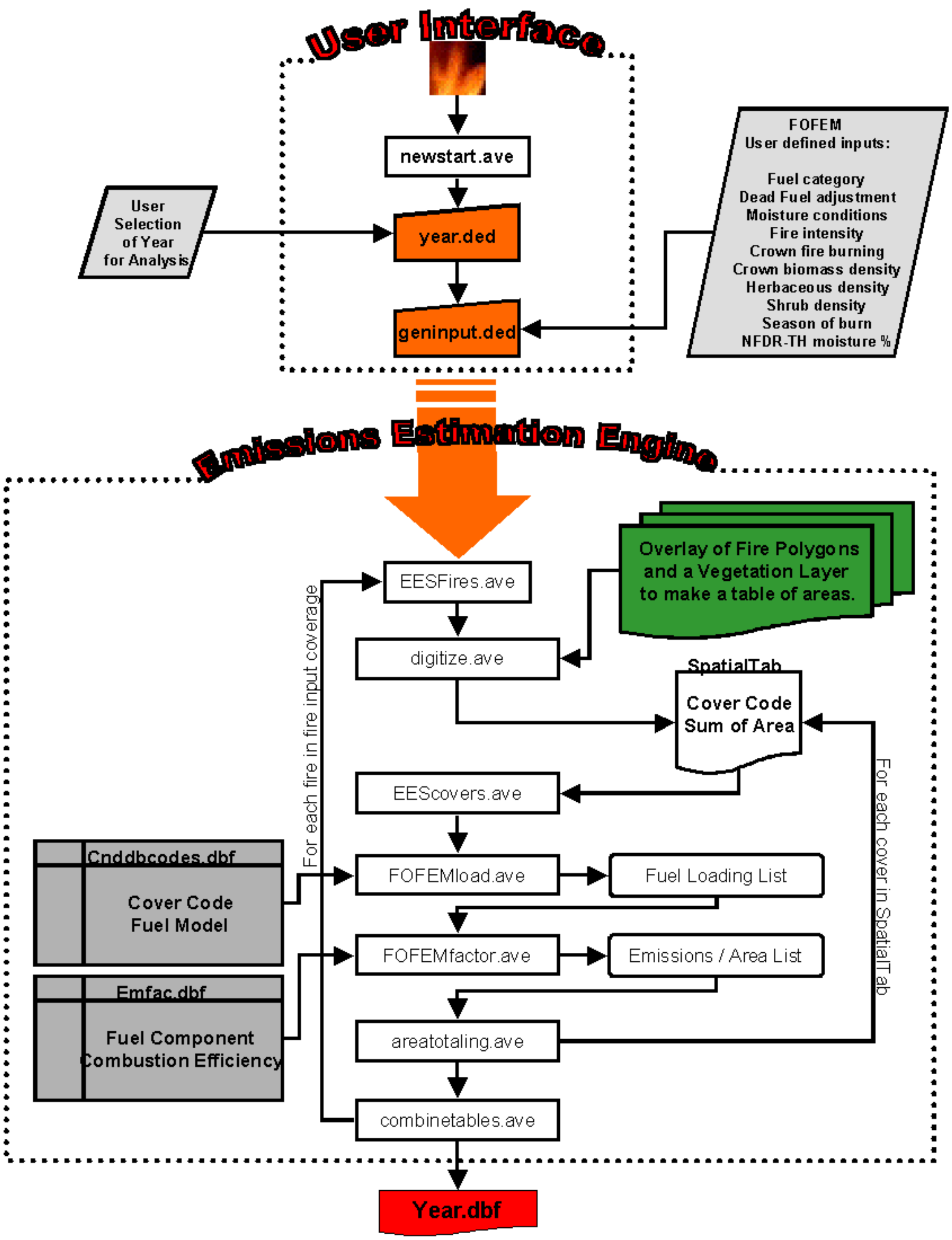
2.7. How the modules fit together in an emissions estimation system

2.7.1. Basic linking of modules

The modules of the EES (fire layer, vegetation layer, EEE, interface, and associated relational tables) are linked together by Avenue scripts in ArcView and, in the case of the web interface, Javascripts. In this way, the scripts accept non-spatial burn parameter inputs, then perform an overlay operation with a fire perimeter polygon and the vegetation layer, clipping the vegetation polygons with the fire perimeter. Another set of scripts iterates through each vegetation type in the fire polygon, evaluating the vegetation type according to the corresponding fuel model in FOFEM. The EEE then iterates through each fuel component in the vegetation type, determining pre-burn fuel loading, fuel mass consumed by the fire, combustion efficiency and emissions created. In the event that the fire boundary module consists of a data layer composed of many polygons, the scripts repeat the above processes for each polygon in the fire input. In the case of the web interface, the user designates only a single burn polygon, so there is no iteration with respect to the fire module.

The interface module is designed to customize how the user interacts with the EES. The desktop interface allows the user to choose the various burn parameters that will be evaluated for any year between 1990 and 1998, and outputs a table of emissions estimates in dBASE format. The web interface operates over the internet, allowing input of the same burn parameters, but produces a table of emissions estimates for only a single burn polygon which the user defines. Javascripts coordinate the EES and the display of information as HTML.

The modular structure of the EES is shown below. This chart details the flow of information between the modules and illustrates how the implementation of the modules occurs through the desktop interface. The structure is slightly different for the workstation and the internet, but the fundamental architecture remains consistent between the various interfaces.



The desktop EES outputs a table of emission estimations. The table contains emissions masses for each fuel component, for each cover type, for each fire that is part of the input coverage.

2.7.2. Ability to iterate over the modules

The workstation interface operates in a slightly different way, by iterating through multiple "incidences" of the EES, that is, multiple module configurations. Inputs to the system, both spatial and non-spatial, are received from a table. Each row of the table specifies a fire module, a vegetation module, a crosswalk sub-module, a vegetation processing type (a switch between alternative and standard GAP processing), and the non-spatial EEE burn parameter inputs. This interface facilitated a comparative analysis designed to identify how emissions estimates vary by vegetation input and by each individual burn parameter. In order to compare these configurations, we compiled a set of default values as follows:

Module / Parameter	Value
Vegetation layer	GAP
Fire layer	CDF
Vegetation processing	Standard (GAP primary type only)
Fuel conditions	Natural
Dead fuel loading	Typical
Moisture conditions	Very dry
Fire intensity	Extreme
Crown burning	Yes
Crown biomass loading	Typical
Herbaceous fuel loading	Typical
Shrub fuel loading	Typical
Regeneration fuel loading	Typical
NFDR-TH moisture percent	20%

3. Results

The results of our analyses using the EES are intended to elucidate the function of the system with respect to various inputs, spatial and non-spatial. The purpose of this section is to examine how the system responds to various configurations. The resultant emissions inventory will vary according to the inputs to the system. In order to produce the most consistent and accurate system output, it is beneficial to understand the function of the system. Through this process, it is possible to identify the best system implementation in terms of configuration and input.

3.1. Processing of system output

The raw output data from the EES are in the form of a table of CO, PM_{10}, and $PM_{2.5}$ emissions values for each fuel component, of each vegetation type, in each fire. To generate the information necessary for various types of analysis, we developed more Avenue scripts to summarize, reorganize, and spatially allocate the raw data. The first step in the summarization process invokes a script that summarizes the raw data by fire to create a table of total emissions and fire identification numbers corresponding to the input fire polygons. Using the fire identification field, we joined the total emissions table to the fire polygons such that the pollutant masses are attributes of each fire polygon.

The information about whether a fire was wild or prescribed is present in the original attributes of the CDF fire coverage. We assumed prescribed fires to have 'Cause' code of 14 or greater. This includes fires described as: prescribed, VMP, Range Improvement Burns, Escaped Prescribed Burn, and Management Ignited Prescribed Fire. We distilled this information in an additional field containing only two values, wildfire or prescribed.

To generate information about the allocation of a fire in terms of air basin or county, we created another script. This script determines the political district of a fire by generating centroids of fire polygons, then performing point in polygon overlays of the centroid coverage with air basin and county coverages. The script outputs this information as a table of fire identification number, air basin, and county. We joined this table to the attributes of the original input fire polygons.

Through this series of joins and summarizing scripts, we enhanced the original attribute table of the input fire coverage with our emissions estimation analysis results. In this improved table, each fire has information describing where it is located, what type of fire it is, total emissions for the three pollutant categories, as well as the original information including area and incident number. We used Microsoft Excel (the Pivot Table Wizard) to summarize this large table by county, air basin and fire type. This table, the amended attributes of the fire coverage, is the synthesis of results from the EES and auxiliary Avenue scripts. It is the compilation of information produced from our system and represents the most up to date, comprehensive emissions inventory we have produced. This information can be generated for 1999 and 2000 upon the creation of a complete fire polygon coverage for these years.

In order to elucidate the effect of the model configuration on model output, we used the workstation interface to run multiple "incidences" of the EES, each corresponding to a unique module combination or input parameter scenario. We created an Avenue script to summarize the raw emissions data by fuel component. In this way, we determined the total emissions from all fires in the input coverage by particular ecosystem element. This allowed us to evaluate the "ecology" of the model in terms of how burn parameters and vegetation classification systems affect emissions estimates for live and dead fuel components.

3.2. Preliminary comparative analyses

As an examination of the effects of vegetation layers and the EEE parameters, we produced emissions estimates for 19 fires in Siskiyou County (totaling 23,522 acres) between 1990 and 1998, and for 102 fires (88,940 acres) over all California in 1998 using default configurations. Neither of these fire boundary layers is comprehensive in terms of the original fire history database. This is due to the fact that some of the fires in the selected time frames occurred completely or partially outside California. However, for the purposes of this analysis, the actual arrangement of fires is irrelevant. These analyses are designed to compare the overall effect of varying *inputs and parameters* on the resultant emissions inventory. The fire history data layer is the controlled constant between the scenarios and its absolute accuracy is thus unnecessary.

3.2.1. Analysis of Siskiyou County – Vegetation

In order to compare the effect of different vegetation data inputs and processing on the results of the EES, we computed emissions estimates for the same 19 fires using three different model configurations. We performed three iterations over the same fire history input: using the GAP vegetation layer as input and standard processing (primary cover type only); using GAP vegetation and alternative processing (primary, secondary and tertiary cover types – see section 2.8.2); and using the CALVEG vegetation data layer as input.

Using default parameters and the standard form of processing the GAP dataset, the EES estimates that for 19 fires between 1990 and 1998 in Siskiyou County, 46,751 tons of emissions were produced. These results, further decomposed into fuel components and pollutant categories, are displayed in **Table 6** in Appendix D. The GAP standard processing emission totals are intermediate between the totals for the alternative form of GAP processing and the totals from the CALVEG vegetation, which produced the lowest estimates of the three configurations. This is a function of differences between the coverages in abundance of different vegetation community types.

The three configurations differ in how emissions are estimated from the various fuel components. For example, CALVEG shows 452% more emissions from the shrub component than the standard GAP, or default configuration. This is likely due to the greater spatial heterogeneity of the CALVEG coverage, which is more likely to represent small patches of chaparral and other shrub communities that are distributed through a matrix of forest and woodland vegetation types. The duff and large woody debris (thousand hour fuels, or dead fuels larger than 3 inches diameter), components that are more abundant in arboreal systems, are the largest sources of emissions. Because CALVEG estimates 63% less large woody emissions and 36% less duff emissions than GAP, the estimate for total emissions is below the estimates produced using the GAP data.

The alternative processing of the GAP vegetation produces the highest emissions estimates. This process evaluates each polygon in terms of the dominant cover type, as well as other cover types in smaller percentages. The large woody debris and the duff are again the components responsible for the discrepancy with 21% and 5% more emissions (respectively) than the GAP defaults. Despite decreases in emissions estimates for other fuel components, the large mass produced by the duff and woody debris accounts for an elevated estimate.

3.2.2. Analysis of entire state – FOFEM parameters

Similar to the comparative analysis for the vegetation inputs, we produced an array of emissions estimates using the same fire history inputs, the same vegetation inputs and processing (standard GAP), but varying the input parameters for the EEE. We evaluated 102 fires from all of California in 1998. From the original CDF data for 1998, we excluded 19 fires that overlapped or were completely outside the California boundary. For this reason, the results may slightly underestimate total emissions for 1998. We varied each EEE input while holding the other inputs constant. These results are displayed as **Table 7** in Appendix D.

The EES results showed the most deviation from the default emission estimates is by varying the National Fire Danger Rating - thousand hour (NFDR-TH) fuel moisture input by 10%. The NFDR-TH moisture percentage extremes of 10% and 30% represent 100% and 0% consumption, respectively, of the affected fuel components. The affected components, duff and large woody debris, also tend to be the largest contributors of emissions. Hence the estimate of total emissions is most sensitive to fluctuations in duff and large woody consumption.

In a similar way, the EES is sensitive to variation in the dead fuel loading levels. The dead fuel loading input of “light” or “heavy” adjusts loadings in the fuel models, which are “typical,” by coefficients. The percentages by which the fuel models are adjusted are illustrated by the percent change in emissions shown in **Table 7**. Unlike the variation resulting from NFDR-TH values, which alter consumption, the dead fuel input affects pre-burn loadings. The rates of consumption are the same as the default parameters.

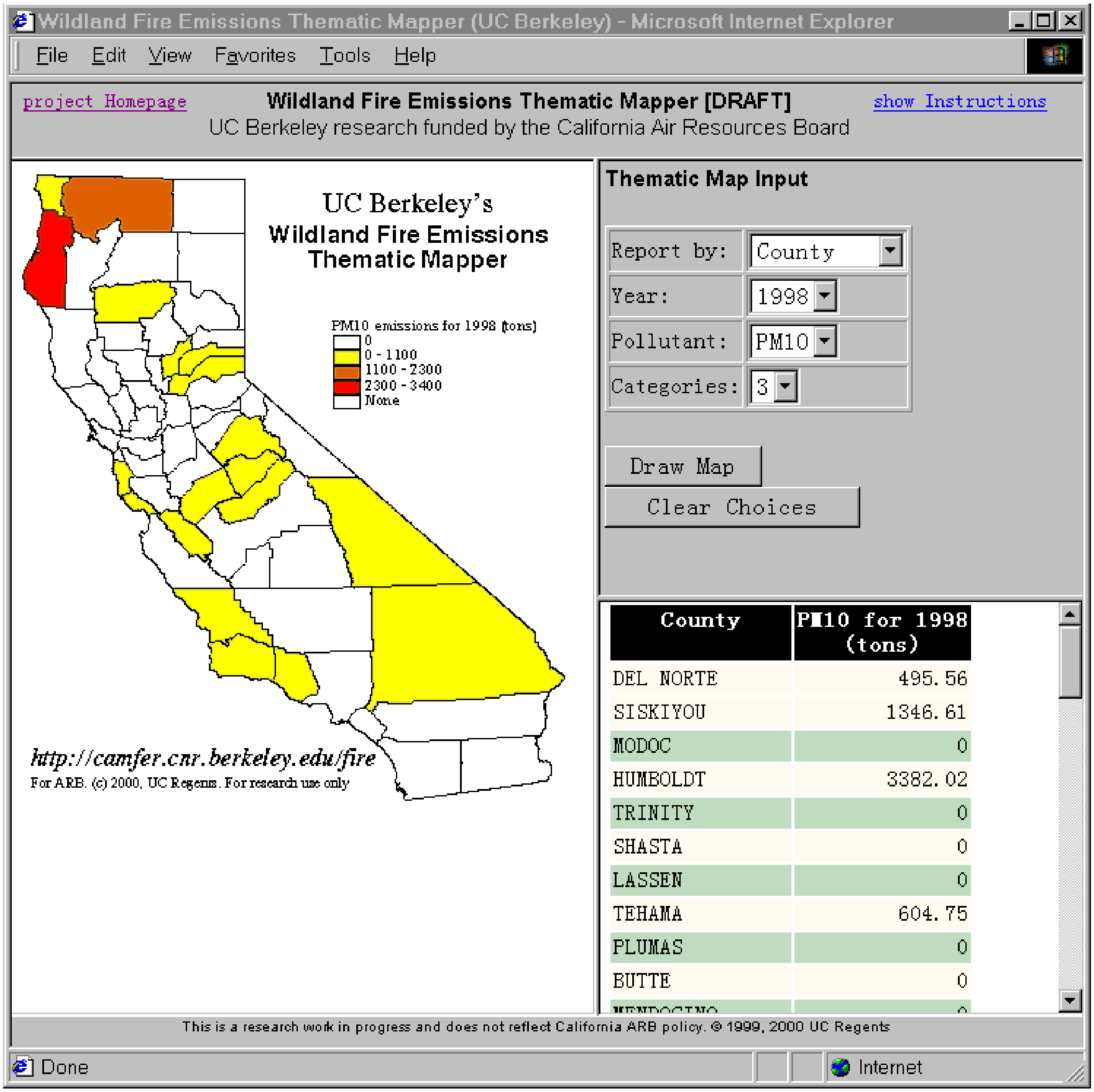
Live fuel adjustments also affect pre-burn loadings, but are not computed with coefficients. Rather, the “sparse”, “typical”, or “abundant” live fuel loads are set based on values already present in the fuel model, the input determining which value from the fuel model to use rather than how a value in the model should be adjusted. Variation of this input results in less than 10% deviation from the default emission estimates, a much smaller change compared to the dead fuel and NFDR-TH deviations of greater than 50%.

Elimination of crown burning from the estimates is also small at 6.9% total deviation from the defaults. This is consistent with the effects of the other “live” fuel parameters, crowns being a form of live fuels. (This effect would be much more pronounced if the CALVEG vegetation input were used since CALVEG would estimate approximately 200% more emissions from crown biomass than GAP)

Variation resulting from the moisture condition input is not a function of either fuel loading or fuel consumption, rather from combustion efficiency. The moisture condition input of “wet”, “moderate” or “dry” refers to the coefficients used to convert consumed mass to carbon monoxide and particulate emissions. Overall, wet conditions result in more emissions due to reduced burning efficiency. For large dead woody fuels, with increasing wetness more of the fuel component is assigned by FOFEM to the smoldering phase. So Table 7 shows increasing emissions with wetness for "Wood 3+ inches." However, for duff, with increasing wetness FOFEM apportions more of the fuel to the flaming phase, so that emissions from duff decrease with increasing wetness. This parameter has slightly more effect than the live fuels, with 18% more emissions predicted in “wet” conditions, but still considerably less effect than varying the consumption and loading of duff and large woody or other dead fuels.

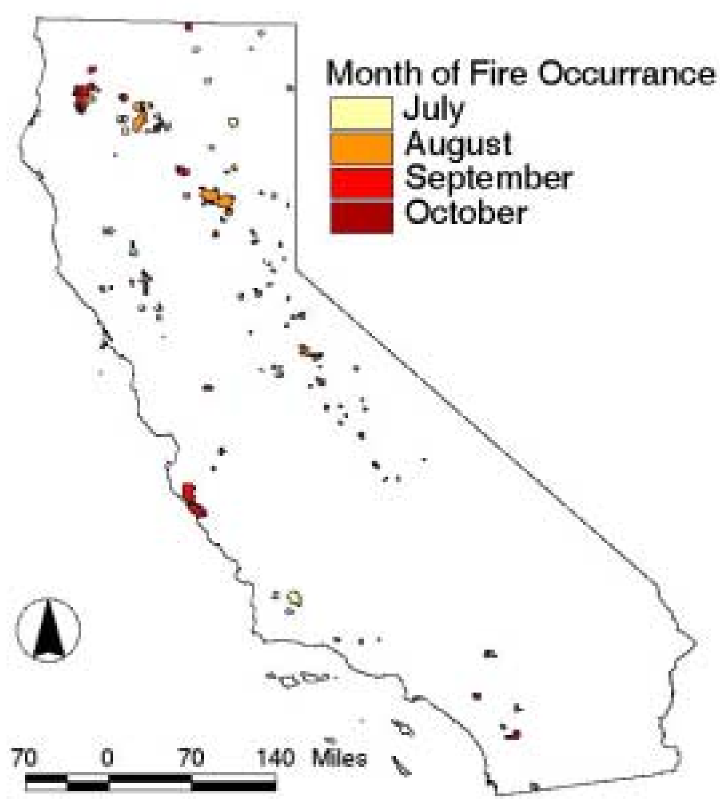
3.3. Preliminary statewide emissions inventory – CDF fires and GAP veg, 1998

The analysis results for all of California in 1998, computed using the default parameters, are shown in **Table 5 and Tables 5b** in Appendix D. Totals for the entire State are displayed in bold at the bottom of the table. For example, the model shows that of the 113,107 tons of PM_{10} emitted, 89.6% were from wildfires. This table also contains more detailed and specific data. It summarizes emissions by emission type (PM_{10}, $PM_{2.5}$ and CO), by emission source (prescribed or wild fire), and by acres burned. These data are reported for both counties *and* airbasins. These data could also be reported graphically, as a thematic map. The following image displays an interactive thematic mapping website, capable of displaying data by county and airbasin for the year of choice. This website is still under development.



3.4. Remote Sensing of Fires – 1999 Selected Months

Preliminary results of fire mapping with remotely sensed data are shown in the map below. These data are polygons for four months of the 1999 fire season. Because CDF is in the process of updating the fire occurrence map, the remotely sensed polygons represent more recent fires. For lack of ground truth information, verification of the remotely sensed data has not yet occurred.



1999 Fires as polygons. We created this shapefile by processing remotely sensed information as images with one kilometer resolution. The burn polygons can be directly input to the EES but are not validated by CDF data.

4. Discussion

The result of this study should be seen as much more than static data. We developed a dynamic and flexible system for producing consistent and detailed information about emissions. The fact that inputs and outputs to the system are spatial is a characteristic that improves on past methods of estimating emissions. The main advantage being that estimates are site specific and based on real data. For a comparison to past emissions estimation protocols, we examined CARB estimates for CO and PM_{10} emissions from Siskiyou county in 1996.

4.1. Siskiyou County 1996 emissions

CARB currently estimates that 4694 tons of CO and 921 tons of PM_{10} emissions were produced by 4374 burned acres, with 3717 acres in "timber and brush fires." The CDF fire history coverage shows only two polygons, totaling 385 acres, in Siskiyou county in 1996. The GAP vegetation layer has these polygons classified as "agricultural land," a vegetation type that does not produce emissions in the EES. Thus, our standard processing technique, which was used for the statewide analysis of 1998, indicates zero emissions for Siskiyou county in 1996. Employing the alternative GAP processing (using secondary cover types from the attributes) would result in emissions from only 30% of the area in the two polygons. In order to obtain emissions estimates for these two polygons, we used the CALVEG layer as input. This analysis shows 80 tons of CO emissions and 8 tons of PM_{10} emissions.

This comparison reveals large discrepancies in output between the EES and conventional CARB protocols. The obvious reason for the lack of agreement is in the "missing" 3990 acres from the CDF fire history input coverage. Since 319 acres of the two fires occurred in grassland types (according to CALVEG), we compared per acre emissions estimates from the EES to per acre estimates for the CARB "grass and woodland fires" category. The two systems show similar estimates for per acre values in equivalent cover types. The EES estimates 0.21 tons per acre for CO and 0.02 tons per acre for PM_{10}. CARB estimates 0.1 tons per acre for CO and 0.02 tons per acre for PM_{10}. These data are illustrated in Table 8, below.

Table 8: ARB vs. UCB-EES Emission Estimates
For calendar year 1996, Siskiyou County

	Area	*Emissions (tons)*		*Emissions (tons/acre)*	
	Acres	*CO*	*PM 10*	*CO*	*PM 10*
ARB - "grass and woodland"	657	66.4	10.32	0.10	0.02
ARB - "timber and brush"	3717	4627.7	910.8	~	~
ARB - TOTAL	4374	4694.1	921.16	~	~
UCB-EES (GAP)	385	0	0	~	~
UCB-EES (CALVEG)	385	79.9	8.1	0.21	0.02

4.2. Sensitivity

The modularity of the system allowed us to experiment with how system configuration influences output. The various configurations we examined indicate that the choice of vegetation input can affect the emissions estimates by about 10%. Output can be affected by as much as

70% through variations in the thousand hour fuel moisture (NFDR-TH) value input. The results also fluctuate by more than 50% with changes in default fuel loadings. This is a high amount of sensitivity to moisture conditions and other inputs. Currently, these parameters are user defined. Using measured, spatial inputs (such as meteorological data) for these parameters could improve the accuracy and reliability of the emissions estimates.

The advantage of the UCB EES is in its transparent methodology. Variability in output can be adjusted by changing both spatial and non-spatial inputs. This flexibility can be used to calibrate emissions to validation data or to other emission estimation systems. The content of the output is designed to maximize the functionality of the EES. By including data from intermediate steps of the analysis in the output, the mathematical assumptions of the system are revealed. In addition, the output retains a large amount of information, insuring that more users will find utility in the system. However, expanding the capabilities of the system, in terms of producing information, also has the effect of increasing the effort required to distill relevant statistics, from a management perspective. The immense amount of data produced essentially precludes development of a simple reporting routine that can simultaneously meet the needs of multiple users.

5. Conclusion

The EES we developed is far more sophisticated than ARB's conventional method of estimating emissions. The system transcends the use of merely two multipliers: acres and emission factor. The EES accepts complex inputs describing fuel loading of multiple ecosystem components, consumption rates, and combustion efficiency. The EES iterative processing produces comprehensive output tables that provide a wealth of information previously unavailable in standard spatial database format.

However, the validity of this plethora of data has yet to be fully tested. Validation of the output through comparison with real, measured emissions is essential to verify the legitimacy of the emissions estimates. A comparative analysis is necessary not only as verification that the data are indeed reflective of realistic emissions, but also as a calibration of the system. In this way, input parameters and even internal algorithms can be adjusted such that the system is more accurate relative to actual burning and smoking conditions.

Another way to improve accuracy and reduce uncertainty is to make more inputs based on remotely sensed or measured spatial data. Images of ten kilometer resolution NFDR-TH dead fuel moisture maps are displayed online at the Forest Service's Wildland Fire Assessment System site (www.fs.fed.us/land/wfas/welcome.htm). Information about live or dead fuel loadings might be derived from remotely sensed data about plant density, stocking or distribution. These data could replace the user input of FOFEM nominal fuel loading parameters, basing these values, instead, on the input of additional data layers.

The quality of the output is a function of its accuracy and its utility. For air quality managers, the data must be capable of synthesis with other air pollutant layers. Standardizing the format of the output in terms of temporal resolution, spatial resolution, data structure (vector or raster), attribute content, and scope would be a first step in the creation of a unified spatial database of emissions. Currently, the output exists as a relational database table with spatially referenced emissions estimates. To leverage the value of the information to decision makers, it needs to be combined with emissions from other sources (biogenics, agricultural burning, domestic and commercial burning). This would not only put the data in context, from an air quality perspective, it would simplify the issue of how to report and synthesize data from multiple emission estimation systems.

The issue of reporting is essentially separate from the problem of how to produce accurate emissions estimates. Different individuals will demand different summary types and contents depending on their particular needs. The immense volume of data in the output of the EES results in many permutations of summary and format type. The issue of how to extract information becomes even more critical with the inclusion of many layers of emissions from diverse sources. Solutions to this problem should be engineered with database software that accepts spatially referenced and standardized data sets. We have designed the EES to produce a large amount of data in order to retain its utility for many tasks. The EES output exists in a logical format that is ready for synthesis with other spatial data in a unified reporting system.

Clearly, there are distinct directions for ongoing research in emissions estimation. The creation of a more complete system for assessing air quality will rely on the refinement of existing systems and the incorporation of additional technology for other emissions types. The dynamic nature of this science makes the flexibility of systems very important. The EES we present is capable of evolution and synergy with other systems to produce a unified framework for statewide air pollution assessment and monitoring.

6. Bibliography

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7. Appendixes

7.1. Appendix A: The Emissions Estimation System Conceptual Model

This conceptual model is a graphical representation of our model framework. It is intended as an overview to the project as a whole as well as a detailed documentation of model flow.

The conceptual model is presented in a web interface encoded in the hypertext markup language (HTML).

Access the concept model using a web browser such as Microsoft Internet Explorer or Netscape Navigator. Open the file by clicking on *starthere.html* in the directory */concept* of the companion CD.

7.2. Appendix B: The Desktop Emissions Estimation System

The Desktop EES is a software tool and compiled data. Specifically, it is an ArcView based collection of scripts, data, and output tools for wildland fire emissions estimation in California. Access the Desktop EES by opening the ArcView 3.2 project file called *ees.apr* in the directory */ees* of the companion CD.

The functionality of the Desktop EES is segmented into the following Views in the project:

7.2.1. Emissions Estimation System Desktop Tool

This view allows the Desktop EES to be launched. It contains the statewide GAP vegetation data, CDF fire history polygons between 1990 and 1998, counties and airbasins. Start the EES by pressing the fire button on the toolbar. A dialog box will be displayed that will allow FOFEM inputs and year of analysis to be set. By choosing a year, the user instructs the EES to produce emissions estimates for those polygons in the CDF fire history layer that represent fires in the selected year. When the selection has been made, press the 'OK' button. The EES will now display another dialog box that asks where the output file should be saved. This file will contain all the emissions information, fire type, location, and fire identification number. The fire identification number will allow the attributes of the fire history coverage to be joined to the EES output table. Select a filename and path for the output table, then press the 'OK' button. The EES will begin processing each fire polygon in the selected year. Be patient. The system will take a couple minutes to complete the analysis. When the EES is done, a report box will be displayed with grand totals for the year and the FOFEM settings used. These data can be selected and pasted into a text editor or word processor, if desired. The output table will then be displayed. It will show emissions for each fuel component, for each cover type, for each fire in the selected year. This is a permanent table on disk and can be manipulated or exported to produce summary information or other statistics. We created Table 7 (see Appendix A) by importing an EES output table to Microsoft Excel and creating a Pivot Table Report.

7.2.2. County Data Viewer: Siskiyou County

This view features the CALVEG dataset for Siskiyou County, California. Note the level of complexity of the data relative to the statewide GAP coverage.

7.2.3. Raster Data Viewer: Episodic Inventory

This view is the Raster Data Viewer showcasing short time-scale episodic event data. Each grid represents daily occurrences of hotspots over all of California. We isolated a selected conflagration in Trinity county from this data to create the animated episode displayed online at: http://www.gisc.berkeley.edu/~jscar/emissions/episode.html. The background of this view is a hillshade depicting topographic features.

7.2.4. Remotely Sensed Data Viewer: Statewide

This view displays two types of remotely sensed fire mapping data. Source data for these coverages are in the form of georeferenced images (.tiff format) created from 10 day composites of hotspots and burn scars. These source images are featured in the View. For analysis in a GIS, we converted the images to grids. Each grid represents one month of fire mapping data. Using an Avenue script, we created a single, polygon coverage of the four months data by overlaying the grids and eliminating overlap. This polygon layer is featured as the shapefile in the View. The hillshade is the background.

7.2.5. Statewide Gridded Emissions: 1998

The data in this view represent 1998 statewide emissions estimates as grids. Each grid represents a different pollutant type. We created these grids by joining emissions values to the attributes of the fire history input file, then converting the shapefile to a grid. We created three grids in this way, one for each emissions category. The background is the hillshade

7.3. Appendix C: Two Web Based Geographic Information Systems

7.3.1. The Web-GIS EES - for Detailed Emissions Estimation

This report delivers emissions estimation functionality via a world wide web based geographic information system (web-GIS). Access the Web-GIS Emissions Estimation System (Web-GIS EES) with a Java enabled web browser. The page is linked to the project homepage at URL:

http://camfer.cnr.berkeley.edu/fire/

The Web-GIS EES yields emissions estimates using the FOFEM emissions estimation engine, over the GAP vegetation dataset. The user manually digitizes a single fire polygon to the screen and also parameterizes the FOFEM model through a form interface. Emissions estimates are returned in a HTML table to a new browser window.

The map interface includes many cartographic enhancements including a shaded relief and reference information such as roads and political boundaries. The HTML interface enables users with limited computing resources to repeatedly run different computationally intensive emissions estimation scenarios.

7.3.2. Emissions Inventory Thematic Mapper - for Statewide Inventory Mapping

Also delivered in this contract is a statewide California internet mapping application. This second prototype web-GIS deploys the spatially explicit emissions inventory generated from the Desktop EES to the web.

This web-GIS does not require Java. The page is linked to the project homepage at URL:

http://camfer.cnr.berkeley.edu/fire/

This example web site is targeted to members of the public or air quality community looking for simply an overview of statewide emissions. The user selects the year and pollutant to map by either county or air basin. The web-GIS server generates a professional looking color thematic map. This custom map could be downloaded for print out or cited for reference in analysis.

This service exemplifies the modular software approach. This thematic mapper works in and independent yet complimentary fashion with the Desktop EES. ARB staff can use the Desktop EES to parameterize, generate, and critique an emissions inventory. This scientific process may be lengthy, use special ARB software and hardware, and generate a volume of data. But with the aid of scripts and the web-GIS, the results can be summarized and published to the web in a form the public can readily digest.

7.4. Appendix D: Tables

Table figures referenced in this document. Other tables appear in the body of the text.

Table 1: Relationship of SAF/FRES System to FOFEM fuel models

**created by the Forest Service, with italicized fuel models added by CAMFER*

Cover Name	Cover Code	Fuel Model Code	Fuel Model Name
White-Red-Jack-Pine	100	*121*	*Jack pine Natural*
Jack Pine (SAF 1)	101	121	Jack pine Natural
Red Pine (SAF 15)	102	131	Red pine Natural
White Pine (SAF 21)	103	141	White pine Natural
White Pine-Hemlock (SAF 22)	104	141	White pine Natural
Hemlock (SAF 23)	105	141	White pine Natural
Spruce-Fir	110	*61*	*ES-SAF Natural*
Balsam Fir (SAF 5)	111		
Black Spruce (SAF 12,204)	112	*151*	*Black spruce Natural*
Red Spruce-Balsam Fir (SAF 33)	113	*51*	*Blue spruce Natural*
Northern White-Cedar (SAF 37)	114		
Tamarack (SAF 38)	115	*101*	*Whitebark Pine Natural*
White Spruce (SAF 107,201)	116	*51*	*Blue spruce Natural*
Longleaf-Slash Pine (SAF 83)	120	401	Slash Pine (Age 10) Natural
Longleaf Pine (SAF 70)	121	391	Longleaf (Age 10) Natural
Slash Pine (SAF 84)	122	401	Slash Pine (Age 10) Natural
Lobolly-Shortleaf Pine (SAF 80)	130	441	Lobl Piedmont (15) Natural
Lobolly Pine Coastal (SAF 81)	131	421	Loblolly Coastal (2) Natural
Loblolly Pine Piedmont (SAF 81)	301	441	Lobl Piedmont (15) Natural
Shortleaf Pine (SAF 75)	132	201	Shortleaf pine Natural
Virginia Pine (SAF 79)	133	211	Virginia pine Natural
Sand Pine (SAF 69)	134	191	pond pine
Eastern Red-Cedar (SAF 46)	135		
Pond Pine (SAF 98)	136	191	pond pine
Pond Pine - Pocosin	25	571	pocosin
Spruce Pine	137	*51*	*Blue spruce Natural*
Pitch Pine (SAF 45)	138		
Table-Mountain Pine	139		
Oak Pine	140	441	Lobl Piedmont (15) Natural
White Pine-Northern Red Oak-White Ash (SAF 20)	141	221	
Eastern Red Cedar Hardwood	142		
Longleaf Pine-Scrub Oak (SAF 71)	143	221	
Shortleaf Pine-Oak (SAF 76)	144	221	
Virginia Pine-Southern Red Oak (SAF 78)	145	221	
Lobolly Pine-Oak (SAF 82)	146	441	Lobl Piedmont (15) Natural
Slash Pine-Hardwood (SAF 85)	147	221	
Other Oak-Pine	149	221	
Oak Hickory	150	231	Black oak Natural
Post Oak, Black Oak Or Bear Oak (SAF 40,43)	151	231	Black oak Natural
Chestnut Oak (SAF 44)	152	231	Black oak Natural
White Oak-Red Oak-Hickory (SAF 52)	153	231	Black oak Natural
White Oak (SAF 53)	154	231	Black oak Natural
Northern Red Oak (SAF 55)	155	231	Black oak Natural
Yellow Poplar-White Oak-Northern Red Oak (SAF 59)	156	231	Black oak Natural
Southern Scrub Oak (SAF 72)	157		
Sweetgum-Yellow Poplar (SAF 87)	158		
Mixed Hardwoods	159		
Oak-Gum-Cypress	160		
Swamp Chestnut Oak-Cherrybark Oak (SAF 91)	161		
Sweetgum-Nuttall Oak-Willow Oak (SAF 92)	162		
Sugarberry-American Elm-Green Ash (SAF 93)	163		
Overcup Oak-Water Hickory (SAF 96)	165		
Atlantic White Cedar (SAF 97)	166		
Baldcypress-Water Tupelo (SAF 102)	167		
Sweetbay-Swamp Tupelo-Red Maple (SAF 104)	168		
Elm-Ash-Cottonwood	170		
Black Ash-American Elm-Red Maple (SAF 39)	171		
River Birch-Sycamore (SAF 61)	172		
Cottonwood (SAF 63)	173	*231*	*Black oak Natural*
Willow (SAF 95)	174	*111*	*Aspen Natural*
Sycamore-Pecan American Elm (SAF 94)	175		
Maple-Beech-Birch	180		
Sugar Maple-Beech-Yellow Birch (SAF 25)	181		
Aspen-Birch	190	561	aspen
Birch	191	561	aspen
Paper Birch (SAF 18,252)	192	561	aspen
Nonstocked	199		

Cover Name	Cover Code	Fuel Model Code	Fuel Model Name
Douglas-fir (SAF 229) Pacific	200	171	Doug fir-w hemlock Natural
Douglas-fir (SAF 210) Interior	201	31	Interior DF Natural
Douglas-fir-Western Hemlock (SAF 230)	202	171	Doug fir-w hemlock Natural
Port-Orford-Cedar-Douglas-fir (SAF 231)	203	171	Doug fir-w hemlock Natural
Ponderosa Pine (SAF 245) Pacific	210	21	Jeffrey pine Natural
Ponderosa Pine (SAF 237) Interior	211	11	Interior PP Natural
Jeffrey Pine (SAF 247)	212	21	Jeffrey pine Natural
Ponderosa Pine-Sugar Pine-Fir (SAF 243)	213	81	Sierra Nevada mixed Natural
Western White Pine	220	*141*	*White pine Natural*
Western White Pine (SAF 215)	221	41	W white pine Natural
Fir-Spruce	230	61	ES-SAF Natural
White Fir (SAF 211)	231	61	ES-SAF Natural
Red Fir (SAF 207)	232	61	ES-SAF Natural
Pacific Silver Fir-Hemlock (SAF 226)	234	171	Doug fir-w hemlock Natural
Englemann Spruce	235	61	ES-SAF Natural
Englemann Spruce Subalpine Fir (SAF 206)	236	61	ES-SAF Natural
Hemlock-Sitka Spruce (SAF 225)	240	171	Doug fir-w hemlock Natural
Western Redcedar (SAF 228)	241	171	Doug fir-w hemlock Natural
Sitka Spruce (SAF 223)	242	171	Doug fir-w hemlock Natural
Mountain Hemlock-Subalpine Fir (SAF 205)	247	61	ES-SAF Natural
Western Hemlock (SAF 224)	248	171	Doug fir-w hemlock Natural
Larch (SAF 212)	250	31	Interior DF Natural
Larch-Douglas-fir (SAF 212)	255	31	Interior DF Natural
Grand Fir-Larch Douglas-fir (SAF 213)	256	71	Grand fir Natural
Ponderosa Pine-Douglas-fir (SAF 244)	257	81	Sierra Nevada mixed Natural
Lodgepole Pine (SAF 218)	260	91	Lodgepole pine Natural
Lodgepole Pine	261	*91*	*Lodgepole pine Natural*
Redwood	270	*171*	*Doug fir-w hemlock Natural*
Redwood (SAF 232)	271	171	Doug fir-w hemlock Natural
Hardwoods	280	*231*	*Black oak Natural*
Red Alder	281	*231*	*Black oak Natural*
Poplar-Birch	282	*111*	*Aspen Natural*
Aspen (SAF 16,217)	283	111	Aspen Natural
California Black Oak (SAF 246)	284	*231*	*Black oak Natural*
Cottonwood-Willow (SAF 222)	285	*231*	*Black oak Natural*
Canyon Live Oak (SAF 249)	286	*231*	*Black oak Natural*
Oak Madrone (SAF 234)	287	*231*	*Black oak Natural*
Chaparral	288	*331*	*Chaparral (mod shrub cover)*
Ohia	289		
Noncommercial Types	290		
Coulter Pine	291	*21*	*Jeffrey pine Natural*
Digger Pine-Oak (SAF 250)	292	*91*	*Lodgepole pine Natural*
Pinyon-Juniper (SAF 239)	293	381	Pinyon Juniper
Knobcone Pine (SAF 248)	294	*91*	*Lodgepole pine Natural*
Bristlecone Pine (SAF 209)	295	*101*	*Whitebark Pine Natural*
Whitebark Pine (SAF 208)	296	101	Whitebark Pine Natural
Chaparral	297	*331*	*Chaparral (mod shrub cover)*
Desert Grasslands (FRES 40)	2	261	Desert Grasslands
Plains Grasslands (FRES 38)	3	271	Plains Grasslands
Mountain Grasslands (FRES 36)	4	281	Mountain Grasslands
Mountain Meadows (FRES 37)	5	291	Mountain Meadows
Prairie - Tall Grass (FRES 39)	6	301	Prairie (Tall Grass)
Wet Grasslands (FRES 41)	7	311	Wet Grasslands
Sagebrush - low shrub cover (FRES 29)	8	461	Sagebrush (low shrub cover)
Sagebrush - moderate shrub cover (FRES 29)	9	321	Sagebrush (mod shrub cover)
Sagebrush - high shrub cover (FRES 29)	10	471	Sagebrush (high shrub cover)
Chaparral - low shrub cover (FRES 34)	11	481	Chaparral (low shrub cover)
Chaparral - moderate shrub cover (FRES 34)	12	331	Chaparral (mod shrub cover)
Chaparral - high shrub cover (FRES 34)	13	491	Chaparral (high shrub cover)
Desert Shrub - low shrub cover (FRES 30)	14	501	Desert Shrub (low shrub)
Desert Shrub - moderate shrub cover (FRES 30)	15	341	Desert Shrub (mod shrub)
Desert Shrub - high shrub cover (FRES 30)	16	511	Desert Shrub (high shrub)
Shinnery - low shrub cover (FRES 31)	17	521	Shinnery (low shrub cover)
Shinnery - moderate shrub cover (FRES 31)	18	351	Shinnery (mod shrub cover)
Shinnery - high shrub cover (FRES 31)	19	531	Shinnery (high shrub cover)
SW Shrub Steppe - low shrub cover (FRES 33)	20	541	SW Shrub Steppe (low shrub)
SW Shrub Steppe - moderate shrub cover (FRES 33)	21	361	SW Shrub Steppe (mod shrub)
SW Shrub Steppe - high shrub cover (FRES 33)	22	551	SW Shrub Steppe (high shrub)
Texas Savannah (FRES-32)	23	371	Texas Savannah

Table 2: Crosswalk* of CALVEG types to the SAF/FRES system
**created by CDF*

CALVEG description	CALVEG code	FOFEM code	SAF/FRES description
Agriculture	AG	199	Nonstocked
Barren/Rock	BA	199	Nonstocked
Bitterbrush	BB	12	Chaparral - moderate shrub cover (FRES 34)
Saltbush	BC	12	Chaparral - moderate shrub cover (FRES 34)
Low Sagebrush	BL	9	Sagebrush - moderate shrub cover (FRES 29)
Curlleaf Mountain Mahogany	BM	297	Chaparral
Rabbitbrush	BR	12	Chaparral - moderate shrub cover (FRES 34)
Basin Sagebrush	BS	9	Sagebrush - moderate shrub cover (FRES 29)
Ultramafic Mixed Shrub	C1	12	Chaparral - moderate shrub cover (FRES 34)
Chamise	CA	297	Chaparral
Salal - California Huckleberry Shrub	CB	12	Chaparral - moderate shrub cover (FRES 34)
Foothill Mixed Chaparral	CC	297	Chaparral
Greenleaf Manzanita	CG	12	Chaparral - moderate shrub cover (FRES 34)
Huckleberry Oak	CH	297	Chaparral
Brewer Oak	CJ	297	Chaparral
Coyote Brush	CK	297	Chaparral
Wedgeleaf Ceanothus	CL	297	Chaparral
Upper Montane Mixed Shrub	CM	12	Chaparral - moderate shrub cover (FRES 34)
Pinemat Manzanita	CN	297	Chaparral
Northern Mixed Chaparral	CQ	297	Chaparral
Scrub Oak	CS	297	Chaparral
Snowbrush	CV	12	Chaparral - moderate shrub cover (FRES 34)
Whiteleaf Manzanita	CW	12	Chaparral - moderate shrub cover (FRES 34)
Montane Mixed Chaparral	CX	12	Chaparral - moderate shrub cover (FRES 34)
Pacific Douglas-Fir	DF	201	Douglas-fir (SAF 210) Interior
Douglas-Fir - Pine	DP	201	Douglas-fir (SAF 210) Interior
Douglas-Fir - White Fir	DW	201	Douglas-fir (SAF 210) Interior
Eastside Pine	EP	211	Ponderosa Pine (SAF 237) Interior
Unknown Grass	GR	3	Plains Grasslands (FRES 38)
Annual Grass/Forbs	HG	3	Plains Grasslands (FRES 38)
Wet Meadows (Grass/Sedge/Rush)	HJ	7	Wet Grasslands (FRES 41)
Jeffrey Pine	JP	212	Jeffrey Pine (SAF 247)
Knobcone Pine	KP	294	Knobcone Pine (SAF 248)
Lodgepole Pine	LP	261	Lodgepole Pine
Mixed Conifer - Fir	MF	231	White Fir (SAF 211)
Mountain Hemlock	MH	247	Mountain Hemlock-Subalpine Fir (SAF 205)
Klamath Mixed Conifer	MK	213	Ponderosa Pine-Sugar Pine-Fir (SAF 243)
Mixed Conifer - Pine	MP	213	Ponderosa Pine-Sugar Pine-Fir (SAF 243)
Ultramafic Mixed Conifer	MU	221	Western White Pine (SAF 215)
Gray Pine	PD	294	Knobcone Pine (SAF 248)
Ponderosa Pine	PP	211	Ponderosa Pine (SAF 237) Interior
Ponderosa Pine - White Fir	PW	211	Ponderosa Pine (SAF 237) Interior
California Bay	QB	286	Canyon Live Oak (SAF 249)
Canyon Live Oak	QC	286	Canyon Live Oak (SAF 249)
Blue Oak	QD	292	Digger Pine-Oak (SAF 250)
White Alder	QE	285	Cottonwood-Willow (SAF 222)
Oregon White Oak	QG	288	Chaparral
Cottonwood - Alder	QJ	285	Cottonwood-Willow (SAF 222)
California Black Oak	QK	284	California Black Oak (SAF 246)
Bigleaf Maple (Dogwood)	QM	281	Red Alder
Willow	QO	285	Cottonwood-Willow (SAF 222)
Red Alder	QR	281	Red Alder
Willow - Aspen	QS	285	Cottonwood-Willow (SAF 222)
Tanoak (Madrone) QV Black Walnut	QT	287	Oak Madrone (SAF 234)
Willow - Alder	QY	285	Cottonwood-Willow (SAF 222)
Redwood - Douglas-Fir	RD	271	Redwood (SAF 232)
Red Fir	RF	232	Red Fir (SAF 207)
Subalpine Conifers	SA	221	Western White Pine (SAF 215)
Blueblossom Ceanothus	SC	297	Chaparral
Manzanita Chaparral	SD	297	Chaparral
Snow/Ice	SN	199	Nonstocked
Mountain Alder	TA	285	Cottonwood-Willow (SAF 222)
Tree Chinquapin	TC	287	Oak Madrone (SAF 234)
Urban/Developed	UB	199	Nonstocked
Water	WA	199	Nonstocked
Whitebark Pine	WB	296	Whitebark Pine (SAF 208)
Whte Fir	WF	231	White Fir (SAF 211)
Western Juniper	WJ	293	Pinyon-Juniper (SAF 239)
Western White Pine	WW	221	Western White Pine (SAF 215)

Table 4: Crosswalk* of all Holland/CNDDB types (GAP layer) to FOFEM fuel models

**created by CAMFER, # Polygons is frequency of Cover Type over the entire state*

Cover Name	Cover Code	Fuel Model Code	Fuel Model Name
URBAN OR BUILT-UP LAND	11100	0	
AGRICULTURAL LAND	11200	0	
ROW AND FIELD CROPS	11201	0	
IRRIGATED HAYFIELD	11202	0	
IRRIGATED GRAIN AND SEED CROPS	11203	0	
DRYLAND GRAIN AND SEED CROPS	11204	0	
PASTURE	11206	0	
ORCHARDS AND VINEYARDS	11210	0	
EVERGREEN ORCHARD	11211	0	
DECIDUOUS ORCHARD	11212	0	
VINEYARDS	11213	0	
EUCALYPTUS	11300	61	ES-SAF Natural
MID-ELEVATION CONIFER PLANTATION	11401	11	Interior PP Natural
UPPER-ELEVATION CONIFER PLANTATION	11402	21	Jeffrey pine Natural
STREAMS AND CANALS	11510	0	
PERMANENTLY-FLOODED LACUSTRINE HABITAT	11520	0	
INTERMITTENTLY-FLOODED LACUSTRINE HABITAT	11521	0	
BAYS AND ESTUARIES	11540	0	
DRY SALT FLATS	11710	0	
BEACHES AND COASTAL DUNES	11720	0	
SANDY AREAS OTHER THAN BEACHES	11730	0	
BARE EXPOSED ROCK	11740	0	
STRIP MINES, QUARRIES AND GRAVEL PITS	11750	0	
TRANSITIONAL BARE AREAS	11760	0	
MIXED BARREN LAND	11770	0	
MUD FLATS	11780	0	
NORTHERN DUNE SCRUB	21310	0	
CENTRAL DUNE SCRUB	21320	0	
DESERT DUNES	22000	0	
MONVERO RESIDUAL DUNE	23300	0	
NORTHERN COASTAL BLUFF SCRUB	31100	321	Sagebrush (mod shrub cover)
SOUTHERN COASTAL BLUFF SCRUB	31200	321	Sagebrush (mod shrub cover)
NORTHERN(FRANCISCAN) COASTAL SCRUB	32100	321	Sagebrush (mod shrub cover)
CENTRAL(LUCIAN) COASTAL SCRUB	32200	321	Sagebrush (mod shrub cover)
VENTURAN COASTAL SAGE SCRUB	32300	321	Sagebrush (mod shrub cover)
DIEGAN COASTAL SAGE SCRUB	32500	321	Sagebrush (mod shrub cover)
DIABLAN SAGE SCRUB	32600	321	Sagebrush (mod shrub cover)
RIVERSIDEAN SAGE SCRUB	32700	321	Sagebrush (mod shrub cover)
SONORAN CREOSOTE BUSH SCRUB	33100	341	Desert Shrub (mod shrub)
SONORAN DESERT MIXED SCRUB	33200	341	Desert Shrub (mod shrub)
MOJAVE CREOSOTE BUSH SCRUB	34100	341	Desert Shrub (mod shrub)
MOJAVE MIXED WOODY SCRUB	34210	341	Desert Shrub (mod shrub)
MOJAVE MIXED STEPPE	34220	341	Desert Shrub (mod shrub)
MOJAVE MIXED WOODY AND SUCCULENT SCRUB	34240	341	Desert Shrub (mod shrub)
BLACKBUSH SCRUB	34300	321	Sagebrush (mod shrub cover)
GREAT BASIN MIXED SCRUB	35100	321	Sagebrush (mod shrub cover)
SALVIA DORRI/CHAMAEBATIARIA SCRUB	35110	321	Sagebrush (mod shrub cover)
BIG SAGEBRUSH SCRUB	35210	321	Sagebrush (mod shrub cover)
LOW SAGEBRUSH SCRUB	35211	321	Sagebrush (mod shrub cover)
SILVER SAGEBRUSH SCRUB	35212	321	Sagebrush (mod shrub cover)
SUBALPINE SAGEBRUSH SCRUB	35220	321	Sagebrush (mod shrub cover)
RABBITBRUSH SCRUB	35400	321	Sagebrush (mod shrub cover)
CERCOCARPUS LEDIFOLIUS WOODLAND	35500	321	Sagebrush (mod shrub cover)
DESERT SALTBUSH SCRUB	36110	341	Desert Shrub (mod shrub)
DESERT SINK SCRUB	36120	341	Desert Shrub (mod shrub)
DESERT GREASEWOOD SCRUB	36130	341	Desert Shrub (mod shrub)
SHADSCALE SCRUB	36140	321	Sagebrush (mod shrub cover)
DESERT HOLLY SCRUB	36150	341	Desert Shrub (mod shrub)
VALLEY SINK SCRUB	36210	321	Sagebrush (mod shrub cover)
VALLEY SALTBUSH SCRUB	36220	321	Sagebrush (mod shrub cover)
INTERIOR COAST RANGE SALTBUSH SCRUB	36320	321	Sagebrush (mod shrub cover)
NORTHERN MIXED CHAPARRAL	37110	331	Chaparral (mod shrub cover)
SOUTHERN MIXED CHAPARRAL	37120	331	Chaparral (mod shrub cover)
CHAMISE CHAPARRAL(CHAMISAL)	37200	331	Chaparral (mod shrub cover)
REDSHANK CHAPARRAL	37300	331	Chaparral (mod shrub cover)
SEMI-DESERT CHAPARRAL	37400	331	Chaparral (mod shrub cover)
MIXED MONTANE CHAPARRAL	37510	331	Chaparral (mod shrub cover)

Cover Name	Cover Code	Fuel Model Code	Fuel Model Name	
OREGON OAK WOODLAND	71110	231	Black oak	Natural
BLACK OAK WOODLAND	71120	231	Black oak	Natural
VALLEY OAK WOODLAND	71130	231	Black oak	Natural
BLUE OAK WOODLAND	71140	231	Black oak	Natural
INTERIOR LIVE OAK WOODLAND	71150	231	Black oak	Natural
COAST LIVE OAK WOODLAND	71160	231	Black oak	Natural
ALVORD OAK WOODLAND	71170	231	Black oak	Natural
DENSE ENGELMANN OAK WOODLAND	71182	231	Black oak	Natural
CALIFORNIA WALNUT WOODLAND	71210	231	Black oak	Natural
OPEN FOOTHILL PINE WOODLAND	71310	91	Lodgepole pine	Natural
SERPENTINE FOOTHILL PINE-CHAPARRAL WOODLAND	71321	91	Lodgepole pine	Natural
NONSERPENTINE FOOTHILL PINE-CHAPARRAL WOODLAND	71322	91	Lodgepole pine	Natural
FOOTHILL PINE-OAK WOODLAND	71410	91	Lodgepole pine	Natural
MIXED NORTH SLOPE CISMONTANE WOODLAND	71420	111	Aspen	Natural
JUNIPER-OAK CISMONTANE WOODLAND	71430	381	Pinyon Juniper	
OAK-PINYON WOODLAND	71600	381	Pinyon Juniper	
GREAT BASIN WOODLAND	72100	231	Black oak	Natural
PINYON-JUNIPER WOODLAND	72200	231	Black oak	Natural
PENINSULAR PINYON AND JUNIPER WOODLANDS	72300	381	Pinyon Juniper	
CISMONTANE JUNIPER WOODLAND AND SCRUB	72400	381	Pinyon Juniper	
JOSHUA TREE WOODLAND	73000	231	Black oak	Natural
MIXED EVERGREEN FOREST	81100	231	Black oak	Natural
CALIFORNIA BAY FOREST	81200	231	Black oak	Natural
COAST LIVE OAK FOREST	81310	231	Black oak	Natural
CANYON LIVE OAK FOREST	81320	231	Black oak	Natural
INTERIOR LIVE OAK FOREST	81330	231	Black oak	Natural
BLACK OAK FOREST	81340	231	Black oak	Natural
TAN-OAK FOREST	81400	231	Black oak	Natural
ASPEN FOREST	81B00	111	Aspen	Natural
SITKA SPRUCE-GRAND FIR FOREST	82100	71	Grand fir	Natural
ALLUVIAL REDWOOD FOREST	82310	171	Doug fir-w hemlock	Natural
UPLAND REDWOOD FOREST	82320	171	Doug fir-w hemlock	Natural
UPLAND DOUGLAS FIR FOREST	82420	31	Interior DF	Natural
BEACH PINE FOREST	83110	121	Jack pine	Natural
BISHOP PINE FOREST	83120	121	Jack pine	Natural
MONTEREY PINE FOREST	83130	121	Jack pine	Natural
MENDOCINO PYGMY CYPRESS FOREST	83161	91	Lodgepole pine	Natural
KNOBCONE PINE FOREST	83210	91	Lodgepole pine	Natural
NORTHERN INTERIOR CYPRESS FOREST	83220	91	Lodgepole pine	Natural
SOUTHERN INTERIOR CYPRESS FOREST	83330	91	Lodgepole pine	Natural
COAST RANGE MIXED CONIFEROUS FOREST	84110	171	Doug fir-w hemlock	Natural
SANTA LUCIA FIR FOREST	84120	171	Doug fir-w hemlock	Natural
COAST RANGE PONDEROSA PINE FOREST	84130	11	Interior PP	Natural
COULTER PINE FOREST	84140	11	Interior PP	Natural
BIGCONE SPRUCE-CANYON OAK FOREST	84150	51	Blue spruce	Natural
NORTHERN ULTRAMAFIC JEFFREY PINE FOREST	84171	21	Jeffrey pine	Natural
ULTRAMAFIC MIXED CONIFEROUS FOREST	84180	81	Sierra Nevada mixed	Natural
WESTSIDE PONDEROSA PINE FOREST	84210	11	Interior PP	Natural
EASTSIDE PONDEROSA PINE FOREST	84220	11	Interior PP	Natural
SIERRAN MIXED CONIFER FOREST	84230	81	Sierra Nevada mixed	Natural
SIERRAN WHITE FIR FOREST	84240	61	ES-SAF	Natural
BIG TREE FOREST	84250	81	Sierra Nevada mixed	Natural
MODOC WHITE FIR FOREST	84260	61	ES-SAF	Natural
JEFFREY PINE FOREST	85100	21	Jeffrey pine	Natural
RED FIR (or LODGEPOLE PINE)-WESTERN WHITE PINE	85120	141	White pine	Natural
JEFFREY PINE-FIR FOREST	85210	81	Sierra Nevada mixed	Natural
RED FIR FOREST	85310	61	ES-SAF	Natural
SOUTHERN CALIFORNIA WHITE FIR FOREST	85320	61	ES-SAF	Natural
SISKIYOU ENRICHED CONIFER FOREST	85410	81	Sierra Nevada mixed	Natural
SALMON-SCOTT ENRICHED CONIFER FOREST	85420	81	Sierra Nevada mixed	Natural
LODGEPOLE PINE FOREST	86100	91	Lodgepole pine	Natural
WHITEBARK PINE-MOUNTAIN HEMLOCK FOREST	86210	61	ES-SAF	Natural
WHITEBARK PINE-LODGEPOLE PINE FOREST	86220	91	Lodgepole pine	Natural
FOXTAIL PINE FOREST	86300	91	Lodgepole pine	Natural
BRISTLECONE PINE FOREST	86400	101	Whitebark Pine	Natural
SOUTHERN CALIFORNIA SUBALPINE FOREST	86500	61	ES-SAF	Natural
WHITEBARK PINE FOREST	86600	101	Whitebark Pine	Natural
LIMBER PINE FOREST	86700	61	ES-SAF	Natural
KLAMATH-CASCADE FELL-FIELD	91110	301	Prairie (Tall Grass)	
SIERRA NEVADA FELL-FIELD	91120	301	Prairie (Tall Grass)	
ALPINE DWARF SCRUB	94000	331	Chaparral (mod shrub cover)	

Cover Name	Cover Code	Fuel Model Code	Fuel Model Name	
MONTANE MANZANITA CHAPARRAL	37520	331	Chaparral (mod shrub cover)	
MONTANE CEANOTHUS CHAPARRALS	37530	331	Chaparral (mod shrub cover)	
SHIN OAK BRUSH	37541	331	Chaparral (mod shrub cover)	
HUCKLEBERRY OAK CHAPARRAL	37542	331	Chaparral (mod shrub cover)	
BUSH CHINQUAPIN CHAPARRAL	37550	331	Chaparral (mod shrub cover)	
MESIC SERPENTINE CHAPARRAL	37610	331	Chaparral (mod shrub cover)	
LEATHER OAK CHAPARRAL	37620	331	Chaparral (mod shrub cover)	
BUCK BRUSH CHAPARRAL	37810	331	Chaparral (mod shrub cover)	
BLUE BRUSH CHAPARRAL	37820	331	Chaparral (mod shrub cover)	
HOARY-LEAFED CHAPARRAL	37830	331	Chaparral (mod shrub cover)	
BIG POD CHAPARRAL	37840	331	Chaparral (mod shrub cover)	
SCRUB OAK CHAPARRAL	37900	331	Chaparral (mod shrub cover)	
INTERIOR LIVE OAK CHAPARRAL	37A00	331	Chaparral (mod shrub cover)	
UPPER SONORAN MANZANITA CHAPARRAL	37B00	331	Chaparral (mod shrub cover)	
NORTHERN MARITIME CHAPARRAL	37C10	331	Chaparral (mod shrub cover)	
CENTRAL MARITIME CHAPARRAL	37C20	331	Chaparral (mod shrub cover)	
IONE CHAPARRAL	37D00	331	Chaparral (mod shrub cover)	
	37E00	331	Chaparral (mod shrub cover)	
COASTAL SAGE-CHAPPARAL SCRUB	37G00	321	Sagebrush (mod shrub cover)	
UPPER SONORAN SUBSHRUB SCRUB	39000	341	Desert Shrub (mod shrub)	
COASTAL PRAIRIE	41000	301	Prairie (Tall Grass)	
VALLEY NEEDLEGRASS GRASSLAND	42110	271	Plains Grasslands	
VALLEY SACATON GRASSLAND	42120	271	Plains Grasslands	
DESERT NATIVE GRASSLAND	42160	261	Desert Grasslands	
NON-NATIVE GRASSLAND	42200	271	Plains Grasslands	
WILDFLOWER FIELD	42300	291	Mountain Meadows	
GREAT BASIN GRASSLAND	43000	271	Plains Grasslands	
NORTHERN HARDPAN VERNAL POOL	44110	0		
NORTHERN CLAYPAN VERNAL POOL	44120	0		
NORTHERN VOLCANIC BASALT FLOW VERNAL POOL	44131	0		
MONTANE MEADOW	45100	291	Mountain Meadows	
SUBALPINE OR ALPINE MEADOW	45200	291	Mountain Meadows	
ALKALI MEADOW	45310	291	Mountain Meadows	
GREAT BASIN WET MEADOW	45500	311	Wet Grasslands	
ALKALI PLAYA	46000	0		
SPHAGNUM BOG	51110	0		
NORTHERN COASTAL SALT MARSH	52110	0		
SOUTHERN COASTAL SALT MARSH	52120	0		
COASTAL BRACKISH MARSH	52200	0		
CISMONTANE ALKALI MARSH	52310	0		
TRANSMONTANE ALKALI MARSH	52320	0		
COASTAL AND VALLEY FRESHWATER MARSH	52410	0		
TRANSMONTANE FRESHWATER MARSH	52420	0		
RED ALDER RIPARIAN FOREST	61130	231	Black oak	Natural
CENTRAL COAST COTTONWOOD-SYCAMORE RIPARIAN	61210	231	Black oak	Natural
CENTRAL COAST LIVE OAK RIPARIAN FOREST	61220	231	Black oak	Natural
CENTRAL COAST ARROYO WILLOW RIPARIAN FOREST	61230	231	Black oak	Natural
SOUTHERN COAST LIVE OAK RIPARIAN FOREST	61310	231	Black oak	Natural
	61320	231	Black oak	Natural
SOUTHERN COTTONWOOD-WILLOW RIPARIAN FOREST	61330	231	Black oak	Natural
GREAT VALLEY COTTONWOOD RIPARIAN FOREST	61410	231	Black oak	Natural
GREAT VALLEY MIXED RIPARIAN FOREST	61420	231	Black oak	Natural
GREAT VALLEY VALLEY OAK RIPARIAN FOREST	61430	231	Black oak	Natural
WHITE ALDER RIPARIAN FOREST	61510	231	Black oak	Natural
ASPEN RIPARIAN FOREST	61520	111	Aspen	Natural
MONTANE BLACK COTTONWOOD RIPARIAN FOREST	61530	231	Black oak	Natural
MODOC-GREAT BASIN COTTONWOOD-WILLOW RIPARIAN	61610	231	Black oak	Natural
MOJAVE RIPARIAN FOREST	61700	371	Texas Savannah	
MESQUITE BOSQUE	61820	371	Texas Savannah	
SYCAMORE ALLUVIAL WOODLAND	62100	231	Black oak	Natural
DESERT DRY WASH WOODLAND	62200	231	Black oak	Natural
SOUTHERN SYCAMORE-ALDER RIPARIAN WOODLAND	62400	231	Black oak	Natural
NORTH COAST RIPARIAN SCRUB	63100	331	Chaparral (mod shrub cover)	
MULE FAT SCRUB	63310	331	Chaparral (mod shrub cover)	
SOUTHERN WILLOW SCRUB	63320	331	Chaparral (mod shrub cover)	
SOUTHERN ALLUVIAL FAN SCRUB	63330	331	Chaparral (mod shrub cover)	
GREAT VALLEY WILLOW SCRUB	63410	331	Chaparral (mod shrub cover)	
GREAT VALLEY MESQUITE SCRUB	63420	331	Chaparral (mod shrub cover)	
MONTANE RIPARIAN SCRUB	63500	331	Chaparral (mod shrub cover)	
MODOC-GREAT BASIN RIPARIAN SCRUB	63600	331	Chaparral (mod shrub cover)	
MOJAVE DESERT WASH SCRUB	63700	341	Desert Shrub (mod shrub)	
TAMARISK SCRUB	63810	331	Chaparral (mod shrub cover)	

Table 5: California 1998 Emissions*, by Jurisdiction and Fire Type
** Computed using default parameters and standard GAP processing*

			Emissions (tons)		
AIRBASIN	**COUNTY**	Data	**prescribed**	**wildfire**	**Grand Total**
GREAT BASIN VALLEYS	*INYO*	PM10 Total (tons)	64.4	0.0	64.4
		PM25 Total (tons)	6.5	0.0	6.5
		CO Total (tons)	5.5	0.0	5.5
		Area Total (acres)	407.1	0.0	407.1
GREAT BASIN VALLEYS PM10 Total (tons)			64.4	0.0	64.4
GREAT BASIN VALLEYS PM25 Total (tons)			6.5	0.0	6.5
GREAT BASIN VALLEYS CO Total (tons)			5.5	0.0	5.5
GREAT BASIN VALLEYS Area Total (acres)			407.1	0.0	407.1
MOJAVE DESERT	*SAN BERNARDINO*	PM10 Total (tons)	0.0	723.8	723.8
		PM25 Total (tons)	0.0	73.0	73.0
		CO Total (tons)	0.0	61.9	61.9
		Area Total (acres)	0.0	781.5	781.5
MOJAVE DESERT PM10 Total (tons)			0.0	723.8	723.8
MOJAVE DESERT PM25 Total (tons)			0.0	73.0	73.0
MOJAVE DESERT CO Total (tons)			0.0	61.9	61.9
MOJAVE DESERT Area Total (acres)			0.0	781.5	781.5
MOUNTAIN COUNTIES	*MARIPOSA*	PM10 Total (tons)	447.6	0.0	447.6
		PM25 Total (tons)	46.5	0.0	46.5
		CO Total (tons)	39.4	0.0	39.4
		Area Total (acres)	183.3	0.0	183.3
	NEVADA	PM10 Total (tons)	623.5	0.0	623.5
		PM25 Total (tons)	64.7	0.0	64.7
		CO Total (tons)	54.9	0.0	54.9
		Area Total (acres)	217.0	0.0	217.0
	PLACER	PM10 Total (tons)	323.9	0.0	323.9
		PM25 Total (tons)	33.6	0.0	33.6
		CO Total (tons)	28.5	0.0	28.5
		Area Total (acres)	120.2	0.0	120.2
	TUOLUMNE	PM10 Total (tons)	6814.3	659.9	7474.3
		PM25 Total (tons)	705.1	68.0	773.1
		CO Total (tons)	598.2	57.7	655.9
		Area Total (acres)	2377.8	167.7	2545.5
MOUNTAIN COUNTIES PM10 Total (tons)			8209.3	659.9	8869.3
MOUNTAIN COUNTIES PM25 Total (tons)			849.8	68.0	917.8
MOUNTAIN COUNTIES CO Total (tons)			721.0	57.7	778.7
MOUNTAIN COUNTIES Area Total (acres)			2898.2	167.7	3065.9
NORTH CENTRAL COAST	*SAN BENITO*	PM10 Total (tons)	0.0	3887.8	3887.8
		PM25 Total (tons)	0.0	397.6	397.6
		CO Total (tons)	0.0	337.3	337.3
		Area Total (acres)	0.0	2794.7	2794.7
	SANTA CRUZ	PM10 Total (tons)	1249.9	0.0	1249.9
		PM25 Total (tons)	133.4	0.0	133.4
		CO Total (tons)	113.1	0.0	113.1
		Area Total (acres)	237.2	0.0	237.2
NORTH CENTRAL COAST PM10 Total (tons)			1249.9	3887.8	5137.7
NORTH CENTRAL COAST PM25 Total (tons)			133.4	397.6	531.0
NORTH CENTRAL COAST CO Total (tons)			113.1	337.3	450.5
NORTH CENTRAL COAST Area Total (acres)			237.2	2794.7	3031.8
NORTH COAST	*DEL NORTE*	PM10 Total (tons)	0.0	7299.6	7299.6
		PM25 Total (tons)	0.0	771.2	771.2
		CO Total (tons)	0.0	654.3	654.3
		Area Total (acres)	0.0	1770.7	1770.7
	HUMBOLDT	PM10 Total (tons)	913.2	48577.4	49490.6
		PM25 Total (tons)	97.4	5184.7	5282.1
		CO Total (tons)	82.7	4399.4	4482.1
		Area Total (acres)	2791.9	21887.8	24679.7
NORTH COAST PM10 Total (tons)			913.2	55877.0	56790.2
NORTH COAST PM25 Total (tons)			97.4	5955.9	6053.3
NORTH COAST CO Total (tons)			82.7	5053.8	5136.4

AIRBASIN	COUNTY	Data	Emissions (tons) prescribed	wildfire	Grand Total
NORTH COAST Area Total (acres)			2791.9	23658.4	26450.3
NORTHEAST PLATEAU	*SISKIYOU*	PM10 Total (tons)	21.9	19274.6	19296.5
		PM25 Total (tons)	2.4	2058.2	2060.6
		CO Total (tons)	2.0	1746.7	1748.8
		Area Total (acres)	172.1	17836.5	18008.6
NORTHEAST PLATEAU PM10 Total (tons)			21.9	19274.6	19296.5
NORTHEAST PLATEAU PM25 Total (tons)			2.4	2058.2	2060.6
NORTHEAST PLATEAU CO Total (tons)			2.0	1746.7	1748.8
NORTHEAST PLATEAU Area Total (acres)			172.1	17836.5	18008.6
SACRAMENTO VALLEY	*TEHAMA*	PM10 Total (tons)	0.0	7302.0	7302.0
		PM25 Total (tons)	0.0	753.3	753.3
		CO Total (tons)	0.0	639.2	639.2
		Area Total (acres)	0.0	3055.7	3055.7
	YUBA	PM10 Total (tons)	49.9	131.7	181.6
		PM25 Total (tons)	5.7	13.6	19.3
		CO Total (tons)	4.9	11.6	16.4
		Area Total (acres)	198.3	1620.1	1818.4
SACRAMENTO VALLEY PM10 Total (tons)			49.9	7433.7	7483.6
SACRAMENTO VALLEY PM25 Total (tons)			5.7	766.8	772.6
SACRAMENTO VALLEY CO Total (tons)			4.9	650.7	655.6
SACRAMENTO VALLEY Area Total (acres)			198.3	4675.8	4874.1
SAN FRANCISCO BAY	*SAN MATEO*	PM10 Total (tons)	10.5	0.0	10.5
		PM25 Total (tons)	1.2	0.0	1.2
		CO Total (tons)	1.0	0.0	1.0
		Area Total (acres)	74.7	0.0	74.7
SAN FRANCISCO BAY PM10 Total (tons)			10.5	0.0	10.5
SAN FRANCISCO BAY PM25 Total (tons)			1.2	0.0	1.2
SAN FRANCISCO BAY CO Total (tons)			1.0	0.0	1.0
SAN FRANCISCO BAY Area Total (acres)			74.7	0.0	74.7
SAN JOAQUIN VALLEY	*MADERA*	PM10 Total (tons)	0.0	60.7	60.7
		PM25 Total (tons)	0.0	6.1	6.1
		CO Total (tons)	0.0	5.2	5.2
		Area Total (acres)	0.0	669.3	669.3
	MERCED	PM10 Total (tons)	0.0	444.2	444.2
		PM25 Total (tons)	0.0	44.6	44.6
		CO Total (tons)	0.0	38.0	38.0
		Area Total (acres)	0.0	6474.9	6474.9
SAN JOAQUIN VALLEY PM10 Total (tons)			0.0	504.9	504.9
SAN JOAQUIN VALLEY PM25 Total (tons)			0.0	50.8	50.8
SAN JOAQUIN VALLEY CO Total (tons)			0.0	43.3	43.3
SAN JOAQUIN VALLEY Area Total (acres)			0.0	7144.2	7144.2
SOUTH CENTRAL COAST	*SAN LUIS OBISPO*	PM10 Total (tons)	362.1	641.2	1003.3
		PM25 Total (tons)	41.7	65.0	106.7
		CO Total (tons)	35.4	55.2	90.6
		Area Total (acres)	1312.9	2122.0	3435.0
	SANTA BARBARA	PM10 Total (tons)	926.2	4321.2	5247.4
		PM25 Total (tons)	98.5	437.6	536.1
		CO Total (tons)	83.7	371.2	454.9
		Area Total (acres)	3365.2	4097.3	7462.5
	VENTURA	PM10 Total (tons)	0.0	6978.3	6978.3
		PM25 Total (tons)	0.0	706.7	706.7
		CO Total (tons)	0.0	599.7	599.7
		Area Total (acres)	0.0	12720.4	12720.4
SOUTH CENTRAL COAST PM10 Total (tons)			1288.2	11940.8	13229.0
SOUTH CENTRAL COAST PM25 Total (tons)			140.2	1209.3	1349.5
SOUTH CENTRAL COAST CO Total (tons)			119.1	1026.1	1145.2
SOUTH CENTRAL COAST Area Total (acres)			4678.1	18939.7	23617.9
SOUTH COAST	*SAN BERNARDINO*	PM10 Total (tons)	0.0	997.4	997.4
		PM25 Total (tons)	0.0	101.0	101.0
		CO Total (tons)	0.0	85.7	85.7
		Area Total (acres)	0.0	1483.8	1483.8
SOUTH COAST PM10 Total (tons)			0.0	997.4	997.4
SOUTH COAST PM25 Total (tons)			0.0	101.0	101.0
SOUTH COAST CO Total (tons)			0.0	85.7	85.7
SOUTH COAST Area Total (acres)			0.0	1483.8	1483.8
California PM10 Total (tons)			**11807.3**	**101299.9**	**113107.2**
California PM25 Total (tons)			**1236.6**	**10680.6**	**11917.2**
California CO Total (tons)			**1049.4**	**9063.2**	**10112.6**
California Burn Area Total (acres)			**11457.6**	**77482.3**	**88939.8**

Tables 5b: California 1998 Emissions Detail

Multiple table print out in ARB format for comparisson between ARB estimates and preliminary Berkeley estimates.

METHOD	**ARB**
CAUSE	**(All / Not specified)**

		Data			
AIRBASIN	COUNTY	Sum of AREA	Sum of CO	Sum of PM25	Sum of PM10
GREAT BASIN VALLEYS	ALPINE	6.0	7.5		1.5
	INYO	1799.0	2178.0		428.5
	MONO	1511.0	1881.2		370.3
GREAT BASIN VALLEYS Total		3316.0	4066.6		800.2
LAKE COUNTY	LAKE	245.0	195.2		38.0
LAKE COUNTY Total		245.0	195.2		38.0
LAKE TAHOE	EL DORADO	0.0	0.0		0.0
	PLACER	4.0	5.0		1.0
LAKE TAHOE Total		4.0	5.0		1.0
MOJAVE DESERT	KERN	658.0	819.2		161.2
	LOS ANGELES	0.0	0.0		0.0
	RIVERSIDE	0.0	0.0		0.0
	SAN BERNARDINO	9784.0	10668.7		2094.0
MOJAVE DESERT Total		10442.0	11487.9		2255.2
MOUNTAIN COUNTIES	AMADOR	37.0	7.2		1.3
	CALAVERAS	113.0	36.6		6.8
	EL DORADO	188.0	80.8		15.3
	MARIPOSA	640.0	159.6		28.9
	NEVADA	36.0	9.4		1.7
	PLACER	57.0	28.6		5.5
	PLUMAS	33.0	41.1		8.1
	SIERRA	12.0	14.9		2.9
	TUOLUMNE	774.0	112.5		18.8
MOUNTAIN COUNTIES Total		1890.0	490.6		89.2
NORTH CENTRAL COAST	MONTEREY	3383.0	3817.2		749.8
	SAN BENITO	2942.0	3500.3		688.3
	SANTA CRUZ	5.0	0.5		0.1
NORTH CENTRAL COAST Total		6330.0	7318.0		1438.2
NORTH COAST	DEL NORTE	425.0	506.2		99.6
	HUMBOLDT	466.0	468.1		91.7
	MENDOCINO	287.0	160.5		30.8
	SONOMA	42.0	8.8		1.6
	TRINITY	279.0	341.6		67.2
NORTH COAST Total		1499.0	1485.3		290.9
NORTHEAST PLATEAU	LASSEN	1233.0	1445.9		284.2
	MODOC	10354.0	12842.7		2527.7
	SISKIYOU	1674.0	1579.6		308.9
NORTHEAST PLATEAU Total		13261.0	15868.2		3120.8

SACRAMENTO VALLEY	BUTTE	222.0	51.0	9.2
	COLUSA	165.0	51.0	9.4
	GLENN	294.0	132.7	25.2
	PLACER	70.0	34.5	6.6
	SACRAMENTO	0.0	0.0	0.0
	SHASTA	322.0	73.7	13.2
	SOLANO	50.0	5.1	0.8
	SUTTER	0.0	0.0	0.0
	TEHAMA	4121.0	2014.4	384.2
	YOLO	7403.0	6473.4	1263.4
	YUBA	405.0	58.1	9.7
SACRAMENTO VALLEY Total		13052.0	8893.8	1721.6
SALTON SEA	IMPERIAL	0.0	0.0	0.0
	RIVERSIDE	16019.0	16313.7	3196.8
SALTON SEA Total		16019.0	16313.7	3196.8
SAN DIEGO	SAN DIEGO	8173.0	7306.2	1426.8
SAN DIEGO Total		8173.0	7306.2	1426.8
SAN FRANCISCO BAY	ALAMEDA	1598.0	175.1	27.3
	CONTRA COSTA	1578.0	271.5	46.8
	MARIN	0.0	0.0	0.0
	NAPA	124.0	48.0	9.0
	SAN FRANCISCO	0.0	0.0	0.0
	SAN MATEO	22.0	2.2	0.3
	SANTA CLARA	686.0	113.9	19.5
	SOLANO	41.0	4.1	0.6
	SONOMA	24.0	5.9	1.1
SAN FRANCISCO BAY Total		4073.0	620.7	104.7
SAN JOAQUIN VALLEY	FRESNO	2405.0	1815.9	352.8
	KERN	670.0	834.2	164.2
	KINGS	0.0	0.0	0.0
	MADERA	1365.0	566.9	107.1
	MERCED	6137.0	619.8	94.4
	SAN JOAQUIN	110.0	11.1	1.7
	STANISLAUS	631.0	63.7	9.7
	TULARE	2612.0	2453.4	479.8
SAN JOAQUIN VALLEY Total		13930.0	6365.0	1209.6
SOUTH CENTRAL COAST	SAN LUIS OBISPO	2771.0	2398.6	468.0
	SANTA BARBARA	6027.0	7503.6	1476.9
	VENTURA	5023.0	6253.6	1230.9
SOUTH CENTRAL COAST Total		13821.0	16155.8	3175.8
SOUTH COAST	LOS ANGELES	1026.0	1277.4	251.4
	ORANGE	79.0	98.4	19.4
	RIVERSIDE	40495.0	29844.9	5793.4
	SAN BERNARDINO	13757.0	16860.9	3317.7
SOUTH COAST Total		55357.0	48081.5	9381.9
Grand Total		161412.0	144653.7	28250.7

METHOD	**Berkeley**
CAUSE	**(All)**

		Data			
AIRBASIN	COUNTY	Sum of AREA	Sum of CO	Sum of PM25	Sum of PM10
GREAT BASIN VALLEYS	ALPINE	0.0	0.0	0.0	0.0
	INYO	407.1	64.4	5.5	6.5
	MONO	0.0	0.0	0.0	0.0
GREAT BASIN VALLEYS Total		407.1	64.4	5.5	6.5
LAKE COUNTY	LAKE	0.0	0.0	0.0	0.0
LAKE COUNTY Total		0.0	0.0	0.0	0.0
LAKE TAHOE	EL DORADO	0.0	0.0	0.0	0.0
	PLACER	0.0	0.0	0.0	0.0
LAKE TAHOE Total		0.0	0.0	0.0	0.0
MOJAVE DESERT	IMPERIAL	0.0	0.0	0.0	0.0
	KERN	0.0	0.0	0.0	0.0
	LOS ANGELES	0.0	0.0	0.0	0.0
	RIVERSIDE	0.0	0.0	0.0	0.0
	SAN BERNARDINO	781.5	723.8	61.9	73.0
MOJAVE DESERT Total		781.5	723.8	61.9	73.0
MOUNTAIN COUNTIES	AMADOR	0.0	0.0	0.0	0.0
	CALAVERAS	0.0	0.0	0.0	0.0
	EL DORADO	0.0	0.0	0.0	0.0
	MARIPOSA	183.3	447.6	39.4	46.5
	NEVADA	217.0	623.5	54.9	64.7
	PLACER	120.2	323.9	28.5	33.6
	PLUMAS	0.0	0.0	0.0	0.0
	SIERRA	0.0	0.0	0.0	0.0
	TUOLUMNE	2545.5	7474.3	655.9	773.1
MOUNTAIN COUNTIES Total		3065.9	8869.3	778.7	917.8
NORTH CENTRAL COAST	MONTEREY	0.0	0.0	0.0	0.0
	SAN BENITO	2794.7	3887.8	337.3	397.6
	SANTA CRUZ	237.2	1249.9	113.1	133.4
NORTH CENTRAL COAST Total		3031.8	5137.7	450.5	531.0
NORTH COAST	DEL NORTE	1770.7	7299.6	654.3	771.2
	HUMBOLDT	24679.7	49490.6	4482.1	5282.1
	MENDOCINO	0.0	0.0	0.0	0.0
	SONOMA	0.0	0.0	0.0	0.0
	TRINITY	0.0	0.0	0.0	0.0
NORTH COAST Total		26450.3	56790.2	5136.4	6053.3
NORTHEAST PLATEAU	LASSEN	0.0	0.0	0.0	0.0
	MODOC	0.0	0.0	0.0	0.0
	SISKIYOU	18008.6	19296.5	1748.8	2060.6
NORTHEAST PLATEAU Total		18008.6	19296.5	1748.8	2060.6

SACRAMENTO VALLEY	BUTTE	0.0	0.0	0.0	0.0
	COLUSA	0.0	0.0	0.0	0.0
	GLENN	0.0	0.0	0.0	0.0
	PLACER	0.0	0.0	0.0	0.0
	SACRAMENTO	0.0	0.0	0.0	0.0
	SHASTA	0.0	0.0	0.0	0.0
	SOLANO	0.0	0.0	0.0	0.0
	SUTTER	0.0	0.0	0.0	0.0
	TEHAMA	3055.7	7302.0	639.2	753.3
	YOLO	0.0	0.0	0.0	0.0
	YUBA	1818.4	181.6	16.4	19.3
SACRAMENTO VALLEY Total		4874.1	7483.6	655.6	772.6
SALTON SEA	IMPERIAL	0.0	0.0	0.0	0.0
	RIVERSIDE	0.0	0.0	0.0	0.0
SALTON SEA Total		0.0	0.0	0.0	0.0
SAN DIEGO	SAN DIEGO	0.0	0.0	0.0	0.0
SAN DIEGO Total		0.0	0.0	0.0	0.0
SAN FRANCISCO BAY	ALAMEDA	0.0	0.0	0.0	0.0
	CONTRA COSTA	0.0	0.0	0.0	0.0
	MARIN	0.0	0.0	0.0	0.0
	NAPA	0.0	0.0	0.0	0.0
	SAN FRANCISCO	0.0	0.0	0.0	0.0
	SAN MATEO	74.7	10.5	1.0	1.2
	SANTA CLARA	0.0	0.0	0.0	0.0
	SOLANO	0.0	0.0	0.0	0.0
	SONOMA	0.0	0.0	0.0	0.0
SAN FRANCISCO BAY Total		74.7	10.5	1.0	1.2
SAN JOAQUIN VALLEY	FRESNO	0.0	0.0	0.0	0.0
	KERN	0.0	0.0	0.0	0.0
	KINGS	0.0	0.0	0.0	0.0
	MADERA	669.3	60.7	5.2	6.1
	MERCED	6474.9	444.2	38.0	44.6
	SAN JOAQUIN	0.0	0.0	0.0	0.0
	STANISLAUS	0.0	0.0	0.0	0.0
	TULARE	0.0	0.0	0.0	0.0
SAN JOAQUIN VALLEY Total		7144.2	504.9	43.3	50.8
SOUTH CENTRAL COAST	SAN LUIS OBISPO	3435.0	1003.3	90.6	106.7
	SANTA BARBARA	7462.5	5247.4	454.9	536.1
	VENTURA	12720.4	6978.3	599.7	706.7
SOUTH CENTRAL COAST Total		23617.9	13229.0	1145.2	1349.5
SOUTH COAST	LOS ANGELES	0.0	0.0	0.0	0.0
	ORANGE	0.0	0.0	0.0	0.0
	RIVERSIDE	0.0	0.0	0.0	0.0
	SAN BERNARDINO	1483.8	997.4	85.7	101.0
SOUTH COAST Total		1483.8	997.4	85.7	101.0
Grand Total		88939.8	113107.2	10112.6	11917.2

METHOD	**Berkeley**
CAUSE	**wildfire**

		Data			
AIRBASIN	COUNTY	Sum of AREA	Sum of CO	Sum of PM25	Sum of PM10
GREAT BASIN VALLEYS	ALPINE	0.0	0.0	0.0	0.0
	INYO	0.0	0.0	0.0	0.0
	MONO	0.0	0.0	0.0	0.0
GREAT BASIN VALLEYS Total		0.0	0.0	0.0	0.0
LAKE COUNTY	LAKE	0.0	0.0	0.0	0.0
LAKE COUNTY Total		0.0	0.0	0.0	0.0
LAKE TAHOE	EL DORADO	0.0	0.0	0.0	0.0
	PLACER	0.0	0.0	0.0	0.0
LAKE TAHOE Total		0.0	0.0	0.0	0.0
MOJAVE DESERT	IMPERIAL	0.0	0.0	0.0	0.0
	KERN	0.0	0.0	0.0	0.0
	LOS ANGELES	0.0	0.0	0.0	0.0
	RIVERSIDE	0.0	0.0	0.0	0.0
	SAN BERNARDINO	781.5	723.8	61.9	73.0
MOJAVE DESERT Total		781.5	723.8	61.9	73.0
MOUNTAIN COUNTIES	AMADOR	0.0	0.0	0.0	0.0
	CALAVERAS	0.0	0.0	0.0	0.0
	EL DORADO	0.0	0.0	0.0	0.0
	MARIPOSA	0.0	0.0	0.0	0.0
	NEVADA	0.0	0.0	0.0	0.0
	PLACER	0.0	0.0	0.0	0.0
	PLUMAS	0.0	0.0	0.0	0.0
	SIERRA	0.0	0.0	0.0	0.0
	TUOLUMNE	167.7	659.9	57.7	68.0
MOUNTAIN COUNTIES Total		167.7	659.9	57.7	68.0
NORTH CENTRAL COAST	MONTEREY	0.0	0.0	0.0	0.0
	SAN BENITO	2794.7	3887.8	337.3	397.6
	SANTA CRUZ	0.0	0.0	0.0	0.0
NORTH CENTRAL COAST Total		2794.7	3887.8	337.3	397.6
NORTH COAST	DEL NORTE	1770.7	7299.6	654.3	771.2
	HUMBOLDT	21887.8	48577.4	4399.4	5184.7
	MENDOCINO	0.0	0.0	0.0	0.0
	SONOMA	0.0	0.0	0.0	0.0
	TRINITY	0.0	0.0	0.0	0.0
NORTH COAST Total		23658.4	55877.0	5053.8	5955.9
NORTHEAST PLATEAU	LASSEN	0.0	0.0	0.0	0.0
	MODOC	0.0	0.0	0.0	0.0
	SISKIYOU	17836.5	19274.6	1746.7	2058.2
NORTHEAST PLATEAU Total		17836.5	19274.6	1746.7	2058.2

SACRAMENTO VALLEY	BUTTE	0.0	0.0	0.0	0.0
	COLUSA	0.0	0.0	0.0	0.0
	GLENN	0.0	0.0	0.0	0.0
	PLACER	0.0	0.0	0.0	0.0
	SACRAMENTO	0.0	0.0	0.0	0.0
	SHASTA	0.0	0.0	0.0	0.0
	SOLANO	0.0	0.0	0.0	0.0
	SUTTER	0.0	0.0	0.0	0.0
	TEHAMA	3055.7	7302.0	639.2	753.3
	YOLO	0.0	0.0	0.0	0.0
	YUBA	1620.1	131.7	11.6	13.6
SACRAMENTO VALLEY Total		4675.8	7433.7	650.7	766.8
SALTON SEA	IMPERIAL	0.0	0.0	0.0	0.0
	RIVERSIDE	0.0	0.0	0.0	0.0
SALTON SEA Total		0.0	0.0	0.0	0.0
SAN DIEGO	SAN DIEGO	0.0	0.0	0.0	0.0
SAN DIEGO Total		0.0	0.0	0.0	0.0
SAN FRANCISCO BAY	ALAMEDA	0.0	0.0	0.0	0.0
	CONTRA COSTA	0.0	0.0	0.0	0.0
	MARIN	0.0	0.0	0.0	0.0
	NAPA	0.0	0.0	0.0	0.0
	SAN FRANCISCO	0.0	0.0	0.0	0.0
	SAN MATEO	0.0	0.0	0.0	0.0
	SANTA CLARA	0.0	0.0	0.0	0.0
	SOLANO	0.0	0.0	0.0	0.0
	SONOMA	0.0	0.0	0.0	0.0
SAN FRANCISCO BAY Total		0.0	0.0	0.0	0.0
SAN JOAQUIN VALLEY	FRESNO	0.0	0.0	0.0	0.0
	KERN	0.0	0.0	0.0	0.0
	KINGS	0.0	0.0	0.0	0.0
	MADERA	669.3	60.7	5.2	6.1
	MERCED	6474.9	444.2	38.0	44.6
	SAN JOAQUIN	0.0	0.0	0.0	0.0
	STANISLAUS	0.0	0.0	0.0	0.0
	TULARE	0.0	0.0	0.0	0.0
SAN JOAQUIN VALLEY Total		7144.2	504.9	43.3	50.8
SOUTH CENTRAL COAST	SAN LUIS OBISPO	2122.0	641.2	55.2	65.0
	SANTA BARBARA	4097.3	4321.2	371.2	437.6
	VENTURA	12720.4	6978.3	599.7	706.7
SOUTH CENTRAL COAST Total		18939.7	11940.8	1026.1	1209.3
SOUTH COAST	LOS ANGELES	0.0	0.0	0.0	0.0
	ORANGE	0.0	0.0	0.0	0.0
	RIVERSIDE	0.0	0.0	0.0	0.0
	SAN BERNARDINO	1483.8	997.4	85.7	101.0
SOUTH COAST Total		1483.8	997.4	85.7	101.0
Grand Total		77482.3	101299.9	9063.2	10680.6

METHOD	Berkeley
CAUSE	prescribed

		Data			
AIRBASIN	COUNTY	Sum of AREA	Sum of CO	Sum of PM25	Sum of PM10
GREAT BASIN VALLEYS	ALPINE	0.0	0.0	0.0	0.0
	INYO	407.1	64.4	5.5	6.5
	MONO	0.0	0.0	0.0	0.0
GREAT BASIN VALLEYS Total		407.1	64.4	5.5	6.5
LAKE COUNTY	LAKE	0.0	0.0	0.0	0.0
LAKE COUNTY Total		0.0	0.0	0.0	0.0
LAKE TAHOE	EL DORADO	0.0	0.0	0.0	0.0
	PLACER	0.0	0.0	0.0	0.0
LAKE TAHOE Total		0.0	0.0	0.0	0.0
MOJAVE DESERT	IMPERIAL	0.0	0.0	0.0	0.0
	KERN	0.0	0.0	0.0	0.0
	LOS ANGELES	0.0	0.0	0.0	0.0
	RIVERSIDE	0.0	0.0	0.0	0.0
	SAN BERNARDINO	0.0	0.0	0.0	0.0
MOJAVE DESERT Total		0.0	0.0	0.0	0.0
MOUNTAIN COUNTIES	AMADOR	0.0	0.0	0.0	0.0
	CALAVERAS	0.0	0.0	0.0	0.0
	EL DORADO	0.0	0.0	0.0	0.0
	MARIPOSA	183.3	447.6	39.4	46.5
	NEVADA	217.0	623.5	54.9	64.7
	PLACER	120.2	323.9	28.5	33.6
	PLUMAS	0.0	0.0	0.0	0.0
	SIERRA	0.0	0.0	0.0	0.0
	TUOLUMNE	2377.8	6814.3	598.2	705.1
MOUNTAIN COUNTIES Total		2898.2	8209.3	721.0	849.8
NORTH CENTRAL COAST	MONTEREY	0.0	0.0	0.0	0.0
	SAN BENITO	0.0	0.0	0.0	0.0
	SANTA CRUZ	237.2	1249.9	113.1	133.4
NORTH CENTRAL COAST Total		237.2	1249.9	113.1	133.4
NORTH COAST	DEL NORTE	0.0	0.0	0.0	0.0
	HUMBOLDT	2791.9	913.2	82.7	97.4
	MENDOCINO	0.0	0.0	0.0	0.0
	SONOMA	0.0	0.0	0.0	0.0
	TRINITY	0.0	0.0	0.0	0.0
NORTH COAST Total		2791.9	913.2	82.7	97.4
NORTHEAST PLATEAU	LASSEN	0.0	0.0	0.0	0.0
	MODOC	0.0	0.0	0.0	0.0
	SISKIYOU	172.1	21.9	2.0	2.4
NORTHEAST PLATEAU Total		172.1	21.9	2.0	2.4

SACRAMENTO VALLEY	BUTTE	0.0	0.0	0.0	0.0
	COLUSA	0.0	0.0	0.0	0.0
	GLENN	0.0	0.0	0.0	0.0
	PLACER	0.0	0.0	0.0	0.0
	SACRAMENTO	0.0	0.0	0.0	0.0
	SHASTA	0.0	0.0	0.0	0.0
	SOLANO	0.0	0.0	0.0	0.0
	SUTTER	0.0	0.0	0.0	0.0
	TEHAMA	0.0	0.0	0.0	0.0
	YOLO	0.0	0.0	0.0	0.0
	YUBA	198.3	49.9	4.9	5.7
SACRAMENTO VALLEY Total		198.3	49.9	4.9	5.7
SALTON SEA	IMPERIAL	0.0	0.0	0.0	0.0
	RIVERSIDE	0.0	0.0	0.0	0.0
SALTON SEA Total		0.0	0.0	0.0	0.0
SAN DIEGO	SAN DIEGO	0.0	0.0	0.0	0.0
SAN DIEGO Total		0.0	0.0	0.0	0.0
SAN FRANCISCO BAY	ALAMEDA	0.0	0.0	0.0	0.0
	CONTRA COSTA	0.0	0.0	0.0	0.0
	MARIN	0.0	0.0	0.0	0.0
	NAPA	0.0	0.0	0.0	0.0
	SAN FRANCISCO	0.0	0.0	0.0	0.0
	SAN MATEO	74.7	10.5	1.0	1.2
	SANTA CLARA	0.0	0.0	0.0	0.0
	SOLANO	0.0	0.0	0.0	0.0
	SONOMA	0.0	0.0	0.0	0.0
SAN FRANCISCO BAY Total		74.7	10.5	1.0	1.2
SAN JOAQUIN VALLEY	FRESNO	0.0	0.0	0.0	0.0
	KERN	0.0	0.0	0.0	0.0
	KINGS	0.0	0.0	0.0	0.0
	MADERA	0.0	0.0	0.0	0.0
	MERCED	0.0	0.0	0.0	0.0
	SAN JOAQUIN	0.0	0.0	0.0	0.0
	STANISLAUS	0.0	0.0	0.0	0.0
	TULARE	0.0	0.0	0.0	0.0
SAN JOAQUIN VALLEY Total		0.0	0.0	0.0	0.0
SOUTH CENTRAL COAST	SAN LUIS OBISPO	1312.9	362.1	35.4	41.7
	SANTA BARBARA	3365.2	926.2	83.7	98.5
	VENTURA	0.0	0.0	0.0	0.0
SOUTH CENTRAL COAST Total		4678.1	1288.2	119.1	140.2
SOUTH COAST	LOS ANGELES	0.0	0.0	0.0	0.0
	ORANGE	0.0	0.0	0.0	0.0
	RIVERSIDE	0.0	0.0	0.0	0.0
	SAN BERNARDINO	0.0	0.0	0.0	0.0
SOUTH COAST Total		0.0	0.0	0.0	0.0
Grand Total		11457.6	11807.3	1049.4	1236.6

Table 6: EES Output - Siskiyou County Vegetation Comparison
** Units in tons and percent deviation from defaults*

		Fuel Component									
Parameterization	*Pollutant*	*Canopy branchwood*	*Canopy foliage*	*Duff*	*Herbs*	*Litter*	*Tree Regen*	*Shrubs*	*Wood 0-1 inch*	*Wood 1-3 inch*	*Wood 3+ inches*
Standard GAP processing (default)											
	PM10 Total	54.39	218.41	1343.07	70.88	90.99	10.32	175.89	77.30	75.49	2009.42
	PM25 Total	46.17	185.35	1139.97	60.42	77.54	8.38	149.37	65.64	64.16	1704.33
	CO Total	539.26	2168.48	13967.42	705.27	513.05	99.84	1747.98	435.34	599.67	18347.00
CALVEG Totals											
	PM10 Total	169.82	628.14	858.26	74.00	56.71	9.42	971.79	31.19	32.97	744.78
	PM25 Total	144.14	533.04	728.05	62.88	48.07	7.77	824.92	26.59	28.04	631.63
	CO Total	1685.35	6236.23	8922.99	735.65	317.73	91.64	9651.00	176.15	261.72	6800.16
CALVEG Totals											
	PM10 %	212.2%	187.6%	-36.1%	4.4%	-37.7%	-8.8%	452.5%	-59.6%	-56.3%	-62.9%
	PM25 %	212.2%	187.6%	-36.1%	4.1%	-38.0%	-7.3%	452.3%	-59.5%	-56.3%	-62.9%
	CO %	212.5%	187.6%	-36.1%	4.3%	-38.1%	-8.2%	452.1%	-59.5%	-56.4%	-62.9%
Alternative GAP processing											
	PM10 Total	37.47	154.71	1412.04	80.15	83.80	10.83	120.21	91.38	89.03	2436.69
	PM25 Total	31.80	131.29	1198.50	68.38	71.33	8.82	102.18	77.59	75.70	2066.73
	CO Total	371.50	1535.99	14684.70	797.40	472.31	104.83	1194.71	514.83	707.36	22248.07
Alternative GAP processing											
	PM10 %	-31.1%	-29.2%	5.1%	13.1%	-7.9%	4.9%	-31.7%	18.2%	17.9%	21.3%
	PM25 %	-31.1%	-29.2%	5.1%	13.2%	-8.0%	5.2%	-31.6%	18.2%	18.0%	21.3%
	CO %	-31.1%	-29.2%	5.1%	13.1%	-7.9%	5.0%	-31.7%	18.3%	18.0%	21.3%

Table 7: EES Output - EEE Parameter Input Comparison
** Units in tons and percent deviation from defaults*

		Fuel Component									
Parameterization	*Pollutant*	*Canopy branchwood*	*Canopy foliage*	*Duff*	*Herbs*	*Litter*	*Tree Regen*	*Shrubs*	*Wood 0-1 inch*	*Wood 1-3 inch*	*Wood 3+ inches*
Default parameters											
	PM10 Total	159.66	632.10	3284.95	277.16	334.49	30.70	1685.00	219.79	183.06	5060.05
	PM25 Total	135.56	536.40	2787.93	235.96	284.61	24.73	1430.53	186.89	155.57	4291.82
	CO Total	1584.97	6275.47	34161.13	2755.15	1883.69	295.96	16735.67	1238.00	1454.25	46200.61
NFDR-TH 30%											
	PM10 Total	159.66	632.10	0.00	277.16	334.49	30.70	1685.00	219.79	183.06	0.00
	PM25 Total	135.56	536.40	0.00	235.96	284.61	24.73	1430.53	186.89	155.57	0.00
	CO Total	1584.97	6275.47	0.00	2755.15	1883.69	295.96	16735.67	1238.00	1454.25	0.00
NFDR-TH 30%											
	PM10 %	0.0%	0.0%	-100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-100.0%
	PM25 %	0.0%	0.0%	-100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-100.0%
	CO %	0.0%	0.0%	-100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-100.0%
NFDR-TH 10%											
	PM10 Total	159.66	632.10	7779.59	277.16	334.49	30.70	1685.00	219.79	183.06	6639.73
	PM25 Total	135.56	536.40	6602.38	235.96	284.61	24.73	1430.53	186.89	155.57	5631.61
	CO Total	1584.97	6275.47	80895.28	2755.15	1883.69	295.96	16735.67	1238.00	1454.25	60626.67
NFDR-TH 10%											
	PM10 %	0.0%	0.0%	136.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	31.2%
	PM25 %	0.0%	0.0%	136.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	31.2%
	CO %	0.0%	0.0%	136.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	31.2%
Wet moisture conditions											
	PM10 Total	159.66	632.10	3047.14	277.16	334.49	30.70	1685.00	219.79	183.06	7046.57
	PM25 Total	135.56	536.40	2582.52	235.96	284.61	24.73	1430.53	186.89	155.57	5960.45
	CO Total	1584.97	6275.47	31188.77	2755.15	1883.69	295.96	16735.67	1238.00	1454.25	71234.90
Wet moisture conditions											
	PM10 %	0.0%	0.0%	-7.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	39.3%
	PM25 %	0.0%	0.0%	-7.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	38.9%
	CO %	0.0%	0.0%	-8.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	54.2%
Moderate moisture conditions											
	PM10 Total	159.66	632.10	3284.95	277.16	334.49	30.70	1685.00	219.79	183.06	5721.99
	PM25 Total	135.56	536.40	2787.93	235.96	284.61	24.73	1430.53	186.89	155.57	4848.03
	CO Total	1584.97	6275.47	34161.13	2755.15	1883.69	295.96	16735.67	1238.00	1454.25	54518.92
Moderate moisture conditions											
	PM10 %	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	13.1%
	PM25 %	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	13.0%
	CO %	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	18.0%
Dry moisture conditions											
	PM10 Total	159.66	632.10	3284.95	277.16	334.49	30.70	1685.00	219.79	183.06	5060.05
	PM25 Total	135.56	536.40	2787.93	235.96	284.61	24.73	1430.53	186.89	155.57	4291.82
	CO Total	1584.97	6275.47	34161.13	2755.15	1883.69	295.96	16735.67	1238.00	1454.25	46200.61
Dry moisture conditions											
	PM10 %	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	PM25 %	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	CO %	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table 7 continued: EES Output - EEE Parameter Input Comparison
** Units in tons and percent deviation from defaults*

		Fuel Component									
Parameterization	*Pollutant*	*Canopy branchwood*	*Canopy foliage*	*Duff*	*Herbs*	*Litter*	*Tree Regen*	*Shrubs*	*Wood 0-1 inch*	*Wood 1-3 inch*	*Wood 3+ inches*
Default parameters											
	PM10 Total	159.66	632.10	3284.95	277.16	334.49	30.70	1685.00	219.79	183.06	5060.05
	PM25 Total	135.56	536.40	2787.93	235.96	284.61	24.73	1430.53	186.89	155.57	4291.82
	CO Total	1584.97	6275.47	34161.13	2755.15	1883.69	295.96	16735.67	1238.00	1454.25	46200.61
No crown burning											
	PM10 Total	0.00	0.00	3284.95	277.16	334.49	30.70	1685.00	219.79	183.06	5060.05
	PM25 Total	0.00	0.00	2787.93	235.96	284.61	24.73	1430.53	186.89	155.57	4291.82
	CO Total	0.00	0.00	34161.13	2755.15	1883.69	295.96	16735.67	1238.00	1454.25	46200.61
No crown burning											
	PM10 %	-100.0%	-100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	PM25 %	-100.0%	-100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	CO %	-100.0%	-100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Low live fuel loading											
	PM10 Total	79.21	316.05	3284.95	133.40	334.49	0.00	1631.61	219.79	183.06	5060.05
	PM25 Total	67.33	268.17	2787.93	113.51	284.61	0.00	1384.86	186.89	155.57	4291.82
	CO Total	786.53	3137.76	34161.13	1322.94	1883.69	0.00	16201.24	1238.00	1454.25	46200.61
Low live fuel loading											
	PM10 %	-50.4%	-50.0%	0.0%	-51.9%	0.0%	-100.0%	-3.2%	0.0%	0.0%	0.0%
	PM25 %	-50.3%	-50.0%	0.0%	-51.9%	0.0%	-100.0%	-3.2%	0.0%	0.0%	0.0%
	CO %	-50.4%	-50.0%	0.0%	-52.0%	0.0%	-100.0%	-3.2%	0.0%	0.0%	0.0%
High live fuel loading											
	PM10 Total	269.60	1134.50	3284.95	465.47	334.49	59.39	1736.44	219.79	183.06	5060.05
	PM25 Total	228.75	962.75	2787.93	394.39	284.61	50.50	1474.30	186.89	155.57	4291.82
	CO Total	2676.17	11263.89	34161.13	4620.53	1883.69	592.89	17245.58	1238.00	1454.25	46200.61
High live fuel loading											
	PM10 %	68.9%	79.5%	0.0%	67.9%	0.0%	93.4%	3.1%	0.0%	0.0%	0.0%
	PM25 %	68.7%	79.5%	0.0%	67.1%	0.0%	104.2%	3.1%	0.0%	0.0%	0.0%
	CO %	68.8%	79.5%	0.0%	67.7%	0.0%	100.3%	3.0%	0.0%	0.0%	0.0%
Low dead fuel loading											
	PM10 Total	159.66	632.10	1971.30	277.16	167.23	30.70	1720.60	153.70	127.79	2023.79
	PM25 Total	135.56	536.40	1672.66	235.96	142.13	24.73	1460.76	130.64	108.88	1716.71
	CO Total	1584.97	6275.47	20496.72	2755.15	941.84	295.96	17087.01	866.06	1018.02	18480.01
Low dead fuel loading											
	PM10 %	0.0%	0.0%	-40.0%	0.0%	-50.0%	0.0%	2.1%	-30.1%	-30.2%	-60.0%
	PM25 %	0.0%	0.0%	-40.0%	0.0%	-50.1%	0.0%	2.1%	-30.1%	-30.0%	-60.0%
	CO %	0.0%	0.0%	-40.0%	0.0%	-50.0%	0.0%	2.1%	-30.0%	-30.0%	-60.0%
High dead fuel loading											
	PM10 Total	159.66	632.10	4599.50	277.16	400.98	30.70	1654.77	284.92	237.46	8095.61
	PM25 Total	135.56	536.40	3904.01	235.96	340.63	24.73	1405.00	242.10	202.22	6866.38
	CO Total	1584.97	6275.47	47824.55	2755.15	2260.10	295.96	16434.72	1609.34	1891.18	73920.76
High dead fuel loading											
	PM10 %	0.0%	0.0%	40.0%	0.0%	19.9%	0.0%	-1.8%	29.6%	29.7%	60.0%
	PM25 %	0.0%	0.0%	40.0%	0.0%	19.7%	0.0%	-1.8%	29.5%	30.0%	60.0%
	CO %	0.0%	0.0%	40.0%	0.0%	20.0%	0.0%	-1.8%	30.0%	30.0%	60.0%