APPENDIX D

Natural Sources

Appendix D: *Natural Sources*

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Appendix D

Introduction

Appendix D contains estimates of emissions from natural processes occurring in terrestrial, marine, or aquatic ecosystems. Natural source air emissions include a variety of compounds and occur as a result of geologic or meteorological activity (such as petroleum seeps, or wildfires), or living processes by flora and fauna (such as emissions from vegetation foliage, or from soil microbes). Emissions resulting from anthropogenic activities, such as soil ammonia (NH_3) emissions resulting from fertilizer application, burning of agricultural crop residues, prescribed burning of natural areas, wildfires that are managed for resources benefit, and windblown dust from crop fields and pastures are provided in Chapter 2. Windblown dust emissions from dry lake beds have not been included.

For this edition of the Almanac, categories of natural sources include geogenic (petroleum seeps) and biogenic (vegetation) sources, and wildfires. Other categories may be added in future editions. Natural emissions are strongly affected by seasonal influences on factors such as temperature and moisture conditions, or wind regimes. Emissions during "peak season" are often orders of magnitude greater than emissions during dormant periods. Emissions for some categories (for example see Figure D-1) are therefore reported with respect to time of year, in addition to annual averages. Emissions can fluctuate greatly from year-to-year due to variation in meteorology or land cover/land use. Methods for forecasting future natural emissions due to changes in climate or land cover/land use remain in the realm of on-going scientific research, and have not been applied in this edition of the Almanac.

Statewide

Natural Source Emissions (tons/day, annual average)

Category	VOC	NO_X	SO_X	PM_{10}	$PM_{2.5}$	NH_3
Biogenic Sources	2067	0	0	0	0	0
Geogenic Sources	31	0	0	0	0	62
Wildfires	335	27	24	445	377	48
Natural Sources Total	2433	27	24	445	377	110

* Biogenic and geogenic emissions are not year-specific.
** Wildfire emissions reflect 10-year averages.
Table D-1

Biogenic Sources

Biogenic volatile organic compounds (BVOCs) are emitted into the atmosphere from terrestrial ecosystems such as vegetation. BVOCs include isoprene, monoterpenes, methylbutenol (MBO), and other biogenic VOCs (OVOCs). These compounds are of interest because of their roles in atmospheric chemistry and climate. In the presence of anthropogenic NO_x compounds, isoprene has been found to play a significant role in ozone chemistry. Monoterpenes and MBO are moderately reactive. OVOCs are a general category comprised of less reactive compounds, such as methanol and acetone. Isoprene, monoterpenes, MBO, and a fraction of the OVOCs are considered as reactive organic gas (ROG).

Plant BVOC emissions vary by compound and by orders of magnitude among various plant species. BVOCs play roles in plant physiology and chemical defense from pests and plant diseases. BVOC emissions are strongly influenced by environmental factors such as temperature and sunlight. Biophysical and environmental mechanisms controlling the synthesis and emission of isoprene, monoterpenes, and MBO have been studied across a variety of plant species and landscapes. Less is known about OVOCs. As a result, the BVOC research community has developed BVOC emission models, which have been routinely applied by the climate research, air quality, and emissions modeling community. A statewide model was developed to estimate BVOC emissions from vegetation over the course of a calendar year. The model runs at a 4 km x 4 km spatial resolution and generates hourly emissions of isoprene, monoterpenes, MBO, and OVOCs. Emissions from vegetation were estimated from plant species leaf mass and emission factors, and environmental adjustment algorithms representing light and temperature dependence of BVOC emissions. Leaf mass density estimates, used to scale emissions from leaf to landscapes, were based on geographic information system (GIS) land use/land cover databases, species leaf weight factors, and monthly satellite leaf area index (LAI) data. Temporal and spatial variation in the model was driven by monthly estimates of leaf mass densities and hourly light and temperature. The annual statewide emission of BVOC (reported here as ROG) is estimated to be over 750,000 tons, composed of 37 percent isoprene, 30 percent MBO, 24 percent monoterpenes, and 9 percent OVOC. As shown in Figure D-1, the majority of biogenic emissions are produced during the ozone season (May through October).

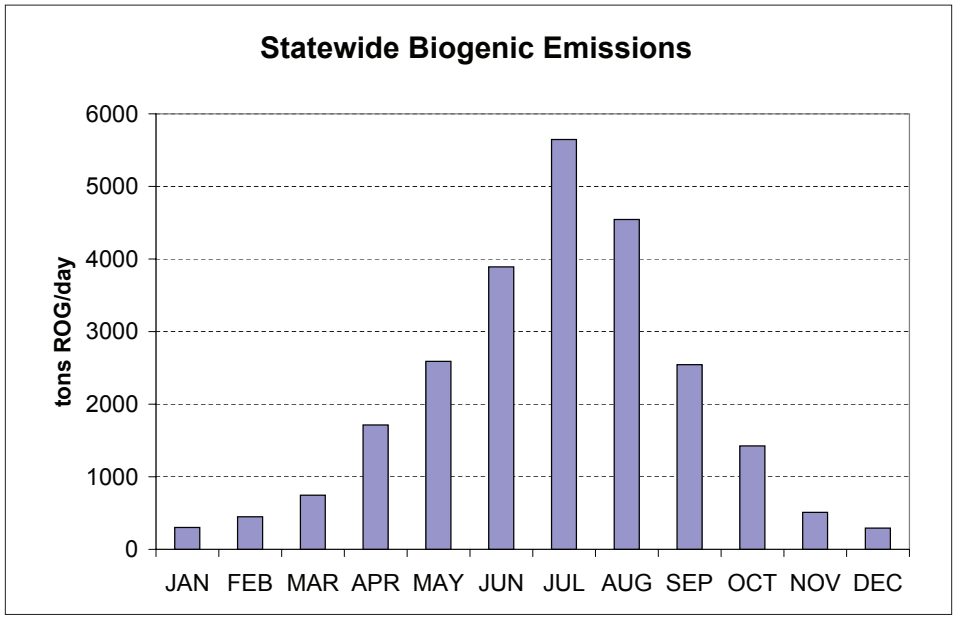

Figure D-1

Natural Source Emissions - Biogenic Sources

(tons/day, annual average)

COUNTY	AIR BASIN	DISTRICT	VOC
Alameda	San Francisco Bay Area	Bay Area AQMD	11
Alpine	Great Basin Valleys	Great Basin Unified APCD	9
Amador	Mountain Counties	Amador County APCD	15
Butte	Sacramento Valley	Butte County AQMD	41
Calaveras	Mountain Counties	Calaveras County APCD	38
Colusa	Sacramento Valley	Colusa County APCD	22
Contra Costa	San Francisco Bay Area	Bay Area AQMD	11
Del Norte	North Coast	North Coast Unified AQMD	24
El Dorado	Lake Tahoe	El Dorado County APCD	2
El Dorado	Mountain Counties	El Dorado County APCD	49
Fresno	San Joaquin Valley	San Joaquin Valley Unified APCD	63
Glenn	Sacramento Valley	Glenn County APCD	17
Humboldt	North Coast	North Coast Unified AQMD	81
Imperial	Salton Sea	Imperial County APCD	3
Inyo	Great Basin Valleys	Great Basin Unified APCD	7
Kern	Mojave Desert	Kern County APCD	23
Kern	San Joaquin Valley	San Joaquin Valley Unified APCD	18
Kings	San Joaquin Valley	San Joaquin Valley Unified APCD	4
Lake	Lake County	Lake County AQMD	55
Lassen	Northeast Plateau	Lassen County APCD	56
Los Angeles	Mojave Desert	Antelope Valley AQMD	6
Los Angeles	South Coast	South Coast AQMD	30
Madera	San Joaquin Valley	San Joaquin Valley Unified APCD	38
Marin	San Francisco Bay Area	Bay Area AQMD	7
Mariposa	Mountain Counties	Mariposa County APCD	35
Mendocino	North Coast	Mendocino County AQMD	117
Merced	San Joaquin Valley	San Joaquin Valley Unified APCD	6
Modoc	Northeast Plateau	Modoc County APCD	54
Mono	Great Basin Valleys	Great Basin Unified APCD	21
Monterey	North Central Coast	Monterey Bay Unified APCD	50

Table D-2

Natural Source Emissions - Biogenic Sources

(tons/day, annual average) ***(Cont)***

COUNTY	AIR BASIN	DISTRICT	VOC
Napa	San Francisco Bay Area	Bay Area AQMD	26
Nevada	Mountain Counties	Northern Sierra AQMD	36
Orange	South Coast	South Coast AQMD	9
Placer	Lake Tahoe	Placer County APCD	1
Placer	Mountain Counties	Placer County APCD	26
Placer	Sacramento Valley	Placer County APCD	7
Plumas	Mountain Counties	Northern Sierra AQMD	43
Riverside	Mojave Desert	Mojave Desert AQMD	0
Riverside	Mojave Desert	South Coast AQMD	0
Riverside	Salton Sea	South Coast AQMD	7
Riverside	South Coast	South Coast AQMD	22
Sacramento	Sacramento Valley	Sacramento Metropolitan AQMD	10
San Benito	North Central Coast	Monterey Bay Unified APCD	17
San Bernardino	Mojave Desert	Mojave Desert AQMD	6
San Bernardino	South Coast	South Coast AQMD	15
San Diego	San Diego	San Diego County APCD	67
San Francisco	San Francisco Bay Area	Bay Area AQMD	1
San Joaquin	San Joaquin Valley	San Joaquin Valley Unified APCD	8
San Luis Obispo	South Central Coast	San Luis Obispo County APCD	32
San Mateo	San Francisco Bay Area	Bay Area AQMD	7
Santa Barbara	South Central Coast	Santa Barbara County APCD	35
Santa Clara	San Francisco Bay Area	Bay Area AQMD	29
Santa Cruz	North Central Coast	Monterey Bay Unified APCD	5
Shasta	Sacramento Valley	Shasta County AQMD	166
Sierra	Mountain Counties	Northern Sierra AQMD	17
Siskiyou	Northeast Plateau	Siskiyou County APCD	159
Solano	Sacramento Valley	Yolo/Solano AQMD	4
Solano	San Francisco Bay Area	Bay Area AQMD	3
Sonoma	North Coast	Northern Sonoma County APCD	23
Sonoma	San Francisco Bay Area	Bay Area AQMD	10

Table D-2 (Cont)

Natural Source Emissions - Biogenic Sources

(tons/day, annual average) *(Cont)*

COUNTY	AIR BASIN	DISTRICT	VOC
Stanislaus	San Joaquin Valley	San Joaquin Valley Unified APCD	12
Sutter	Sacramento Valley	Feather River AQMD	3
Tehama	Sacramento Valley	Tehama County APCD	66
Trinity	North Coast	North Coast Unified AQMD	118
Tulare	San Joaquin Valley	San Joaquin Valley Unified APCD	61
Tuolumne	Mountain Counties	Tuolumne County APCD	46
Ventura	South Central Coast	Ventura County APCD	26
Yolo	Sacramento Valley	Yolo/Solano AQMD	15
Yuba	Sacramento Valley	Feather River AQMD	15

Table D-2 (Cont)

* Biogenic emissions are not year-specific.

Geogenic Sources

Petroleum gas and oil seeps occur naturally in California and have been active for millennia. Oil and gas seeps form where oil or natural gas emerge from subsurface sources to the ground or water surface. Seeps are associated with water springs in which oil floats to the surface of the water, and gas bubbles out into the atmosphere. Large seeps may be comprised of nearly pure oil, asphaltum, or semisolid bitumen. Most seeps are mixed with varying amounts of sand, clay, and biomass debris. Terrestrial seep flows vary with the seasons, with elevated flows occurring during warm weather. Seismic activity can create new seeps or cause increased flows from existing seeps. Major marine seeps are located off the coast of Santa Barbara County. Other seeps occur in regions of oil and gas production throughout the state.

Natural Source Emissions - Geogenic Sources

(tons/day, annual average)

COUNTY	AIR BASIN	DISTRICT	VOC	NH_3
Alameda	San Francisco Bay Area	Bay Area AQMD	0	0
Alpine	Great Basin Valleys	Great Basin Unified APCD	0	0
Amador	Mountain Counties	Amador County APCD	0	0
Butte	Sacramento Valley	Butte County AQMD	0	1
Calaveras	Mountain Counties	Calaveras County APCD	0	1
Colusa	Sacramento Valley	Colusa County APCD	0	0
Contra Costa	San Francisco Bay Area	Bay Area AQMD	0	0
Del Norte	North Coast	North Coast Unified AQMD	0	1
El Dorado	Lake Tahoe	El Dorado County APCD	0	0
El Dorado	Mountain Counties	El Dorado County APCD	0	1
Fresno	San Joaquin Valley	San Joaquin Valley Unified APCD	0	2
Glenn	Sacramento Valley	Glenn County APCD	0	0
Humboldt	North Coast	North Coast Unified AQMD	0	3
Imperial	Salton Sea	Imperial County APCD	0	1
Inyo	Great Basin Valleys	Great Basin Unified APCD	0	3
Kern	Mojave Desert	Kern County APCD	0	1
Kern	San Joaquin Valley	San Joaquin Valley Unified APCD	0	1
Kings	San Joaquin Valley	San Joaquin Valley Unified APCD	0	0
Lake	Lake County	Lake County AQMD	0	1
Lassen	Northeast Plateau	Lassen County APCD	0	2
Los Angeles	Mojave Desert	Antelope Valley AQMD	0	0
Los Angeles	South Coast	South Coast AQMD	0	1
Madera	San Joaquin Valley	San Joaquin Valley Unified APCD	0	1
Marin	San Francisco Bay Area	Bay Area AQMD	0	0
Mariposa	Mountain Counties	Mariposa County APCD	0	1
Mendocino	North Coast	Mendocino County AQMD	0	2
Merced	San Joaquin Valley	San Joaquin Valley Unified APCD	0	0
Modoc	Northeast Plateau	Modoc County APCD	0	2
Mono	Great Basin Valleys	Great Basin Unified APCD	0	1
Monterey	North Central Coast	Monterey Bay Unified APCD	0	1

Table D-3

Natural Source Emissions - Geogenic Sources

(tons/day, annual average) ***(Cont)***

COUNTY	AIR BASIN	DISTRICT	VOC	NH_3
Napa	San Francisco Bay Area	Bay Area AQMD	0	0
Nevada	Mountain Counties	Northern Sierra AQMD	0	1
Orange	South Coast	South Coast AQMD	0	0
Placer	Lake Tahoe	Placer County APCD	0	0
Placer	Mountain Counties	Placer County APCD	0	1
Placer	Sacramento Valley	Placer County APCD	0	0
Plumas	Mountain Counties	Northern Sierra AQMD	0	2
Riverside	Mojave Desert	Mojave Desert AQMD	0	0
Riverside	Mojave Desert	South Coast AQMD	0	1
Riverside	Salton Sea	South Coast AQMD	0	1
Riverside	South Coast	South Coast AQMD	0	1
Sacramento	Sacramento Valley	Sacramento Metropolitan AQMD	0	0
San Benito	North Central Coast	Monterey Bay Unified APCD	0	0
San Bernardino	Mojave Desert	Mojave Desert AQMD	0	5
San Bernardino	South Coast	South Coast AQMD	0	0
San Diego	San Diego	San Diego County APCD	0	1
San Francisco	San Francisco Bay Area	Bay Area AQMD	0	0
San Joaquin	San Joaquin Valley	San Joaquin Valley Unified APCD	0	0
San Luis Obispo	South Central Coast	San Luis Obispo County APCD	0	1
San Mateo	San Francisco Bay Area	Bay Area AQMD	0	0
Santa Barbara	Outer Continental Shelf	Santa Barbara County APCD	9	0
Santa Barbara	South Central Coast	Santa Barbara County APCD	18	1
Santa Clara	San Francisco Bay Area	Bay Area AQMD	0	1
Santa Cruz	North Central Coast	Monterey Bay Unified APCD	0	0
Shasta	Sacramento Valley	Shasta County AQMD	0	2
Sierra	Mountain Counties	Northern Sierra AQMD	0	1
Siskiyou	Northeast Plateau	Siskiyou County APCD	0	4
Solano	Sacramento Valley	Yolo/Solano AQMD	0	0
Solano	San Francisco Bay Area	Bay Area AQMD	0	0
Sonoma	North Coast	Northern Sonoma County APCD	0	1

Table D-3 (Cont)

Natural Source Emissions - Geogenic Sources

(tons/day, annual average) *(Cont)*

COUNTY	AIR BASIN	DISTRICT	VOC	NH_3
Sonoma	San Francisco Bay Area	Bay Area AQMD	0	0
Stanislaus	San Joaquin Valley	San Joaquin Valley Unified APCD	0	0
Sutter	Sacramento Valley	Feather River AQMD	0	0
Tehama	Sacramento Valley	Tehama County APCD	0	1
Trinity	North Coast	North Coast Unified AQMD	0	2
Tulare	San Joaquin Valley	San Joaquin Valley Unified APCD	0	2
Tuolumne	Mountain Counties	Tuolumne County APCD	0	1
Ventura	South Central Coast	Ventura County APCD	4	1
Yolo	Sacramento Valley	Yolo/Solano AQMD	0	0
Yuba	Sacramento Valley	Feather River AQMD	0	0

Table D-3 (Cont)

* Geogenic emissions are not year-specific.

Wildfires

A wildfire is a natural event that burns a variety of vegetation types ranging in timing, scale and severity. This wildfire category does not include prescribed fires such as agriculture burning, forest management fires, or Wildland Fire Use (WFU). A prescribed burn is a fire ignited by a planned management action whereas a WFU is a naturally ignited lightning fire that is managed for resources benefit.

Wildfires can vary significantly from year to year; an area may have extreme wildfire behavior one year and none the following year. Emissions for PM_{10}, $PM_{2.5}$, NO_x, SO_x, NH_3, and VOC (Total Non-Methane Hydrocarbon, reported here as VOC) are estimated by air basin and county. About 90 percent of wildfires occur between May and October, with July as the highest month. The wildfire emission estimates presented in this Almanac are based on a 10-year average that was calculated from actual 2001 - 2010 wildfire activity. Figure D-2 is a map showing all of the wildfires that burned between 2001 and 2010 in California. The tables that follow show the 10-year average emissions per county and air basin.

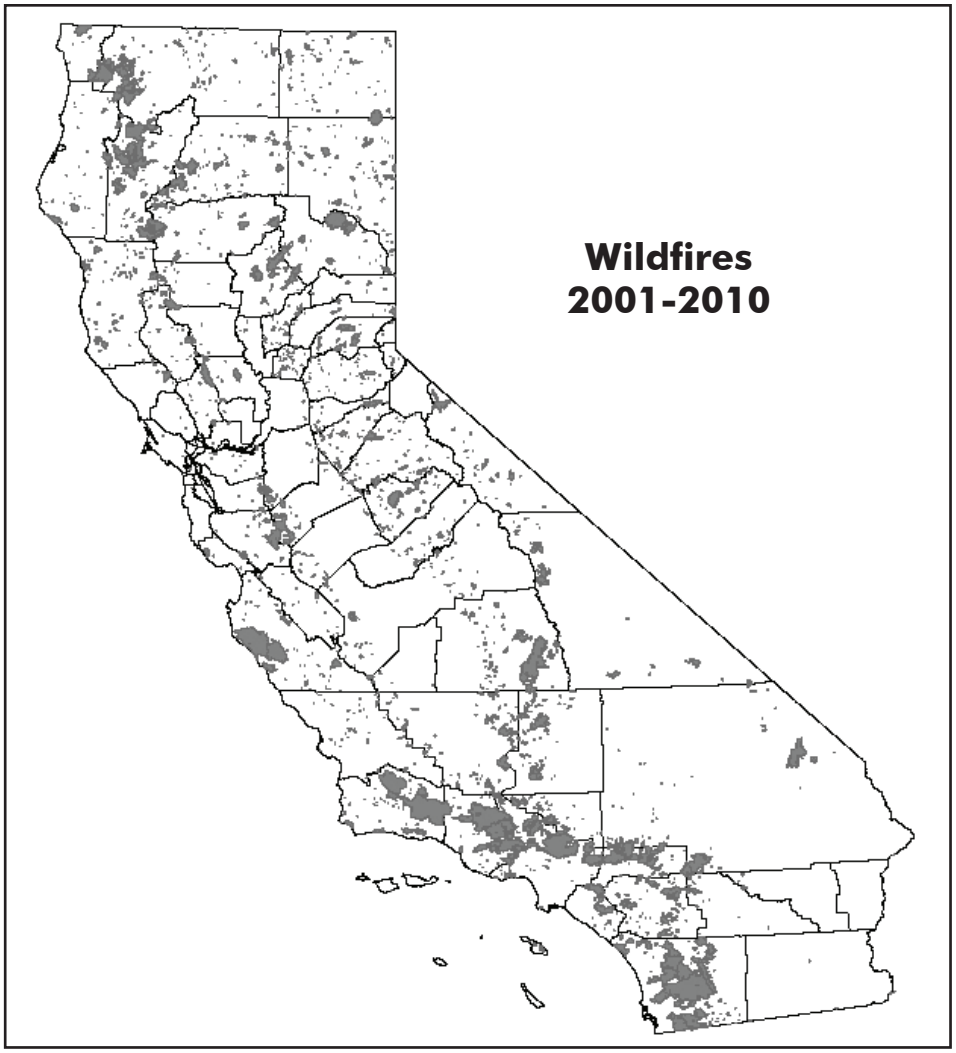

Figure D-2

Natural Source Emissions - Wildfires

(tons/day, annual average)

COUNTY	AIR BASIN	DISTRICT	VOC	NO_x	SO_x	PM_{10}	$PM_{2.5}$	NH_3
Alameda	San Francisco Bay Area	Bay Area AQMD	0	0	0	0	0	0
Alpine	Great Basin Valleys	Great Basin Unified APCD	0	0	0	0	0	0
Amador	Mountain Counties	Amador County APCD	2	0	0	3	2	0
Butte	Sacramento Valley	Butte County AQMD	9	0	1	11	10	1
Calaveras	Mountain Counties	Calaveras County APCD	1	0	0	2	1	0
Colusa	Sacramento Valley	Colusa County APCD	1	0	0	2	2	0
Contra Costa	San Francisco Bay Area	Bay Area AQMD	0	0	0	0	0	0
Del Norte	North Coast	North Coast Unified AQMD	11	0	1	14	12	2
El Dorado	Lake Tahoe	El Dorado County APCD	1	0	0	1	1	0
El Dorado	Mountain Counties	El Dorado County APCD	1	0	0	2	2	0
Fresno	San Joaquin Valley	San Joaquin Valley Unified APCD	1	0	0	1	1	0
Glenn	Sacramento Valley	Glenn County APCD	3	0	0	4	4	0
Humboldt	North Coast	North Coast Unified AQMD	5	0	0	6	5	1
Imperial	Salton Sea	Imperial County APCD	0	0	0	0	0	0
Inyo	Great Basin Valleys	Great Basin Unified APCD	1	0	0	1	1	0
Kern	Mojave Desert	Kern County APCD	8	0	0	11	9	1
Kern	San Joaquin Valley	San Joaquin Valley Unified APCD	1	0	0	1	1	0
Kings	San Joaquin Valley	San Joaquin Valley Unified APCD	0	0	0	0	0	0
Lake	Lake County	Lake County AQMD	2	0	0	3	3	0
Lassen	Northeast Plateau	Lassen County APCD	6	0	0	8	7	1
Los Angeles	Mojave Desert	Antelope Valley AQMD	1	0	0	2	2	0
Los Angeles	South Coast	South Coast AQMD	12	2	1	17	14	2
Madera	San Joaquin Valley	San Joaquin Valley Unified APCD	1	0	0	1	1	0
Marin	San Francisco Bay Area	Bay Area AQMD	0	0	0	0	0	0
Mariposa	Mountain Counties	Mariposa County APCD	5	0	0	6	5	1
Mendocino	North Coast	Mendocino County AQMD	18	0	1	23	19	3
Merced	San Joaquin Valley	San Joaquin Valley Unified APCD	0	0	0	0	0	0
Modoc	Northeast Plateau	Modoc County APCD	3	0	0	4	4	0
Mono	Great Basin Valleys	Great Basin Unified APCD	2	0	0	3	3	0
Monterey	North Central Coast	Monterey Bay Unified APCD	24	1	1	31	26	3

Table D-4

Natural Source Emissions - Wildfires

(tons/day, annual average) ***(Cont)***

COUNTY	AIR BASIN	DISTRICT	VOC	NO_x	SO_x	PM_{10}	$PM_{2.5}$	NH_3
Napa	San Francisco Bay Area	Bay Area AQMD	1	0	0	1	1	0
Nevada	Mountain Counties	Northern Sierra AQMD	1	0	0	2	1	0
Orange	South Coast	South Coast AQMD	1	0	0	1	1	0
Placer	Lake Tahoe	Placer County APCD	0	0	0	0	0	0
Placer	Mountain Counties	Placer County APCD	7	0	0	9	8	1
Placer	Sacramento Valley	Placer County APCD	0	0	0	0	0	0
Plumas	Mountain Counties	Northern Sierra AQMD	22	1	1	28	24	3
Riverside	Mojave Desert	Mojave Desert AQMD	0	0	0	0	0	0
Riverside	Mojave Desert	South Coast AQMD	0	0	0	0	0	0
Riverside	Salton Sea	South Coast AQMD	0	0	0	0	0	0
Riverside	South Coast	South Coast AQMD	2	1	0	3	2	0
Sacramento	Sacramento Valley	Sacramento Metropolitan AQMD	0	0	0	0	0	0
San Benito	North Central Coast	Monterey Bay Unified APCD	0	0	0	0	0	0
San Bernardino	Mojave Desert	Mojave Desert AQMD	2	0	0	3	3	0
San Bernardino	South Coast	South Coast AQMD	7	1	1	10	8	1
San Diego	San Diego	San Diego County APCD	17	5	2	25	21	2
San Francisco	San Francisco Bay Area	Bay Area AQMD	0	0	0	0	0	0
San Joaquin	San Joaquin Valley	San Joaquin Valley Unified APCD	0	0	0	0	0	0
San Luis Obispo	South Central Coast	San Luis Obispo County APCD	0	0	0	0	0	0
San Mateo	San Francisco Bay Area	Bay Area AQMD	0	0	0	0	0	0
Santa Barbara	South Central Coast	Santa Barbara County APCD	11	2	1	15	13	2
Santa Clara	San Francisco Bay Area	Bay Area AQMD	2	0	0	2	2	0
Santa Cruz	North Central Coast	Monterey Bay Unified APCD	2	0	0	3	3	0
Shasta	Sacramento Valley	Shasta County AQMD	13	1	1	17	15	2
Sierra	Mountain Counties	Northern Sierra AQMD	1	0	0	1	1	0
Siskiyou	Northeast Plateau	Siskiyou County APCD	37	2	2	48	41	5
Solano	Sacramento Valley	Yolo/Solano AQMD	0	0	0	0	0	0
Solano	San Francisco Bay Area	Bay Area AQMD	0	0	0	0	0	0
Sonoma	North Coast	Northern Sonoma County APCD	1	0	0	1	1	0
Sonoma	San Francisco Bay Area	Bay Area AQMD	0	0	0	0	0	0

Table D-4 (Cont)

Natural Source Emissions - Wildfires

(tons/day, annual average) *(Cont)*

COUNTY	AIR BASIN	DISTRICT	VOC	NO_x	SO_x	PM_{10}	$PM_{2.5}$	NH_3
Stanislaus	San Joaquin Valley	San Joaquin Valley Unified APCD	2	0	0	3	2	0
Sutter	Sacramento Valley	Feather River AQMD	0	0	0	0	0	0
Tehama	Sacramento Valley	Tehama County APCD	10	0	1	13	11	1
Trinity	North Coast	North Coast Unified AQMD	34	2	2	44	38	5
Tulare	San Joaquin Valley	San Joaquin Valley Unified APCD	27	1	2	35	29	4
Tuolumne	Mountain Counties	Tuolumne County APCD	5	0	0	6	5	1
Ventura	South Central Coast	Ventura County APCD	11	2	1	15	13	2
Yolo	Sacramento Valley	Yolo/Solano AQMD	0	0	0	1	0	0
Yuba	Sacramento Valley	Feather River AQMD	0	0	0	1	0	0

Table D-4 (Cont)

* Wildfire emissions reflect 10-year averages.