A2.5.6 Sewage Treatment Plant Digesters

Sludge from waste water treatment plants is processed in anaerobic digesters in order to reduce sludge volume and render the residue less offensive. In the process, methane-rich gases containing hydrogen sulfide are generated. This digester gas can be used for fuel. Emissions from power plants and refineries burning digester gas have already been included in the fuel burning portions of this inventory. Digester gas not taken by refineries and power plants is either used to power the treatment plant, or it is incinerated as a waste product. Since it is hard to separate useful fuel burning from waste gas incineration in this inventory, emissions at sewage treatment plants arising from digester gas production were assigned to the digestion process itself. Emissions estimates totaling 0.64 tons per day were made for four major coastal area sewage treatment plants. Emissions estimates for Los Angeles County treatment plants were based on discussion with plant operators. Orange County treatment plant emissions estimates were based on discussion with engineers at the Southern California APCD - Southern Zone offices.

A2.5.7 Permitted Incinerators

Data copied from the APCD permit file contained SO_x emissions estimates for 49 incinerators. About half of these units appear to be pathological incinerators at hospitals and similar institutions. Permit file emissions estimates for all incinerators combined total only 0.074 tons per day. Domestic incinerators are banned in Southern California. Since incinerator emissions are so minor, permit file emissions were accumulated directly to the grid system with no effort being expended to refine the emission estimates.

A2.6 Mobile Sources

The mobile source emissions inventory is broken down into four classes of highway transportation, plus ships, railroads and aircraft. The categories used to represent mobile source emissions are:

- Automobiles and light trucks - surface streets
- Heavy trucks and buses - surface streets
- Automobiles and light trucks - freeways
- Heavy trucks and buses - freeways
- Airports
- Ship Traffic
- Railroad Operations

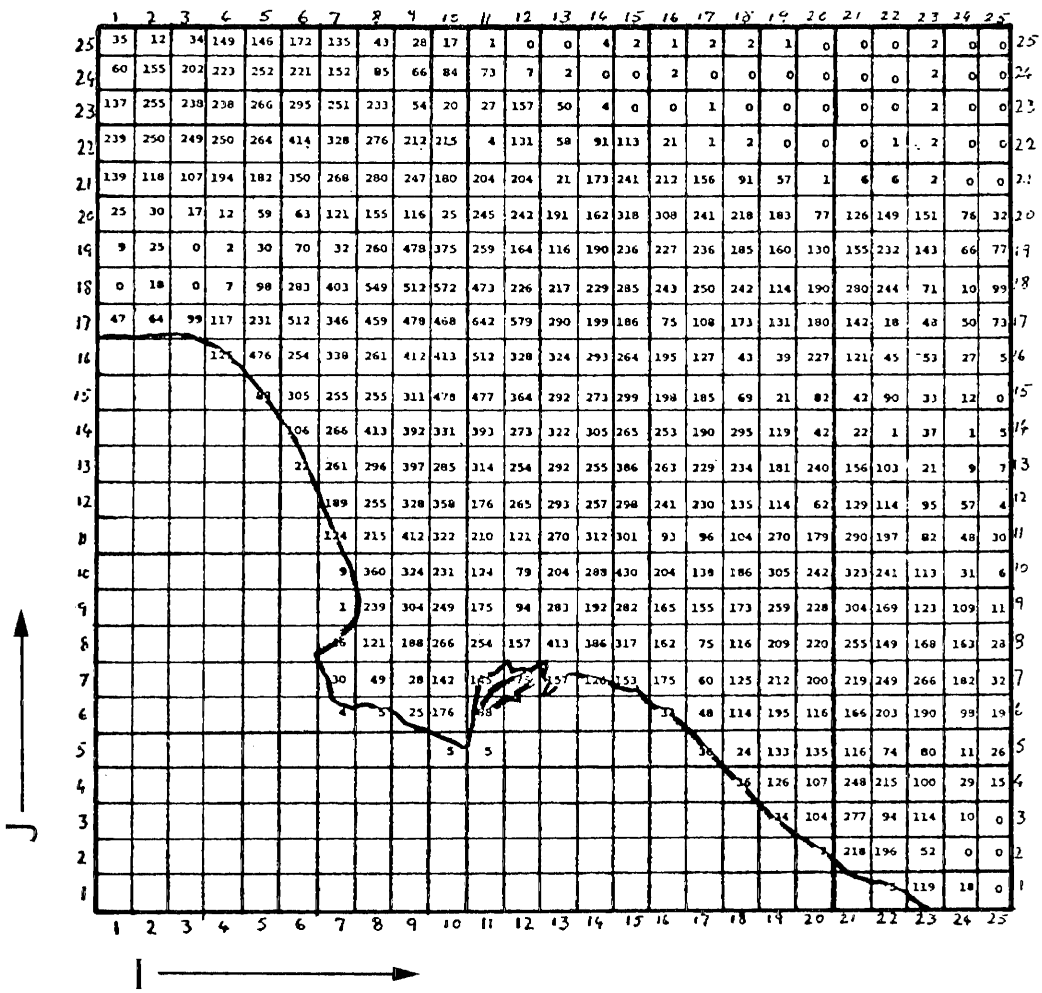
The principal reason for subdividing automotive and truck traffic into the four categories shown is to permit a later analysis of the future sulfate air quality impact of oxidation catalyst-equipped vehicles. Catalytic converters were introduced to the vehicle fleet at the start of the 1975 model year in an effort to reduce automotive hydrocarbons and CO emissions. These oxidizing catalysts also are capable of oxidizing a portion of the sulfur originally contained in gasoline to form sulfuric acid mist at the car's tail pipe. A change in the relative proportion of SO_2 and H_2SO_4 in vehicle exhaust in future years can be modeled conveniently if the catalyst-equipped vehicle SO_x emissions are separable from non-catalyst vehicles in the inventory. Only autos and light trucks are currently being equipped with oxidation catalysts. Freeway and surface street driving are separated since driving cycle influences catalyst-equipped vehicle sulfuric acid mist emission rates.

A2.6.1 Automobiles and Light Trucks - Surface Streets

Baseline surface street traffic counts have been assembled by Roth et al. (1974) for the 50 by 50 mile grid for the year 1969. These 1969 traffic data are shown in Figure A2.22 in units of thousands of vehicle miles traveled daily in each grid square.

A spatially resolved traffic growth study was conducted to update 1969 surface street traffic density to the 1972 through 1974 period of interest. Annual average traffic counts were acquired for each of the years 1969 through 1974 at 456 street locations spread as evenly as possible across the 50 by 50 mile square. Of these traffic counts, 268 intersections were located on state-maintained surface routes as described by the Califoria Department of Public Works (1969 and 1972) and the California Department of Transportation traffic volume reports (1973 and 1974 editions). Sixty-two traffic samples were taken from the directional traffic flow data of the Orange County Road Departments' Annual Traffic Census (1963 through 1969, 1970 through 1973, and 1974 editions). Data on the remaining 126 locations were hand copied from the traffic count records of the Los Angeles County Road Department and City of Los Angeles Department of Traffic. Whenever data for a given year at some chosen intersection were unavailable, they were estimated by linear interpolation between data for preceeding and following years at that location.

Traffic counts from the sampled intersections were accumulated



J \ I	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	35	12	34	149	146	172	135	43	28	17	1	0	0	4	2	1	2	2	1	0	0	0	2	0	0
24	60	155	202	223	252	221	152	85	66	84	73	7	2	0	0	2	0	0	0	0	0	0	2	0	0
23	137	255	238	238	266	295	251	233	54	20	27	157	50	4	0	0	1	0	0	0	0	0	2	0	0
22	239	250	249	250	264	414	328	276	212	215	4	131	58	91	113	21	1	2	0	0	0	1	2	0	0
21	139	118	107	194	182	350	268	280	247	180	204	204	21	173	241	212	156	91	57	1	6	6	2	0	0
20	25	30	17	12	59	63	121	155	116	25	245	242	191	162	318	308	241	218	183	77	126	149	151	76	32
19	9	25	0	2	30	70	32	260	478	375	259	164	116	190	236	227	236	185	160	130	155	232	143	66	77
18	0	18	0	7	98	283	403	549	512	572	473	226	217	229	285	243	250	242	114	190	280	244	71	10	99
17	47	64	99	117	231	512	346	459	478	468	642	579	290	199	186	75	108	173	131	180	142	18	48	50	73
16				125	476	254	338	261	412	413	512	328	324	293	264	195	127	43	39	227	121	45	53	27	5
15					89	305	255	255	311	478	477	364	292	273	299	198	185	69	21	82	42	90	33	12	0
14						106	266	413	392	331	393	273	322	305	265	253	190	295	119	42	22	1	37	1	5
13						22	261	296	397	285	314	254	292	255	386	263	229	234	181	240	156	103	21	9	7
12							189	255	328	358	176	265	293	257	298	241	230	135	114	62	129	114	95	57	4
11							124	215	412	322	210	121	270	312	301	93	96	104	270	179	290	197	82	48	30
10							9	360	324	231	124	79	204	288	430	204	138	186	305	242	323	241	113	31	6
9							1	239	304	249	175	94	283	192	282	165	155	173	259	228	304	169	123	109	11
8							16	121	188	266	254	157	413	386	317	162	75	116	209	220	255	149	168	163	28
7							30	49	28	142	145	75	157	120	153	175	60	125	212	200	219	249	266	182	32
6							4	5	25	176	88					32	48	114	195	116	166	203	190	99	19
5										5	5						36	24	133	135	116	74	80	11	26
4																		36	126	107	248	215	100	29	15
3																			34	104	277	94	114	10	0
2																				[illegible]	218	196	52	0	0
1																						[illegible]	119	18	0

FIGURE A2.22

The Spatial Distribution of Surface Street Traffic--1969 (thousands of vehicle miles traveled daily within each grid square) From Roth et al. (1974).

to the grid system. Scale factors needed to represent 1972, 1973 and 1974 traffic counts in each sampled square as a multiple of that square's 1969 sampled traffic were computed. Whenever a given grid cell contained more than one surveyed intersection, the root mean square of the various traffic observations in that grid cell in each year was used as the basis for the scale factor computations.

Next, the scale factors computed based on small traffic samples within individual grid cells were smoothed to better reflect regional traffic growth trends. This smoothing was accomplished by averaging the scale factors computed at all grid cells within a given "neighborhood" composed of nearby cells.

Review of the relationship between our grid system and the air basin's topography led us to form these neighborhoods from the twenty-five large square areas which may be defined by dividing the 50 by 50 mile study area into ten mile by ten mile subdivisions. When this is done, the East and West San Fernando Valleys each occupy one neighborhood, the East and West San Gabriel Valleys each occupy one neighborhood, and major physical traffic barriers (like the Santa Monica Mountains) fall roughly along neighborhood dividing lines.

Scale factors needed to represent 1974 surface street traffic in terms of each grid square's 1969 surface street traffic volume may be converted into compound annual growth rate estimates. The neighborhood-averaged growth rates computed in this manner over the period 1969 through 1974 are given in Figure A2.23. The pattern emerging from those figures indicates (not surprisingly) that surface street traffic growth in the older established portions of central

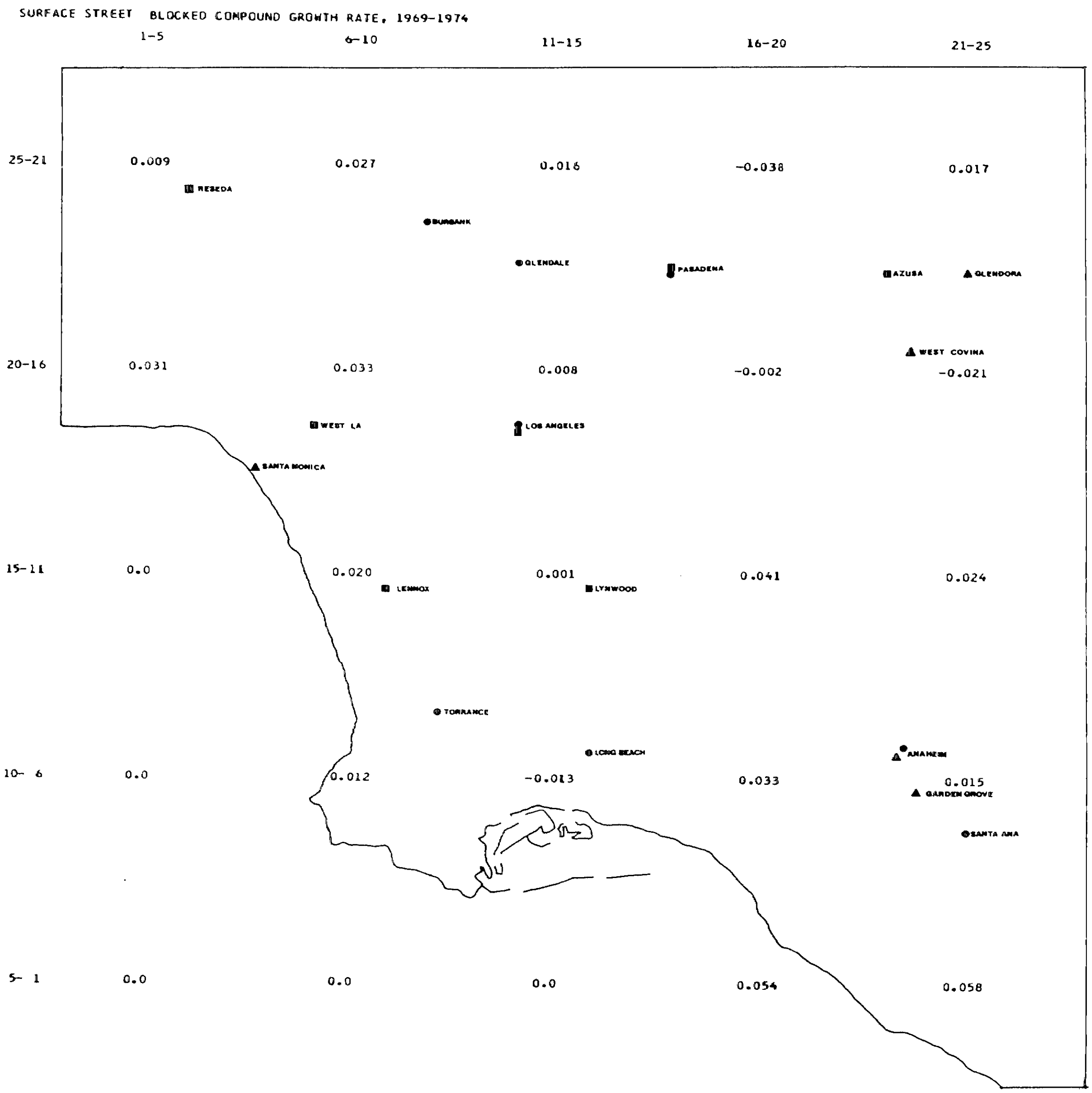


FIGURE A2.23

A Compound Growth Rate Matrix for Surface Street Traffic. Numbers shown should be multiplied by 100 to obtain growth rates in percent per year.

Los Angeles (e.g. square I 11-15 by J 11-15) over the years from 1969 to 1974 has been practically zero. Meanwhile, rapidly developing coastal Orange County (squares I 15-20 by J 5-1 and I 21-25 by J 5-1) has seen compound traffic growth rates of about 6% annually averaged over the period 1969 through 1974 resulting in about one third more vehicle miles traveled in 1974 than in 1969. The high traffic growth area of Los Angeles County appears to be West Los Angeles and the Santa Monica mountains. The decline in surface street traffic in portions of the San Gabriel Valley (square I 16-20 by J 25-21) may be due to the diversion of traffic onto several recently completed freeways.

Scale factors averaged over each neighborhood were assigned to each individual 2 mile by 2 mile square in that neighborhood. The resulting matrices were then used to scale the 1969 surface street traffic counts of Figure A2.22 to the years 1972, 1973 and 1974 as shown in Figures A2.24 through A2.26. Total surface street traffic in 1974 is estimated to average 79,376,000 vehicle miles traveled per day within the 50 by 50 mile study area.

The annual average daily traffic densities given in Figures A2.24 through A2.26 were then used to compute automobile and light duty truck SO_x emissions on a spatially resolved basis. Total surface street traffic density was uniformly apportioned to vehicle miles traveled daily by automobiles, light trucks, heavy duty gasoline trucks and buses, and diesel trucks and buses according to the fraction of total VMT driven by each vehicle type as given in Table A2.12. Average automobile and light truck miles traveled

SURFACE STREET TRAFFIC COUNTS FOR 1972 IN THOUSANDS OF VMT PER DAY

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	34	11	33	145	142	180	141	45	29	17	1	0	0	4	2	0	1	1	0	0	0	0	2	0	0
24	58	151	197	218	246	231	159	88	69	87	74	7	2	0	0	1	0	0	0	0	0	0	2	0	0
23	134	249	232	232	260	308	262	243	56	20	27	160	51	4	0	0	0	0	0	0	0	0	2	0	0
22	233	244	243	244	258	433	343	288	221	225	4	134	59	93	115	17	0	1	0	0	0	1	2	0	0
21	136	115	104	189	178	366	280	293	258	188	208	208	21	177	246	177	130	76	47	0	6	6	2	0	0
20	29	35	20	14	69	67	129	165	123	26	249	246	194	164	323	319	249	225	189	79	111	132	134	67	28
19	10	29	0	2	35	74	34	277	509	399	263	166	118	193	240	235	244	191	165	134	137	206	127	58	68
18	0	21	0	8	116	301	429	585	546	610	481	230	220	233	290	251	259	250	118	196	248	216	63	8	87
17	55	75	117	138	273	546	369	489	509	499	653	589	295	202	189	77	111	179	135	186	126	15	42	44	64
16	0	0	0	148	563	270	360	278	439	440	521	333	329	298	268	202	131	44	40	235	107	39	47	23	4
15	0	0	0	0	0	347	290	290	354	544	491	374	300	281	307	214	200	74	22	88	43	93	34	12	0
14	0	0	0	0	0	120	303	470	446	377	404	281	331	314	272	273	205	319	128	45	22	1	38	1	5
13	0	0	0	0	0	25	297	337	452	324	323	261	300	262	397	284	247	253	196	259	162	106	21	9	7
12	0	0	0	0	0	0	215	290	373	407	181	272	301	264	306	260	249	146	123	67	133	119	98	59	4
11	0	0	0	0	0	0	141	245	469	366	216	124	278	321	309	100	103	112	292	193	301	204	85	49	31
10	0	0	0	0	0	0	9	376	338	241	123	78	202	286	427	221	149	201	331	262	342	255	119	32	6
9	0	0	0	0	0	0	1	249	317	260	173	93	281	190	280	179	169	187	281	247	322	179	130	115	11
8	0	0	0	0	0	0	48	126	196	278	252	156	410	383	315	175	81	125	226	236	270	157	177	172	29
7	0	0	0	0	0	0	31	51	29	148	144	74	156	125	152	189	65	135	230	217	231	263	281	192	33
6	0	0	0	0	0	0	4	5	26	184	57	0	0	0	0	34	52	123	211	125	175	215	201	103	20
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	43	28	160	162	141	93	97	13	31
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	43	151	128	331	261	121	35	18
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40	125	336	114	139	12	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	265	239	63	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	144	21	0

RESEDA
BURBANK
GLENDALE
PASADENA
AZUSA
GLENDORA
WEST COVINA
WEST LA
LOS ANGELES
SANTA MONICA
LENNOX
LYNWOOD
TORRANCE
LONG BEACH
ANAHEIM
GARDEN GROVE
SANTA ANA

TOTAL SURFACE STREET TRAFFIC FOR 1972 = 75716.0 IN THOUSANDS OF VMT PER DAY

FIGURE A2.24

SURFACE STREET TRAFFIC COUNTS FOR 1973 IN THOUSANDS OF VMT PER DAY

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	36	12	35	155	151	200	157	50	32	19	1	0	0	4	2	0	1	1	0	0	0	0	2	0	0
24	62	161	210	232	262	257	176	98	76	97	79	7	2	0	0	1	0	0	0	0	0	0	2	0	0
23	142	265	247	247	276	343	292	271	62	23	29	170	54	4	0	0	0	0	0	0	0	0	2	0	0
22	248	260	259	260	274	482	381	321	246	250	4	142	62	98	122	17	0	1	0	0	0	1	2	0	0
21	144	122	111	201	189	407	312	325	287	209	221	221	22	187	261	175	129	75	47	0	6	5	2	0	0
20	29	35	19	14	69	72	139	179	134	28	243	240	190	161	316	303	237	214	180	75	111	131	133	67	28
19	10	29	0	2	35	80	36	300	552	433	257	163	115	189	234	223	232	192	157	127	137	205	175	58	69
18	0	21	0	8	114	327	465	634	591	661	470	225	216	228	283	239	245	239	112	186	247	215	62	8	87
17	54	74	115	136	270	591	399	530	552	540	639	576	288	198	185	73	106	170	128	177	125	15	42	44	64
16	0	0	0	146	556	293	390	301	476	477	509	326	322	291	262	191	124	42	36	223	107	39	46	23	4
15	0	0	0	0	0	345	288	288	352	541	486	371	297	278	304	220	205	76	23	91	42	90	33	12	0
14	0	0	0	0	0	120	301	467	444	375	400	278	328	311	270	281	211	327	132	46	22	1	37	1	5
13	0	0	0	0	0	24	295	335	449	322	320	259	297	260	393	292	254	250	201	266	156	103	21	9	7
12	0	0	0	0	0	0	214	289	371	405	179	270	298	262	303	267	255	150	126	68	129	114	95	57	4
11	0	0	0	0	0	0	140	243	466	364	214	123	275	319	306	103	106	115	300	198	291	197	82	48	30
10	0	0	0	0	0	0	9	377	339	242	117	74	193	272	406	228	154	207	340	270	339	252	113	32	6
9	0	0	0	0	0	0	1	250	318	260	165	88	267	181	266	184	173	193	239	254	319	177	129	114	11
8	0	0	0	0	0	0	48	126	196	278	240	148	390	365	299	181	83	129	233	245	267	156	176	171	29
7	0	0	0	0	0	0	51	51	29	148	137	70	148	119	144	195	67	139	236	223	229	261	279	191	33
6	0	0	0	0	0	0	4	5	26	184	83	0	0	0	0	35	53	127	217	129	174	213	199	102	19
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	48	32	180	183	155	99	107	14	34
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	48	170	145	333	288	134	38	20
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	46	141	372	126	153	13	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	292	263	69	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	159	24	0

RESEDA, BURBANK, GLENDALE, PASADENA, AZUSA, GLENDORA, WEST COVINA, WEST LA, LOS ANGELES, SANTA MONICA, LENNOX, LYNWOOD, TORRANCE, LONG BEACH, ANAHEIM, GARDEN GROVE, SANTA ANA

TOTAL SURFACE STREET TRAFFIC FOR 1973 = 77129.1 IN THOUSANDS OF VMT PER DAY

FIGURE A2.25

SURFACE STREET TRAFFIC COUNTS FOR 1974 IN THOUSANDS OF VMT PER DAY

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	37	12	36	160	157	202	158	50	32	20	1	0	0	4	2	0	1	1	0	0	0	0	2	0	0
24	64	166	217	240	271	260	178	100	77	98	79	7	2	0	0	1	0	0	0	0	0	0	2	0	0
23	147	274	256	256	286	347	295	274	63	23	29	171	54	4	0	0	0	0	0	0	0	0	2	0	0
22	257	269	268	269	284	487	386	324	249	253	4	143	63	99	123	17	0	1	0	0	0	1	2	0	0
21	149	127	115	208	196	412	315	329	290	211	223	223	22	189	263	175	129	75	47	0	6	6	2	0	0
20	29	35	20	14	70	75	145	186	139	30	258	255	201	171	335	307	240	217	182	76	114	135	137	69	29
19	10	29	0	2	35	84	38	313	576	452	273	173	122	200	249	226	235	184	159	129	140	210	129	59	69
18	0	21	0	8	117	341	485	661	617	689	499	238	229	241	300	242	249	241	113	189	254	221	64	9	89
17	56	76	116	140	277	617	417	553	576	564	677	611	306	210	196	74	107	172	130	179	129	16	43	45	66
16	0	0	0	149	570	306	407	314	496	497	540	346	342	309	278	194	126	42	38	226	109	40	49	24	4
15	0	0	0	0	0	339	283	283	345	531	484	365	296	277	303	243	227	84	25	100	48	104	38	13	0
14	0	0	0	0	0	117	295	459	435	366	399	277	327	309	269	310	233	362	146	51	25	1	43	1	5
13	0	0	0	0	0	24	290	329	441	316	319	258	296	259	392	322	281	287	222	294	181	119	24	10	8
12	0	0	0	0	0	0	210	283	364	398	178	269	297	261	302	295	282	165	139	76	150	132	110	66	4
11	0	0	0	0	0	0	137	239	459	358	213	122	274	317	305	114	117	127	331	219	337	229	95	55	34
10	0	0	0	0	0	0	9	383	345	246	116	74	191	270	403	241	163	220	361	287	350	261	122	33	6
9	0	0	0	0	0	0	1	254	324	265	164	88	265	180	264	195	183	205	307	270	329	183	133	118	11
8	0	0	0	0	0	0	49	129	200	283	238	147	387	362	297	192	88	137	247	260	276	161	182	176	30
7	0	0	0	0	0	0	31	52	29	151	136	70	147	118	143	207	71	148	251	237	237	270	288	197	34
6	0	0	0	0	0	0	4	5	26	187	82	0	0	0	0	37	56	135	231	137	180	220	205	106	20
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	47	51	175	177	158	101	109	15	35
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	47	165	140	338	293	136	39	20
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	44	136	378	128	155	13	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	297	267	70	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	162	24	0

RESEDA, BURBANK, GLENDALE, PASADENA, AZUSA, GLENDORA, WEST COVINA, WEST LA, LOS ANGELES, SANTA MONICA, LENNOX, LYNWOOD, TORRANCE, LONG BEACH, ANAHEIM, GARDEN GROVE, SANTA ANA

TOTAL SURFACE STREET TRAFFIC FOR 1974 = 79375.8 IN THOUSANDS OF VMT PER DAY

FIGURE A2.26

TABLE A2.12

Percentage of Vehicle Miles Traveled and Fuel Economy for each Vehicle Type

Vehicle Type	Percent of Total Vehicle Miles Traveled	Fuel Economy (mpg)
Light Duty Autos	80.4%	13.6
Light Duty Trucks	11.8%	10.0
Heavy Duty Trucks (Gasoline)	4.6%	6.0
Heavy Duty Trucks and Buses (Diesel)	3.2%	4.6

Reference: Environmental Protection Agency (1975) (Nationwide vehicle mix) daily were converted to annual average fuel quantities consumed in each grid cell daily using the fuel economy data in Table A2.12. Then the monthly variation about the annual average daily gasoline consumption in each square was estimated in proportion to the relative variation in total gasoline sales in California reported for each month of that year by the Ethyl Corporation (1974).

Having determined a time history of light duty vehicle gasoline use on surface streets for each month, sulfur oxides emissions for each month from this source class were calculated on the basis of gasoline sulfur content data given by the Bureau of Mines as shown in Table A2.13. Light duty vehicle surface street sulfur oxides emissions for a typical month in 1973 are shown in Figure A2.27.

A2.6.2 Heavy Duty Trucks and Buses - Surface Streets

SO_x emissions from heavy duty trucks and buses were estimated by a procedure analogous to that for light duty vehicles. The fraction of surface street traffic driven by each of these vehicle types is again listed in Table A2.12. The sulfur content of the gasoline pool is again given in Table A2.13. The sulfur content of diesel fuel is taken from Bureau of Mines data which are also shown in Table A2.13. Since data on the seasonal variations in diesel fuel sales are unknown to us, the seasonal variation in vehicle miles traveled is again taken as proportional to monthly fluctuations in gasoline sales volume in California.

The resulting calculated heavy duty vehicle SO_x emissions pattern is shown in Figure A2.28 for a typical month in 1973. Total

TABLE A2.13

Sulfur Content of Vehicle Fuels

Fuel Type	Period	Average Sulfur Content (% by Weight)		
		Regular Gasoline	Premium Gasoline	Diesel Fuels
Gasoline[a]				
	Winter 1971-72	0.095	0.041	
	Summer 1972	0.061	0.042	
	Winter 1972-73	0.069	0.042	
	Summer 1973	0.046	0.034	
	Winter 1973-74	0.061	0.039	
	Summer 1974	0.057	0.033	
	Winter 1974-75	0.067	0.045	
Diesel Fuel[b]	1972			0.218
	1973			0.230
	1974			0.265

References:

(a) Bureau of Mines (1972f through 1975f) and Energy Research and Development Administration Petroleum Product Survey Series, for example the study referenced to Shelton (1975).

(b) Bureau of Mines (1972d through 1975d).

AUTO & LT TRUCK SURFACE STREET SOX EMISSIONS FOR YEAR 1973 , MONTH 7 IN TONS/DAY AS SO2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	0.01	0.00	0.01	0.03	0.03	0.04	0.03	0.01	0.01	0.00	0.00	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.0	0.0	0.00	0.0	0.0
24	0.01	0.03	0.04	0.04	0.05	0.05	0.03	0.02	0.01	0.02	0.01	0.00	0.00	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0
23	0.03	0.05	0.05	0.05	0.05	0.06	0.05	0.05	0.01	0.00	0.01	0.03	0.01	0.00	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0
22	0.05	0.05	0.05	0.05	0.05	0.09	0.07	0.06	0.04	0.05	0.00	0.03	0.01	0.02	0.02	0.00	0.00	0.00	0.0	0.0	0.0	0.00	0.00	0.0	0.0
21	0.03	0.02	0.02	0.04	0.03	0.07	0.06	0.06	0.05	0.04	0.04	0.04	0.00	0.03	0.05	0.03	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.0	0.0
20	0.01	0.01	0.00	0.00	0.01	0.01	0.03	0.03	0.02	0.01	0.04	0.04	0.03	0.03	0.06	0.06	0.04	0.04	0.03	0.01	0.02	0.02	0.02	0.01	0.01
19	0.00	0.01	0.0	0.00	0.01	0.01	0.01	0.05	0.10	0.08	0.05	0.03	0.02	0.03	0.04	0.04	0.04	0.03	0.03	0.02	0.02	0.04	0.02	0.01	0.01
18	0.0	0.00	0.0	0.00	0.02	0.06	0.08	0.12	0.11	0.12	0.09	0.04	0.04	0.04	0.05	0.04	0.04	0.04	0.02	0.03	0.05	0.04	0.01	0.00	0.02
17	0.01	0.01	0.02	0.02	0.05	0.11	0.07	0.10	0.10	0.10	0.12	0.11	0.05	0.04	0.03	0.01	0.02	0.03	0.02	0.03	0.02	0.00	0.01	0.01	0.01
16	0.0	0.0	0.0	0.03	0.10	0.05	0.07	0.05	0.09	0.09	0.09	0.06	0.06	0.05	0.05	0.03	0.02	0.01	0.01	0.04	0.02	0.01	0.01	0.00	0.00
15	0.0	0.0	0.0	0.0	0.0	0.06	0.05	0.05	0.06	0.10	0.09	0.07	0.05	0.05	0.06	0.04	0.04	0.01	0.00	0.02	0.01	0.02	0.01	0.00	0.0
14	0.0	0.0	0.0	0.0	0.0	0.02	0.05	0.09	0.08	0.07	0.07	0.05	0.06	0.06	0.05	0.05	0.04	0.06	0.02	0.01	0.00	0.00	0.01	0.00	0.00
13	0.0	0.0	0.0	0.0	0.0	0.00	0.05	0.06	0.08	0.06	0.06	0.05	0.05	0.05	0.07	0.05	0.05	0.05	0.04	0.05	0.03	0.02	0.00	0.00	0.00
12	0.0	0.0	0.0	0.0	0.0	0.0	0.04	0.05	0.07	0.07	0.03	0.05	0.05	0.05	0.06	0.05	0.05	0.03	0.02	0.01	0.02	0.02	0.02	0.01	0.00
11	0.0	0.0	0.0	0.0	0.0	0.0	0.03	0.04	0.09	0.07	0.04	0.02	0.05	0.06	0.06	0.02	0.02	0.02	0.05	0.04	0.05	0.04	0.02	0.01	0.01
10	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.07	0.06	0.04	0.02	0.01	0.04	0.05	0.07	0.04	0.03	0.04	0.06	0.05	0.06	0.05	0.02	0.01	0.00
9	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.05	0.06	0.05	0.03	0.02	0.05	0.03	0.05	0.03	0.03	0.04	0.05	0.05	0.06	0.03	0.02	0.02	0.00
8	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.02	0.04	0.05	0.04	0.03	0.07	0.07	0.05	0.03	0.02	0.02	0.04	0.04	0.05	0.03	0.03	0.03	0.01
7	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.01	0.01	0.03	0.02	0.01	0.03	0.02	0.03	0.04	0.01	0.03	0.04	0.04	0.04	0.05	0.05	0.03	0.01
6	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.03	0.02	0.0	0.0	0.0	0.0	0.01	0.01	0.02	0.04	0.02	0.03	0.04	0.04	0.02	0.00
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.01	0.03	0.03	0.03	0.02	0.02	0.00	0.01
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.03	0.03	0.06	0.05	0.02	0.01	0.00
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.03	0.07	0.02	0.03	0.00	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.05	0.05	0.01	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.03	0.00	0.0

SOX TONS/DAY	FRACTION AS SO3
14.055	0.017

FIGURE A2.27

HEAVY DUTY VEHICLE SURFACE STREET SOX EMISSIONS FOR YEAR 1973 , MONTH 7 IN TCNS/DAY AS SO2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	0.01	0.00	0.00	0.02	0.02	0.03	0.02	0.01	0.00	0.00	0.00	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.0	0.0	0.00	0.0	0.0
24	0.01	0.02	0.03	0.03	0.04	0.04	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0
23	0.02	0.04	0.03	0.03	0.04	0.05	0.04	0.04	0.C1	0.00	0.00	0.02	0.01	0.00	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0
22	0.03	0.04	0.04	0.04	0.04	0.07	0.05	0.04	0.03	0.04	0.00	0.02	0.01	0.01	0.02	0.00	0.00	0.00	0.0	0.0	0.0	0.00	0.00	0.0	0.0
21	0.02	0.02	0.02	0.03	0.03	0.06	0.04	0.05	0.C4	0.03	0.03	0.03	0.00	0.03	0.04	0.02	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.0	0.0
20	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.03	0.02	0.00	0.03	0.03	0.03	0.02	0.04	0.04	0.03	0.03	0.03	0.01	0.02	0.02	0.02	0.01	0.00
19	0.00	0.00	0.0	0.00	0.00	0.01	0.01	0.04	0.08	0.06	0.04	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.03	0.C2	0.01	0.01
18	0.C	0.00	0.0	0.00	0.02	0.05	0.07	0.09	0.08	0.09	0.07	0.03	0.03	0.03	0.04	0.03	0.03	0.03	0.02	0.03	0.03	0.03	0.01	0.00	0.01
17	0.01	0.01	0.02	0.02	0.04	0.08	0.06	0.07	0.08	0.08	0.C9	0.08	0.04	0.03	0.03	0.01	0.01	0.02	0.02	0.02	0.02	0.00	0.01	0.01	0.01
16	0.0	0.0	0.0	0.02	0.08	0.04	0.05	0.04	0.07	0.07	0.07	0.05	0.05	0.04	0.04	0.03	0.02	0.01	0.01	0.03	0.01	0.01	0.01	0.00	0.00
15	0.0	0.0	0.0	0.0	0.0	0.05	0.04	0.04	0.05	0.08	0.07	0.05	0.04	0.04	0.04	0.03	0.03	0.01	0.00	0.01	0.01	0.01	0.00	0.00	0.0
14	0.0	0.0	0.0	0.0	0.0	0.02	0.04	0.07	0.06	0.05	0.06	0.04	0.05	0.04	0.04	0.04	0.03	0.05	0.02	0.01	0.00	0.00	0.01	0.00	0.00
13	0.0	0.0	0.0	0.0	0.0	0.00	0.04	0.C5	0.C6	C.05	0.04	0.04	0.04	0.04	0.06	0.04	0.04	0.04	0.03	0.04	0.02	0.01	0.00	0.00	0.00
12	0.0	0.0	0.0	0.0	0.0	0.0	0.03	0.04	0.05	0.06	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.02	0.02	0.01	0.02	0.02	0.01	0.01	0.00
11	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.03	0.07	0.05	0.03	0.02	0.04	0.04	0.04	0.01	0.01	0.02	0.04	0.03	0.04	0.03	0.01	0.01	0.00
10	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.05	0.05	0.03	0.02	0.01	0.03	0.04	0.06	0.03	0.02	0.03	0.05	0.04	0.05	0.04	0.02	0.00	0.00
9	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.04	0.04	0.04	0.02	0.01	0.04	0.03	0.04	0.03	0.02	0.03	0.04	0.04	0.04	0.02	0.02	0.02	0.00
8	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.02	0.03	0.04	0.03	0.02	0.05	0.05	0.04	0.03	0.01	0.02	0.03	0.03	0.04	0.02	0.02	0.02	0.00
7	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.01	0.00	0.02	0.02	0.01	0.02	0.02	0.02	0.03	0.01	0.02	0.03	0.03	0.03	0.04	0.04	0.03	0.00
6	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.03	[illegible]	0.0	0.0	0.0	0.0	0.01	0.01	0.02	0.03	0.02	0.02	0.03	0.03	0.01	0.00
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.00	0.03	0.03	0.02	0.01	0.02	0.00	0.00
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.02	0.02	0.05	0.04	0.02	0.01	0.00
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.02	0.05	0.02	0.02	0.00	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.04	0.04	0.01	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.02	0.00	0.0

SOX TONS/DAY	FRACTION AS SO3
10.799	0.011

FIGURE A2.28

SO_x emissions from heavy duty vehicles are only slightly smaller than from light duty vehicles even though heavy duty vehicle miles traveled are modest by comparison to automotive and light truck travel. This is due to the higher sulfur content of diesel fuel combined with the greater fuel consumption per mile driven by larger vehicles.

A2.6.3 Automobiles and Light Trucks - Freeway

While surface street traffic patterns had to be established by "growing" historic data up to the years of interest using several hundred spot checks, sufficient data exist to completely recount freeway traffic flows from scratch. Virtually all freeway mileage within our study area is part of the state highway system. Because of the importance of freeway traffic flow to the regional transportation system in Los Angeles, the California Department of Transportation (Cal Trans) maintains a dense network of traffic gauging points at nearly every freeway on-ramp or interchange. Each gauging point is assigned a milepost number. The difference between the milepost numbers at two consecutive traffic counting points gives one the length of the freeway segment (in miles) located between those two mileposts. Between each pair of mileposts, traffic counts are given listing the average number of vehicles using that stretch of highway daily during each year of interest. By multiplying road segment length by the number of vehicles transiting each segment daily, one can calculate annual average vehicle miles traveled (VMT) daily on the freeway system in any recent year.

The difficult part of the freeway traffic counting procedure arises when one tries to assign traffic counts geographically to our grid system. Because of the relatively fine spacing of our 2 mile by 2 mile grid cells, road segments between mileposts usually intersect grid cell boundaries. When this occurs, appropriate fractions of a road segment's traffic flow must be assigned to two or sometimes three grid cells. Secondly, because of the large number of freeways in the Los Angeles area and their often meandering roadbeds, a number of pathological grid cell traffic assignment situations arise in which a freeway literally lies on a grid cell boundary for a portion of its length, or passes through adjacent cell boundaries at a very oblique angle. Finally, certain California Department of Transportation mileposts are assigned by name to freeway interchanges or on-ramp complexes which themselves are several tenths of a mile in length. It is not always clear from looking at a freeway map exactly where some road segments start or end. This latter problem is compounded by Cal Trans' practice of making occasional small adjustments in milepost numbers representing the same intersection in consecutive years.

The above discussion is intended to indicate that a freeway traffic counting procedure using the available data is not as straightforward as it might seem at first glance. The person doing the work must continually exercise his judgment in close situations. Two groups of people carefully following the same instructions will certainly come to a slightly different geographic distribution of traffic flows on this freeway system. Realizing this, we first attempted to reproduce the baseline freeway traffic counts for the year 1969 given by Roth, et al. (1974). This attempted reproduction of Roth, et al.'s work would serve as a check on gross errors in assignment of freeway segments to individual grid cells. Once the freeway segments are properly located, it is relatively easy to count traffic in a consistent manner in later years.

The 50 by 50 mile square grid was transferred to a street map drawn to a scale of 2800 feet to the inch (Thomas Brothers Maps, 1975). Grid alignment was adjusted until it closely followed the surface street locations shown on our grid system reference map obtained from the APCD (Taylor, 1976) and also the 1969 freeway map provided by Roth, et al., 1974, as shown in Figure A2.29.

Next, freeway segments defined by the milepost locations given by the California Department of Transportation (1974) were assigned to the grid squares in which they resided. Single freeway segments falling across grid square boundaries were assigned to the appropriate grid cells in proportion to the fraction of freeway segment length in each cell. Over seven hundred freeway fragments were thus defined. Freeway segments completed in the latter years of our study period were entered as having zero traffic in years prior to their construction. Special adjustments were made for a few cases in which the 1974 grid square location of a given route did not reflect its physical location in some prior year(s) due to freeway reconstruction or rerouting.

Annual average daily traffic volumes given by the California

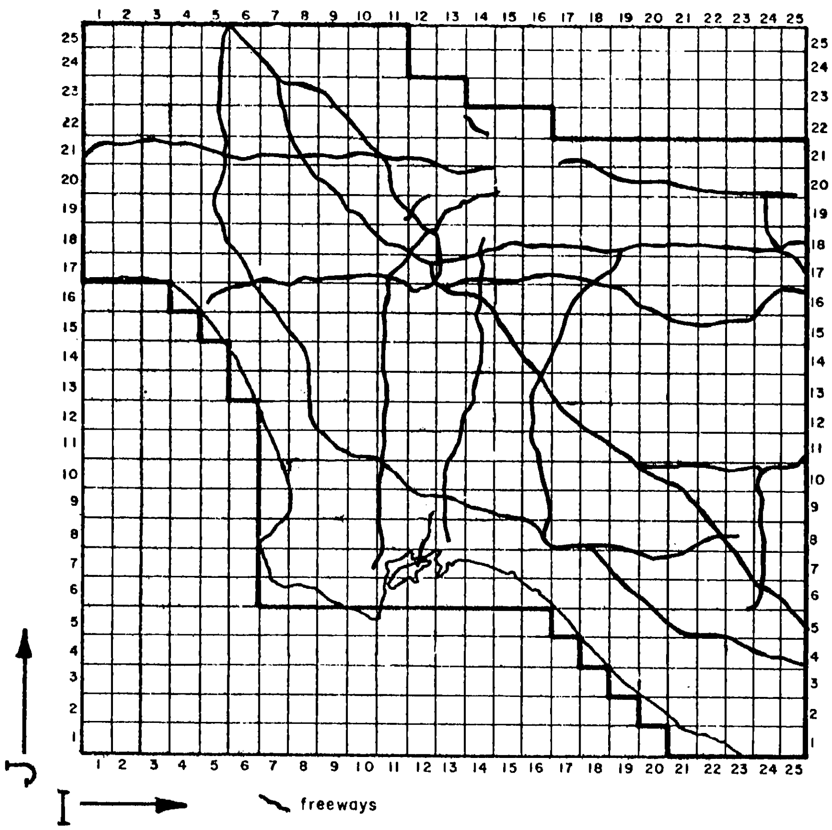


FIGURE A2.29

The Modeling Region

(showing Roth et al.'s (1974) grid network and the Los Angeles freeway system as it existed in 1969).

Department of Public Works (1969 and 1972) and California Department of Transportation (1973 and 1974) were associated with each freeway segment or fraction thereof in each of the years 1969, 1972, 1973 and 1974, then multiplied by road length to obtain vehicle miles traveled per day. All traffic counts within a grid cell were then added together for each year to obtain the freeway traffic count maps shown in Figures A2.30 through A2.33.

Average freeway traffic volume in 1969 from our survey totaled 40,155 thousand vehicle miles traveled daily within the 50 by 50 mile square. That value is within 4.3% of the 41,926 thousand vehicle miles traveled daily on freeways in 1969 as reported by Roth, et al. (1974) as shown in Figure A2.34. When Roth, et al.'s traffic pattern in 1969 is subtracted from ours on a square by square basis, a difference map is obtained. About half of the occupied grid cell traffic estimates are within 10% or 10 thousand VMT of each other on a cell by cell basis. Each of the grid cells in which tight agreement was not obtained were examined more closely. Several good reasons for disagreement were uncovered.

For example, Roth, et al. report freeway traffic in numerous grid cells near the right hand side of the 50 by 50 mile square (columns I21 through I25) in which we show no freeway traffic in 1969. The reason for this discrepancy apparently arises from a difference in the definition of what constitutes a freeway. We have used the California Department of Transportation's definition of freeway starting locations as given in the state's traffic volume books (California Department of Public Works, 1969). In 1969, however,

FREEWAY TRAFFIC COUNTS FOR 1969 IN THOUSANDS OF VMT PER DAY (PRESENT STUDY)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	68	9	0	0	102	136	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	164	53	179	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	232	0	160	145	164	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	292	0	102	41	103	150	0	0	0	37	0	0	0	0	0	0	0	0	0	0	0
21	159	248	304	352	759	414	407	494	179	322	301	49	0	4	0	0	0	12	0	0	0	0	0	0	0
20	0	0	0	0	325	0	0	96	296	0	330	13	14	124	24	0	0	29	79	65	40	0	0	0	0
19	0	0	0	0	348	0	0	0	116	299	165	380	206	61	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	141	209	0	0	0	115	428	635	212	274	314	324	316	281	379	246	258	196	181	179	171
17	0	0	0	0	0	416	170	289	403	474	832	546	503	451	224	228	197	332	47	0	0	0	0	0	0
16	0	0	0	0	91	235	541	87	0	0	478	393	575	543	0	0	273	124	142	67	0	0	0	0	0
15	0	0	0	0	0	0	256	168	0	0	360	0	0	239	313	0	234	0	0	2	47	0	0	0	0
14	0	0	0	0	0	0	0	382	0	0	323	0	0	215	144	386	12	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	345	0	0	286	0	0	220	0	520	21	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	323	41	0	249	0	80	116	0	295	302	96	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	377	340	222	0	223	0	54	314	91	239	282	0	0	13	0	0	0
10	0	0	0	0	0	0	0	0	0	0	584	40	213	0	0	213	0	33	77	345	216	123	98	138	0
9	0	0	0	0	0	0	0	0	0	0	122	341	519	370	345	201	0	0	0	0	176	78	0	135	0
8	0	0	0	0	0	0	0	0	0	0	101	45	60	0	0	578	348	241	163	0	33	412	153	169	0
7	0	0	0	0	0	0	0	0	0	0	78	22	0	0	0	0	0	180	112	171	145	0	248	135	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	163	70	0	0	56	265	94
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	135	165	137	212	0	96
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	53	76	64
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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TOTAL VMT/DAY IN 1969 = 40155. IN THOUSANDS OF VMT PER DAY

FIGURE A2.30

FREEWAY TRAFFIC COUNTS FOR 1972 IN THOUSANDS OF VMT PER DAY (PRESENT STUDY)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	93	34	0	0	133	156	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	182	62	208	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	242	0	181	149	168	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	289	0	126	49	104	153	0	0	0	39	0	0	0	0	0	0	0	0	0	0	0
21	147	240	298	354	749	383	368	511	216	384	367	120	46	9	0	0	71	46	0	0	0	0	0	0	0
20	0	0	0	0	341	0	0	99	334	0	320	13	52	141	25	0	0	58	181	168	127	49	33	63	6
19	0	0	0	0	360	0	0	0	125	284	156	378	202	68	0	0	0	0	175	0	0	51	46	59	0
18	0	0	0	0	144	217	0	0	0	107	414	644	217	271	300	312	301	262	467	226	227	177	156	235	198
17	0	0	0	0	0	447	187	324	436	504	893	533	501	483	260	255	220	363	50	0	0	0	0	69	4
16	0	0	0	0	108	276	612	97	0	0	492	429	587	580	0	0	298	161	220	139	0	0	54	205	68
15	0	0	0	0	0	0	321	186	0	0	386	0	0	277	320	0	238	0	0	6	135	120	129	0	0
14	0	0	0	0	0	0	0	424	0	0	351	0	0	250	155	402	12	0	0	0	0	0	81	0	0
13	0	0	0	0	0	0	0	376	0	0	330	0	0	254	0	568	21	0	0	0	0	68	0	0	0
12	0	0	0	0	0	0	0	352	42	0	296	0	88	132	0	375	304	87	0	0	0	94	0	0	0
11	0	0	0	0	0	0	0	0	408	372	268	0	314	265	261	515	238	257	248	0	0	125	0	0	78
10	0	0	0	0	0	0	0	0	0	0	670	40	274	0	0	240	0	113	227	499	297	208	151	275	63
9	0	0	0	0	0	0	0	0	0	0	173	348	543	376	357	237	0	0	0	0	214	92	0	165	0
8	0	0	0	0	0	0	0	0	0	0	140	45	65	0	0	639	401	244	151	0	36	470	183	235	0
7	0	0	0	0	0	0	0	0	0	0	128	23	0	0	0	0	0	238	141	171	150	0	284	209	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	234	97	0	0	78	342	111
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	182	217	175	305	0	114
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	86	124	111
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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TOTAL VMT/DAY IN 1972 = 47578. IN THOUSANDS OF VMT PER DAY

FIGURE A2.31

FREEWAY TRAFFIC COUNTS FOR 1973 IN THOUSANDS OF VMT PER DAY (PRESENT STUDY)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	93	34	0	0	136	173	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	186	62	208	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	248	0	185	146	168	0	6	38	21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	306	0	130	51	104	153	0	0	15	56	0	0	0	0	0	0	0	0	0	0	0
21	148	248	310	377	801	420	400	540	223	388	377	127	49	64	0	0	75	46	0	0	0	0	0	0	0
20	0	0	0	0	343	0	0	106	348	0	324	13	56	144	23	0	0	58	184	172	127	54	40	58	4
19	0	0	0	0	362	0	0	0	133	316	160	377	202	68	0	0	0	0	179	0	0	61	57	71	0
18	0	0	0	0	144	217	0	0	0	118	445	651	209	277	301	308	286	252	460	213	222	176	156	261	213
17	0	0	0	0	0	450	190	324	443	507	885	550	528	501	274	267	240	387	51	0	0	0	0	91	4
16	0	0	0	0	109	280	597	99	0	0	492	432	617	589	0	0	305	177	249	147	0	0	56	236	70
15	0	0	0	0	0	0	317	189	0	0	386	0	0	271	340	0	243	0	0	6	140	125	158	0	0
14	0	0	0	0	0	0	0	427	0	0	352	0	0	245	163	418	12	0	0	0	0	0	114	0	0
13	0	0	0	0	0	0	0	373	0	0	332	0	0	249	0	589	22	0	0	0	0	93	0	0	0
12	0	0	0	0	0	0	0	351	42	0	297	0	87	130	0	383	317	91	0	0	0	125	0	0	0
11	0	0	0	0	0	0	0	0	414	380	268	0	327	326	310	553	262	272	258	0	0	156	0	0	77
10	0	0	0	0	0	0	0	0	0	0	678	41	278	0	0	264	0	123	239	528	318	231	167	293	66
9	0	0	0	0	0	0	0	0	0	0	173	356	550	380	362	256	0	0	0	0	224	97	0	165	0
8	0	0	0	0	0	0	0	0	0	0	141	45	67	0	0	644	404	246	151	0	36	482	184	235	0
7	0	0	0	0	0	0	0	0	0	0	134	23	0	0	0	0	0	243	142	171	150	0	296	210	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	238	100	0	0	78	354	119
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	187	225	183	313	0	124
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	80	95	139	126
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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TOTAL VMT/DAY IN 1973 = 49343. IN THOUSANDS OF VMT PER DAY

FIGURE A2.32

FREEWAY TRAFFIC COUNTS FOR 1974 IN THOUSANDS OF VMT PER DAY (PRESENT STUDY)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	93	34	0	0	112	161	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	174	59	208	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	241	0	186	150	176	0	6	38	21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	302	0	130	51	111	161	0	0	15	56	0	0	0	0	0	0	0	0	0	0	0
21	172	257	316	376	795	413	389	532	217	386	383	134	49	58	0	0	72	44	0	0	0	0	0	0	0
20	0	0	0	0	343	0	0	106	348	0	331	13	55	140	22	0	0	56	173	163	126	54	42	59	4
19	0	0	0	0	362	0	0	0	133	315	163	381	192	66	0	0	0	0	167	0	0	57	59	71	0
18	0	0	0	0	144	216	0	0	0	116	425	636	208	275	301	308	286	252	448	203	211	161	144	250	197
17	0	0	0	0	0	443	183	313	431	495	880	550	522	504	274	267	240	388	51	0	0	0	0	98	4
16	0	0	0	0	104	270	582	95	0	0	490	432	614	571	0	0	312	181	261	156	0	0	60	253	78
15	0	0	0	0	0	0	342	184	0	0	386	0	0	236	340	0	253	0	0	6	149	135	169	0	0
14	0	0	0	0	0	0	0	393	0	0	352	0	0	214	163	429	12	0	0	0	0	0	120	0	0
13	0	0	0	0	0	0	0	358	0	0	329	0	0	221	0	608	22	0	0	0	0	95	0	0	0
12	0	0	0	0	0	0	0	340	41	0	291	0	78	116	0	412	317	91	0	0	0	128	0	0	0
11	0	0	0	0	0	0	0	0	401	368	258	0	305	331	316	584	259	272	258	0	0	157	0	0	76
10	0	0	0	0	0	0	0	0	0	0	650	40	264	0	0	287	0	122	244	542	331	267	202	348	68
9	0	0	0	0	0	0	0	0	0	0	181	340	529	372	361	293	0	0	0	0	233	100	0	217	0
8	0	0	0	0	0	0	0	0	0	0	144	45	67	0	0	673	404	251	159	0	37	510	190	273	0
7	0	0	0	0	0	0	0	0	0	0	135	23	0	0	0	0	0	243	145	179	160	0	302	235	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	244	103	0	0	89	368	114
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	197	239	207	349	0	116
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	80	98	145	131
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TOTAL VMT/DAY IN 1974 = 49523. IN THOUSANDS OF VMT PER DAY

FIGURE A2.33

FREEWAY TRAFFIC COUNTS FOR 1969 IN THOUSANDS OF VMT PER DAY (ROTH ET AL, 1974)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	59	0	0	0	94	119	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	155	68	144	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	242	0	156	158	109	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	222	0	126	17	104	150	0	0	0	37	0	0	0	0	0	0	0	0	0	0	0
21	169	271	311	383	890	456	426	494	178	395	190	51	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	352	0	0	140	275	0	423	0	13	90	28	0	0	41	74	66	65	43	11	0	0
19	0	0	0	0	356	0	0	0	215	194	290	335	193	109	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	242	137	0	0	0	205	436	620	257	257	297	306	311	254	362	291	214	203	170	173	159
17	0	0	0	0	0	473	141	333	426	466	795	452	585	518	224	79	234	285	147	0	0	0	0	0	16
16	0	0	0	0	101	295	511	51	0	0	531	449	623	576	0	0	205	263	156	70	0	0	0	32	15
15	0	0	0	0	0	0	295	160	0	0	391	0	0	283	332	0	265	0	0	12	59	42	21	3	0
14	0	0	0	0	0	0	0	404	0	0	366	0	0	281	129	444	33	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	348	0	0	305	0	0	302	0	527	30	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	351	32	0	257	0	159	131	0	314	289	104	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	391	326	217	0	241	0	56	383	102	243	253	0	0	15	0	0	16
10	0	0	0	0	0	0	0	0	0	0	625	0	236	0	0	278	0	59	83	330	251	138	108	207	85
9	0	0	0	0	0	0	0	0	0	0	131	343	545	340	323	195	0	0	0	0	145	68	0	137	0
8	0	0	0	0	0	0	0	0	0	0	143	45	107	0	0	529	349	213	144	0	25	398	156	161	0
7	0	0	0	0	0	0	0	0	0	0	11	22	0	0	0	0	0	181	112	183	150	0	257	131	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	153	78	0	0	67	169	77
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	115	160	163	148	0	91
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	97	95	61	59
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	80	6	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TOTAL VMT/DAY = 41926. IN THOUSANDS OF VMT PER DAY

FIGURE A2.34

there were a few state-maintained divided highways (for example portions of Route 55) which on a map would look as wide as a freeway; which Roth, et al. apparently classified as a freeway even though the State Department of Public Works did not. This difference in the definition of what constitutes a freeway is less important to our traffic counts for 1972 through 1974. This is because most divided highway segments in question were soon upgraded to full freeway status by Cal Trans after necessary grade separations at major intersections were completed to remove cross-traffic conflicts to high speed travel. Our exclusion of non-freeway divided highways from the 1969 freeway traffic inventory is one reason why our traffic count total is 4.3% lower than that of Roth, et al. for that year. Most remaining discrepancies in the traffic counts could be eliminated by a 1/8 mile or less local realignment of grid cell boundaries. Resolution of these small boundary alignment problems was felt to be unnecessary since they result from an area source description of a line source problem in which the grid cell concept artificially obscures each freeway's location by averaging it over a four square mile area anyway.

In a few notable cases, however, no minor realignment of the grid system would successfully explain observed differences in traffic density. The largest disagreement on the map is a difference of 149 thousand VMT daily in square I 16 by J 17. The only freeway in that square is the Pomona Freeway, which completely transects that grid cell while proceeding from west to east (see Roth, et al.'s map, Figure A2.29). That freeway's minimum length in that cell is at least two miles by definition of the grid dimensions. All segments of that freeway within that square carried in excess of 100,000 vehicles daily in 1969 (California Department of Public Works, 1969), making total vehicle miles traveled necessarily greater than 200,000 VMT daily in that grid square. Roth, et al. show 79,000 VMT daily in that square, while we obtain 228,000 VMT daily. Another large difference in traffic density for which we have yet to find a complete explanation arises at the intersection of the San Diego and Ventura Freeways in square I 5 by J 21. The 131 thousand VMT difference between these two surveys at that point is the third largest on the grid. Roth, et al. indicate that that grid cell contains the heaviest freeway traffic density in the Los Angeles area, while our survey indicates that there is a greater freeway traffic density near the intersection of the Harbor and Santa Monica freeways near downtown Los Angeles. We do not intend to claim that our traffic counts are any better than those of Roth, et al. On the contrary, we feel that their data were carefully prepared or we would not have used Roth, et al.'s surface street traffic counts for 1969 as the basis for our surface street traffic growth study. Undoubtedly, many of the discrepancies between these two traffic surveys represent occasional human errors on both parts. We simply wished to illustrate that the existence of a few rather large discrepancies is the natural result of the complexity of tackling this traffic assignment problem manually and not a reflection of carelessness.

The traffic density maps of Figure A2.30 through A2.33 were thus accepted as a reasonable representation of freeway traffic in those years. SO_x emissions from light duty vehicle freeway travel were then calculated by the method previously described for surface streets. The resulting emission density map for a typical month in the year 1973 is shown in Figure A2.35.

A2.6.4 Heavy Duty Trucks and Buses - Freeway

SO_x emissions from freeway travel by heavy duty trucks and buses were computed by the same method as previously described for surface street travel by these vehicles. The only difference was to substitute the appropriate proportion of total freeway traffic volumes in place of surface street traffic data. The resulting emission density map for a typical month in 1973 is given in Figure A2.36.

A2.6.5 Airport Operations

SO_x emissions from airport operations were computed for major civilian and military airports within the grid system on the basis of fuel usage. The fuel use inventory technique employed was identical to that described in the Energy Balance section of Appendix A3 to this report; Section A3.4.3.2 - Jet Fuel and Aviation Gasoline Consumption. The only difference was that airports were located geographically on our grid system, and off-grid airports are not shown. Sulfur oxides emissions were computed from fuel use data at each airport on the basis of the fuel sulfur content assumed for jet fuel and aviation gasoline in Table A3.10 of the Sulfur Balance section of Appendix A3 to this report. Total on-grid SO_x emissions from aircraft take-offs and landings are dominated by traffic at Los Angeles International Airport. Estimated SO_x emissions from that airport's traffic averaged

AUTO & LT TRUCK FREEWAY SCX EMISSIONS FCR YEAR 1973 , MONTH 7 IN TONS/DAY AS SO2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	0.02	0.01	0.0	0.0	0.02	0.03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.03	0.01	0.04	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.05	0.0	0.03	0.03	0.03	0.0	0.00	0.01	0.00	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.06	0.0	0.02	0.01	0.02	0.03	0.0	0.0	0.00	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.03	0.05	0.06	0.07	0.15	0.08	0.07	0.10	0.04	0.07	0.07	0.02	0.01	0.01	0.0	0.0	0.01	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.06	0.0	0.0	0.02	0.06	0.0	0.06	0.00	0.01	0.03	0.00	0.0	0.0	0.01	0.03	0.03	0.02	0.01	0.01	0.01	0.00
19	0.0	0.0	0.0	0.0	0.07	0.0	0.0	0.0	0.02	0.06	0.03	0.07	0.04	0.01	0.0	0.0	0.0	0.0	0.03	0.0	0.0	0.01	0.01	0.01	0.0
18	0.0	0.0	0.0	0.0	0.03	0.04	0.0	0.C	0.C	0.02	0.08	0.12	0.04	0.05	0.05	0.06	0.05	0.05	0.08	0.04	0.04	0.03	0.03	0.05	0.04
17	0.0	0.0	0.0	0.0	0.0	0.08	0.03	0.06	0.08	0.09	0.16	0.10	0.10	0.09	0.05	0.05	0.04	0.07	0.01	0.0	0.0	0.0	0.0	0.02	0.00
16	0.0	0.0	0.0	0.0	0.02	0.05	0.11	0.02	0.C	0.0	0.09	0.08	0.11	0.11	0.0	0.0	0.06	0.03	0.05	0.03	0.0	0.0	0.01	0.04	0.01
15	0.0	0.0	0.0	0.0	0.0	0.0	0.06	0.03	0.0	0.0	0.07	0.0	0.0	0.05	0.06	0.0	0.04	0.0	0.0	0.00	0.03	0.02	0.03	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.08	0.0	0.0	0.06	0.0	0.0	0.04	0.03	0.08	0.00	0.0	0.0	0.0	0.0	0.0	0.02	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.07	0.0	0.0	0.06	0.0	0.0	0.05	0.0	0.11	0.00	0.0	0.0	0.0	0.0	0.02	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.06	0.01	0.0	0.05	0.0	0.02	0.02	0.0	0.07	0.06	0.02	0.0	0.0	0.0	0.02	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.08	0.07	C.05	0.0	0.06	0.06	0.06	0.10	0.05	0.05	0.05	0.0	0.0	0.03	0.0	0.0	0.01
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.12	0.01	0.05	0.0	0.0	0.05	0.0	0.02	0.04	0.10	0.06	0.04	0.03	0.05	0.01
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.03	0.06	0.10	0.07	0.07	0.05	0.0	0.0	0.0	0.0	0.04	0.02	0.0	0.03	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.03	0.01	0.01	0.0	0.0	0.12	0.07	0.04	0.03	0.0	0.01	0.09	0.03	0.04	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.00	0.0	0.0	0.0	0.0	0.0	0.04	0.03	0.03	0.03	0.0	0.05	0.04	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.04	0.02	0.0	0.0	0.01	0.06	0.02
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.03	0.04	0.03	0.06	0.0	0.02
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.02	0.03	0.02
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

RESEDA, BURBANK, GLENDALE, PASADENA, AZUSA, GLENDORA, WEST COVINA, WEST LA, LOS ANGELES, SANTA MONICA, LENNOX, LYNWOOD, TORRANCE, LONG BEACH, ANAHEIM, GARDEN GROVE, SANTA ANA

SOX TONS/DAY	FRACTION AS SO3
8.993	0.017

FIGURE A2.35

HEAVY DUTY VEHICLE FREEWAY SOX EMISSIONS FOR YEAR 1973 , MONTH 7 IN TONS/DAY AS SO2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	0.01	0.00	0.0	0.0	0.02	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.03	0.01	0.03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.03	0.0	0.03	0.02	0.02	0.0	0.00	0.01	0.C0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.04	0.0	0.02	0.01	0.01	0.02	0.0	0.0	0.00	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.02	0.03	0.04	0.05	0.11	0.06	0.06	0.08	0.03	0.05	0.C5	0.02	0.01	0.01	0.0	0.0	0.01	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.05	0.0	0.0	0.01	0.05	0.0	0.05	0.00	0.01	0.02	0.00	0.0	0.0	0.01	0.03	0.02	0.02	0.01	0.01	0.01	0.00
19	0.0	0.0	0.0	0.0	0.05	0.0	0.0	0.C	0.02	0.04	0.02	0.05	0.C3	0.01	0.0	0.0	0.0	0.0	0.03	0.0	0.0	0.01	0.01	0.01	0.0
18	0.0	0.0	0.0	0.0	0.02	0.03	0.0	0.0	0.0	0.02	0.06	0.09	0.03	0.04	0.04	0.04	0.04	0.04	0.06	0.03	0.03	0.02	0.02	0.04	0.03
17	0.0	0.0	0.0	0.0	0.0	0.06	0.03	0.05	0.C6	0.07	C.12	0.08	0.07	0.07	0.04	0.04	0.03	0.05	0.01	0.0	0.0	0.0	0.0	0.01	0.00
16	0.0	0.0	0.0	0.0	0.02	0.04	0.08	0.01	0.0	0.0	0.07	0.06	0.09	0.08	0.C	0.0	0.04	0.02	0.03	0.02	0.0	0.0	0.01	0.03	0.01
15	0.0	0.0	0.0	0.0	0.0	0.0	0.04	0.03	0.0	0.C	C.C5	0.0	0.0	0.04	0.05	0.0	0.03	0.0	0.0	0.00	0.02	0.02	0.02	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.06	0.0	0.0	0.05	0.0	0.0	0.03	0.02	0.06	0.00	0.0	0.0	0.0	0.0	0.0	0.02	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.05	0.C	C.0	0.05	0.0	0.0	0.03	0.0	0.08	0.00	0.0	0.0	0.0	0.0	0.01	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.05	0.C1	0.0	0.04	0.0	0.01	0.02	0.0	0.05	0.04	0.01	0.0	0.0	0.0	0.02	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.06	0.05	0.04	0.0	0.05	0.05	0.04	0.08	0.04	0.04	0.04	0.0	0.0	0.02	0.0	0.0	0.01
10	0.0	C.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.09	0.01	0.04	0.0	0.0	0.04	0.0	0.02	0.03	0.07	0.04	0.03	0.02	0.04	0.01
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.05	0.08	0.05	0.05	0.04	0.0	0.0	0.0	0.0	0.03	0.01	0.0	0.02	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.01	0.01	0.0	0.0	0.09	0.06	0.03	0.02	0.0	0.01	0.07	0.03	0.03	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	C.02	0.00	0.0	0.0	0.0	0.0	0.0	0.03	0.02	0.02	0.02	0.0	0.04	0.03	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.03	0.01	0.0	0.0	0.01	0.05	0.02
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.C	C.0	C.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.03	0.03	0.03	0.04	0.0	0.02
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.01	0.02	0.02
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

RESEDA, BURBANK, GLENDALE, PASADENA, AZUSA, GLENDORA, WEST COVINA, WEST LA, LOS ANGELES, SANTA MONICA, LENNOX, LYNWOOD, TORRANCE, LONG BEACH, ANAHEIM, GARDEN GROVE, SANTA ANA

SOX TONS/DAY	FRACTION AS SO3
6.910	0.011

FIGURE A2.36

0.88 tons per day during 1973 versus total on-grid aircraft take-off and landing emissions of about 1.06 tons per day in that year, as shown in Figure A2.37.

A2.6.6 Shipping Operations

Fuel oil combustion by ship traffic was inventoried in three parts: dockside operations, fuel use by ships under way in the harbor plus harbor entrance area, and fuel use in shipping lanes at sea which run parallel to the coast. The methodology for computing fuel use for each part of the shipping traffic inventory is described in detail in Appendix A3 to this report; Section A3.4.3.3 - Residual and Distillate Fuel Oil Consumption. Sulfur oxides emissions were calculated from fuel use data using the sulfur content of ship fuel given in Appendix A3: Sulfur Balance, Table A3.10. The spatial distribution of emissions was estimated by drawing the grid system over the NOAA shipping lane map cited in Appendix A3. Total fuel use at dockside locations was apportioned to grid squares in proportion to the length of waterfront dock area in each square. Fuel use by ships under way in the harbor and harbor entrance were apportioned to grid squares by the fraction of the harbor area plus harbor entrance precautionary area falling into each grid square as shown on the NOAA map.

Shipping lanes are shown on the map as having a northbound and southbound track paralleling the coast. These shipping lanes are each several miles in width. Vessel-miles traveled in each track of the shipping lanes were computed from lane-length and ship movement records as described in Appendix A3 to this report. Total emissions

AIRPORT OPERATION SOX EMISSIONS FOR YEAR 1973 , MONTH 7 IN TONS/DAY AS SO2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.02	0.C	C.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	C.0	0.0	0.0	0.00	0.0	0.0	0.02	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.00	C.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.88	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.01	0.01	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.02	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

RESEDA, BURBANK, GLENDALE, PASADENA, AZUSA, GLENDORA, WEST COVINA, WEST LA, LOS ANGELES, SANTA MONICA, LENNOX, LYNWOOD, TORRANCE, LONG BEACH, ANAHEIM, GARDEN GROVE, SANTA ANA

SOX TONS/DAY	FRACTION AS SO3
1.061	0.010

FIGURE A2.37

for each track of the shipping lanes were computed from vessel fuel economy and fuel sulfur content. Finally, the emissions in the shipping lanes were apportioned to the grid system on the basis of the fraction of the area of each shipping lane falling within a given grid square.

Shipping operations SO_x emissions estimates for a month in 1973 are shown in Figure A2.38. Total on-grid shipping emissions are in excess of ten tons per day of SO_x, which is greater than annual average fuel burning emissions from harbor area refineries. The reason for the substantial SO_x emission rate from ship traffic is found in the ships' ability to avoid limitations on the sulfur content of their fuel. High sulfur fuel oil which could not be burned legally by a stationary source in the harbor area can be burned in unregulated maritime boilers.

A2.6.7 Railroad Operations

Railroad operation SO_x emissions were inventoried by procedures outlined in Appendix A3 of this report. The Residual and Distillate Oil Consumption Section A3.4.3.3 of Appendix A3 should be consulted for detailed references on fuel use data. The sulfur content of railroad fuels is given in Appendix A3, Table A3.10.

Briefly, the procedure used to estimate railroad SO_x emissions was as follows. Fuel use by railroads was obtained for the entire state for each year from Bureau of Mines publications. Total California railroad track mileage was obtained from the U.S. Department of Transportation's Federal Railway Administration, and fuel use per

SHIPPING OPERATION SOX EMISSIONS FOR YEAR 1973 , MONTH 7 IN TONS/DAY AS SO2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.51	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.41	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.07	0.10	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.87	1.71	1.24	0.01	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.03	0.01	0.08	0.09	0.01	0.0	0.0	0.0	0.0	0.0	1.87	0.02	0.02	0.02	0.02	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.04	0.07	0.02	0.03	0.10	0.06	0.04	0.03	0.04	0.04	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.00	0.05	0.07	0.01	0.04	0.06	0.06	0.06	0.06	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.04	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.01	0.06	0.07	0.06	0.07	0.07	0.06	0.02	0.02	0.02	0.02	0.02	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.01	0.07	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.05	0.06	0.06	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

SOX TONS/DAY	FRACTION AS SO3
10.126	0.030

FIGURE A2.38

average track mile was computed for the state. Then track mileage within each grid square was measured on U. S. Geological Survey 7 1/2" maps. Fuel use per grid square was then estimated by multiplying total track mileage per grid square by fuel use per track mile. Compensation for heavy traffic in railroad yards was attempted by counting all side tracks in the yards as being in active use (admittedly a rather crude guess). Next, the sulfur content of fuel was used to compile total SO_x emissions on a daily average basis. An example SO_x emissions estimate for railroads is shown in Figure A2.39 for a typical month in 1973. Many grid squares contain non-zero SO_x emissions of less than .01 tons per day and thus do not show any significant emissions on that map. Occupied squares of that type are indicated as "0.00" while track-less grid cells are given as "0.0".

A2.6.8 Mobile Source Emissions in Time Series

In order to view mobile source emissions in time series, seasonal changes in fuel sales have been combined with fluctuations in fuel sulfur content and traffic volume growth. The SO_x emissions from gasoline use seem nearly level over our three year study period, as shown in Figure A2.40. SO_x emissions from ships, railroads, aircraft and heavy duty vehicles are likewise nearly constant over time as seen in Figure A2.41.

But while automotive emissions seem nearly constant over time on a seasonal basis, there is still a strong diurnal variation in hourly traffic volumes. As seen in Figure A2.42, motor vehicle traffic peaks twice daily (at morning and evening rush hours).

RAILROAD OPERATION SOX EMISSIONS FOR YEAR 1973 , MONTH 7 IN TONS/DAY AS SO2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	0.00	0.00	0.0	0.0	0.0	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.01	0.01	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.01	0.01	0.01	0.01	0.01	0.0	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.01	0.0	0.0	0.01	0.00	0.01	0.01	0.03	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.01	0.01	0.0	0.00	0.01	0.01	0.01	0.01	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.0	0.0	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.11	0.01	0.00	0.0	0.01	0.0	0.0	0.0	0.00	0.01	0.0	0.00	0.01	0.06
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.14	0.01	0.0	0.02	0.00	0.01	0.01	0.0	0.01	0.01	0.01	0.00	0.0	0.03
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.19	0.05	0.01	0.0	0.0	0.0	0.00	0.01	0.01	0.0	0.0	0.0	0.0	0.06
16	0.0	0.0	0.0	0.0	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.15	0.11	0.06	0.02	0.01	0.0	0.01	0.01	0.03	0.02	0.00	0.00	0.01	0.0
15	0.0	0.0	0.0	0.0	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.08	0.05	0.05	0.03	0.02	0.02	0.00	0.0	0.0	0.01	0.02	0.01	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.00	0.0	0.0	0.03	0.02	0.01	0.00	0.02	0.03	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.01	0.00	0.01	0.01	0.02	0.02	0.02	0.01	0.00	0.02	0.00	0.01	0.01	0.01	0.01	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.02	0.00	0.0	0.01	0.01	0.02	0.03	0.00	0.00	0.01	0.02	0.00	0.0	0.01	0.0	0.01	0.01	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.0	0.01	0.0	0.01	0.01	0.03	0.01	0.00	0.01	0.00	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.04
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.02	0.01	0.01	0.03	0.01	0.0	0.0	0.01	0.00	0.00	0.01	0.0	0.01	0.0	0.01	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.01	0.03	0.02	0.0	0.0	0.0	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.07	0.0	0.01	0.00	0.0	0.0	0.0	0.00	0.01	0.00	0.01	0.01	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.04	0.0	0.0	0.0	0.02	0.09	0.03	0.00	0.0	0.01	0.00	0.02	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.03	0.0	0.0	0.0	0.0	0.01	0.03	0.01	0.01	0.0	0.0	0.0	0.01	0.01	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.00	0.01	0.0	0.01	0.01	0.01	0.00	0.01
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.01	0.0	0.0	0.0	0.0	0.0	0.01
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.01
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01

SOX TONS/DAY	FRACTION AS SO3
3.323	0.011

FIGURE A2.39

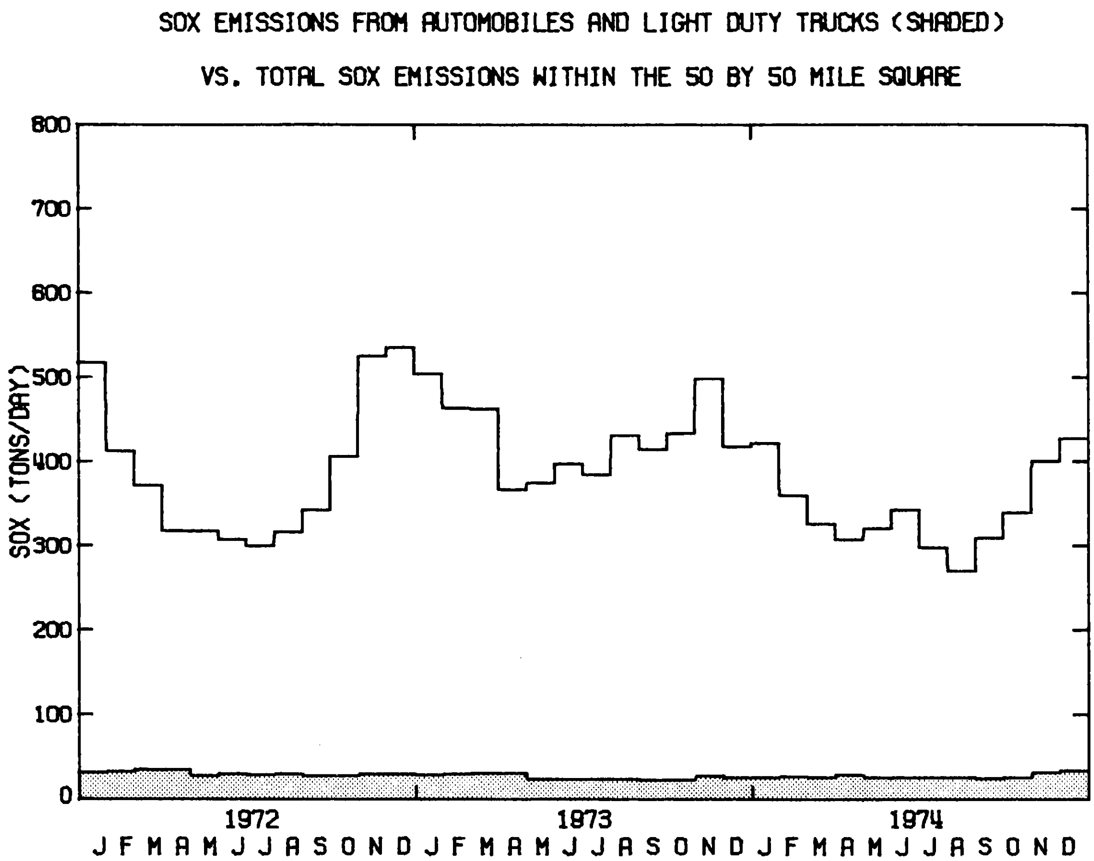
SOX EMISSIONS FROM AUTOMOBILES AND LIGHT DUTY TRUCKS (SHADED)
VS. TOTAL SOX EMISSIONS WITHIN THE 50 BY 50 MILE SQUARE
SOX (TONS/DAY)
800
700
600
500
400
300
200
100
0
1972
1973
1974
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D

FIGURE A2.40

SOX EMISSIONS FROM SHIPS, AIRCRAFT, RAILROADS AND HEAVY DUTY VEHICLES (SHADED)

VS. TOTAL SOX EMISSIONS WITHIN THE 50 BY 50 MILE SQUARE

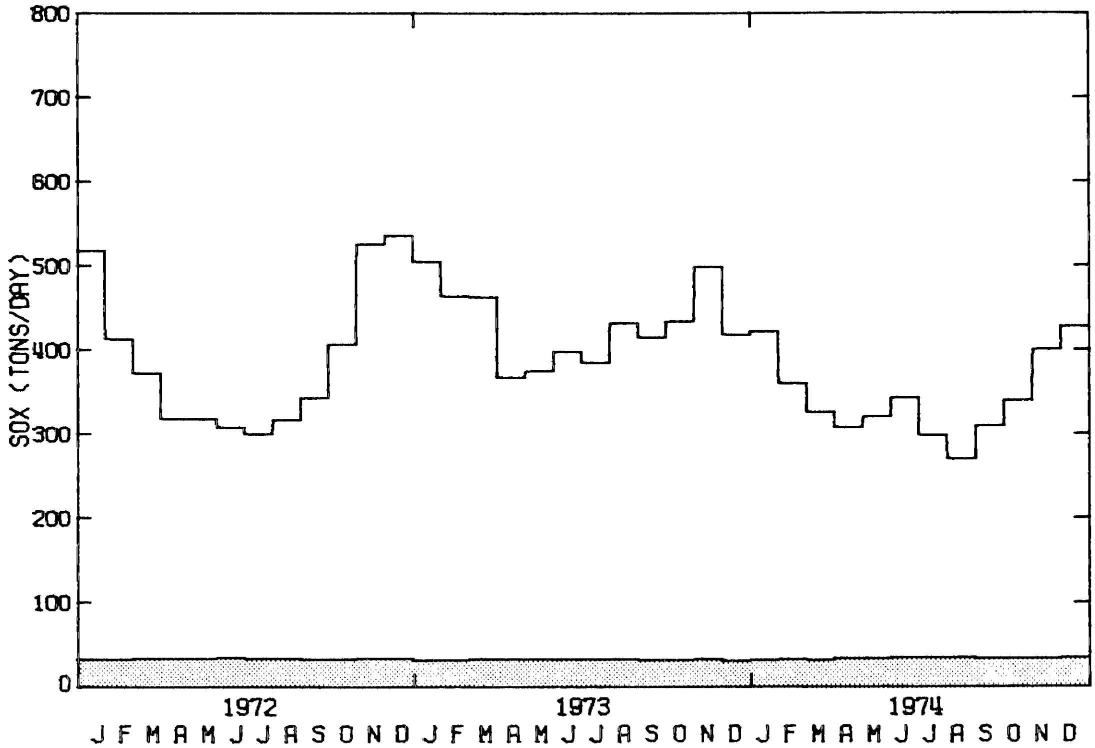

FIGURE A2.41

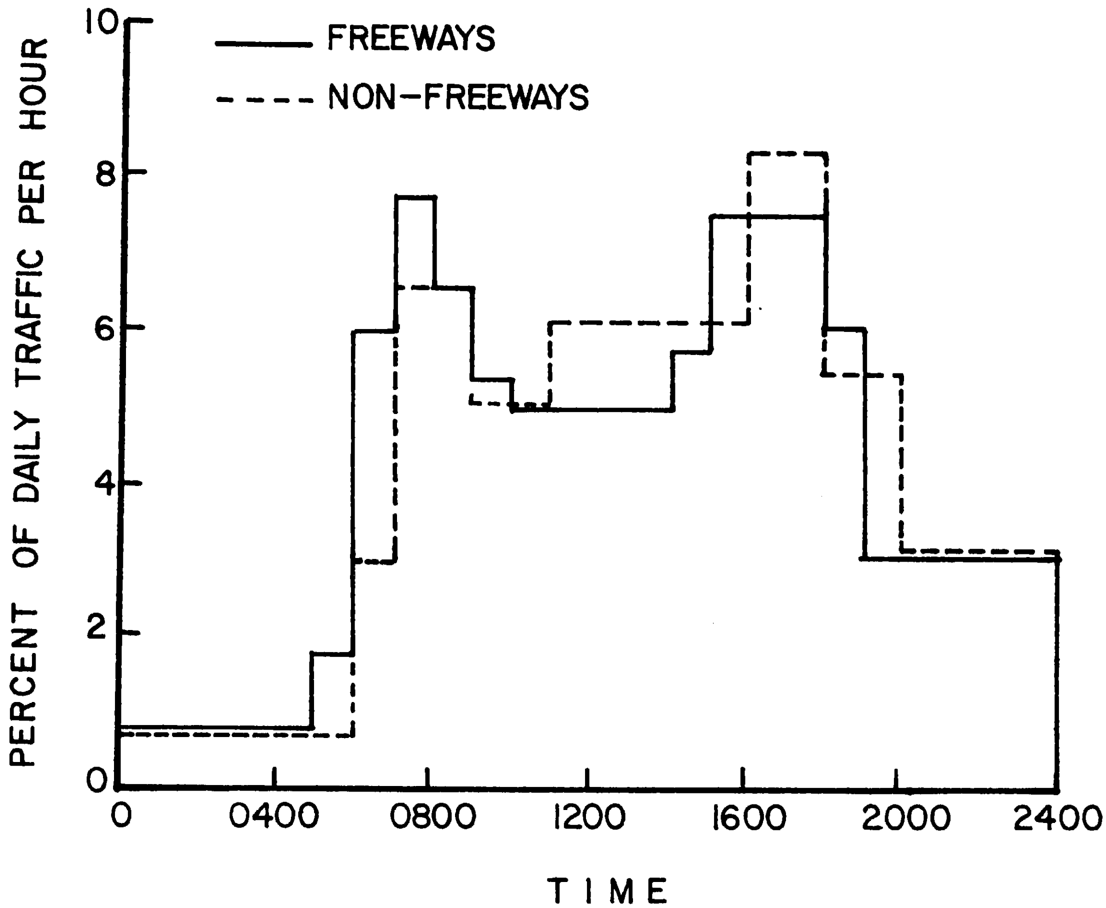

FIGURE A2.42

Diurnal Variation of Los Angeles Traffic Flow
(from Nordsieck, 1974)

A2.7 Emission Inventory Summary and Discussion

Figure A2.43 summarizes sulfur oxides emissions within the 50 by 50 mile square for the years 1972 through 1974. From Figure A2.43 we note that the majority of sulfur oxides emissions arise from combustion-related sources, both stationary and mobile. Electric utility fuel combustion was the largest single SO_x emission source category during 1974. This represents a substantial change since 1972 when sulfur recovery and sulfuric acid plants in the chemical plant category constituted the largest group of SO_x sources on an annual average basis. This shift in relative source contributions is attributed mainly to the installation of tail gas clean-up equipment at Los Angeles County chemical plants, combined with increased oil burning at power plants due to natural gas curtailment.

A second major shift in relative source contributions is seen to be seasonal in nature. Power plants historically have emitted greater quantities of SO_x during the winter months. From Figure A2.43, one might quickly assume that electricity demand is vastly higher in the winter months than in the summer, but that conclusion would be wrong. Energy use within the 50 by 50 mile square grid is detailed in Figure A2.44 from information gathered while compiling Appendices A2 and A3 to this study. Total monthly electricity use within that study area is fairly constant throughout the year. Instead, what has happened is that residential, commercial and industrial demands for fossil fuel rise sharply during the winter. These customers have a higher priority for receiving service from the relatively fixed supply of natural gas available throughout the year than do the

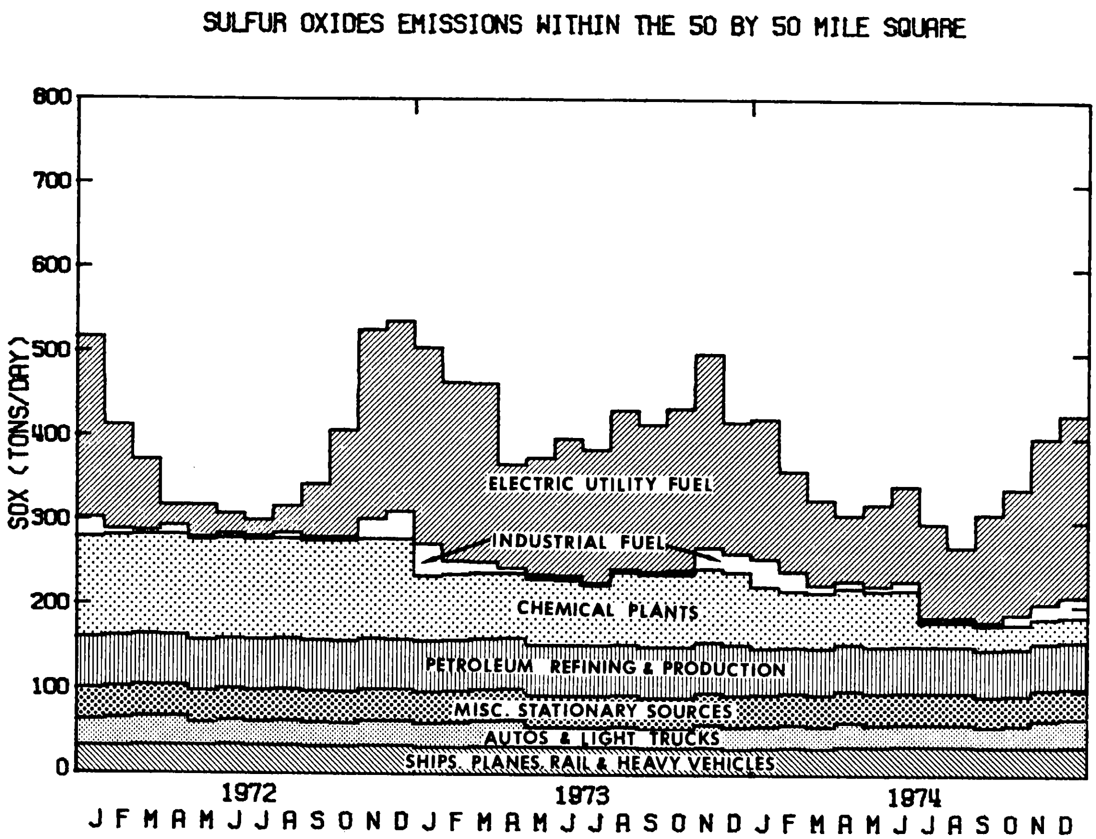
SULFUR OXIDES EMISSIONS WITHIN THE 50 BY 50 MILE SQUARE
800
700
600
500
400
300
200
100
0
SOX (TONS/DAY)
ELECTRIC UTILITY FUEL
INDUSTRIAL FUEL
CHEMICAL PLANTS
PETROLEUM REFINING & PRODUCTION
MISC. STATIONARY SOURCES
AUTOS & LIGHT TRUCKS
SHIPS, PLANES, RAIL & HEAVY VEHICLES
1972
1973
1974
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D

FIGURE A2.43

ENERGY USE WITHIN THE 50 BY 50 MILE SQUARE

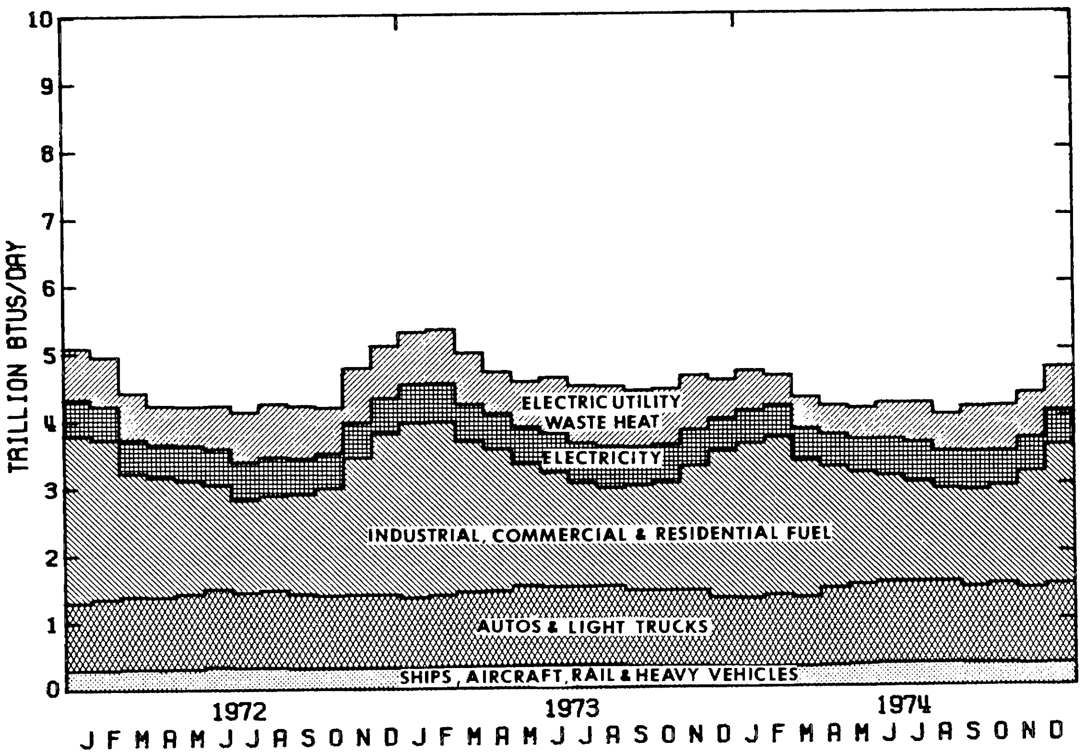

FIGURE A2.44

basin's electric utilities. The result is that the gas supply to utilities and some large industries has been curtailed during winter months, with an attendant substitution of sulfur-bearing fuel oils for natural gas by those customers. These major shifts in source emission strength from month to month will provide a tough test for any air quality model validation effort. This is particularly true for a sulfate air quality modeling study since sulfate concentration seasonal trends tend to buck the SO_x emissions history shown here: Los Angeles sulfate concentrations generally peak in the summer months (for example, see Chapter 2).

It would be tempting to refer to these emission patterns as winter emissions and summer emissions, respectively. That may be misleading however, since only the availability of natural gas during the summer has prevented the higher emission pattern from appearing in the summer season. In fact, as can be seen in Figure A2.43, total SO_x emissions for August 1973 were as high as any winter period of the year 1974. By the year 1979 or 1980, natural gas supplies to electric utilities and large industries in Southern California are expected to be completely curtailed in all months of the year (1975 California Gas Report). The implication is that, in the absence of changes in 1974 emission control regulations, the summertime trough in electric utility SO_x emissions would be "filled in" to about the level of past winter emissions peaks. SO_x from industrial fuel burning would rise substantially.

Tables A2.14 through A2.16 show the monthly emissions history for individual source and equipment types within the general source

TABLE A2.14a

1972 Sulfur Oxides Emissions Within the 50 by 50 Mile Square Grid
(in short tons per day as SO_2)

STATIONARY SOURCES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Fuel Combustion													
Electric Utilities	214.86	123.46	83.56	23.90	38.33	23.98	18.54	32.22	62.40	126.81	223.96	225.17	99.81
Refinery Fuel	17.69	5.78	3.66	9.55	2.50	3.62	3.42	5.86	3.38	3.85	20.95	19.69	8.33
Other Interruptible Gas Customers	5.56	1.37	0.61	0.75	0.64	0.67	0.39	0.63	0.51	0.59	2.74	13.29	2.33
Firm Gas Customers	0.46	0.43	0.29	0.27	0.24	0.20	0.17	0.15	0.16	0.18	0.30	0.40	0.27
Chemical Plants													
Sulfur Recovery	93.53	93.53	93.53	93.53	93.53	93.53	93.53	93.53	93.53	93.53	93.53	93.53	93.53
Sulfuric Acid	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
Other Chemicals	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Petroleum Refining and Production													
Fluid Catalytic Crackers	52.07	52.07	52.07	52.07	52.07	52.07	52.07	52.07	52.07	52.07	52.07	52.07	52.07
Sour Water Strippers	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Delayed Cokers	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28
Misc. Refinery Process	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
Oil Field Production	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Misc. Stationary Sources													
Petroleum Coke Kilns	25.52	25.52	25.52	25.52	25.52	25.52	25.52	25.52	25.52	25.52	25.52	25.52	25.52
Glass Furnaces	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Metals Industries	8.78	8.78	8.78	8.78	8.78	8.78	8.78	8.78	8.78	8.78	8.78	8.78	8.78
Mineral Products	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sewage Treatment Digesters	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64
Other Industrial Processes	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Permitted Incinerators	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
MOBILE SOURCES													
Autos and Lt. Trucks-Surface	19.43	20.25	21.14	20.98	17.04	18.00	17.27	17.81	16.97	16.70	18.07	17.93	18.46
Autos and Lt. Trucks-Freeway	12.21	12.72	13.28	13.18	10.70	11.31	10.85	11.91	10.66	10.49	11.35	11.26	11.60
Heavy Duty Vehicles-Surface	9.71	10.14	10.44	10.35	10.29	10.85	10.40	10.68	10.17	10.00	10.25	10.20	10.29
Heavy Duty Vehicles-Freeway	6.10	6.37	6.56	6.50	6.46	6.81	6.53	6.71	6.39	6.28	6.44	6.41	6.46
Airport Operations	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15
Shipping Operations	11.89	11.89	11.89	11.89	11.89	11.89	11.89	11.89	11.89	11.89	11.89	11.89	11.89
Railroad Operations	3.39	3.39	3.39	3.39	3.39	3.39	3.39	3.39	3.39	3.39	3.39	3.39	3.39
TOTAL	517.60	412.10	371.12	317.06	317.78	307.02	299.15	317.55	342.22	406.48	525.64	535.93	389.13

TABLE A2.14b

Major Off-Grid Emission Sources Included within the 1972 South Coast Air Basin Sulfur Oxides Modeling Inventory
(in short tons per day as SO_2)

STATIONARY SOURCES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Fuel Combustion													
Electric Utilities	55.74	24.32	16.79	6.75	9.99	6.01	9.52	10.52	19.56	29.19	58.04	63.68	25.89
Refinery Fuel	---	---	---	---	---	---	---	---	---	---	---	---	---
Other Interruptible Gas Customers	---	---	---	---	---	---	---	---	---	---	---	---	---
Firm Gas Customers	---	---	---	---	---	---	---	---	---	---	---	---	---
Chemical Plants													
Sulfur Recovery	---	---	---	---	---	---	---	---	---	---	---	---	---
Sulfuric Acid	---	---	---	---	---	---	---	---	---	---	---	---	---
Other Chemicals	---	---	---	---	---	---	---	---	---	---	---	---	---
Petroleum Refining and Production													
Fluid Catalytic Crackers	---	---	---	---	---	---	---	---	---	---	---	---	---
Sour Water Strippers	---	---	---	---	---	---	---	---	---	---	---	---	---
Delayed Cokers	---	---	---	---	---	---	---	---	---	---	---	---	---
Misc. Refinery Processes	---	---	---	---	---	---	---	---	---	---	---	---	---
Oil Field Production	---	---	---	---	---	---	---	---	---	---	---	---	---
Misc. Stationary Sources													
Petroleum Coke Kilns	---	---	---	---	---	---	---	---	---	---	---	---	---
Glass Furnaces	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
Metals Industries	35.20	35.20	35.20	35.20	35.20	35.20	35.20	35.20	35.20	35.20	35.20	35.20	35.20
Mineral Products	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30
Sewage Treatment Digesters	---	---	---	---	---	---	---	---	---	---	---	---	---
Other Industrial Processes	---	---	---	---	---	---	---	---	---	---	---	---	---
Permitted Incinerators	---	---	---	---	---	---	---	---	---	---	---	---	---
TOTAL	93.47	62.05	54.52	44.48	47.72	43.74	47.25	48.25	57.29	66.92	95.77	101.41	63.62

TABLE A2.15a

1973 Sulfur Oxides Emissions Within the 50 by 50 Mile Square Grid
(in short tons per day as SO_2)

STATIONARY SOURCES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Fuel Combustion													
Electric Utilities	232.77	212.31	212.13	123.36	139.48	163.87	157.77	189.23	174.16	192.05	229.72	155.48	181.71
Refinery Fuel	25.07	13.50	10.61	4.26	3.99	3.73	2.91	2.14	2.37	4.01	21.69	18.96	9.42
Other Interruptible Gas Customers	12.78	2.24	2.07	0.98	0.81	0.39	0.39	0.40	0.43	0.76	3.58	2.57	2.29
Firm Gas Customers	0.46	0.46	0.37	0.33	0.26	0.21	0.17	0.16	0.19	0.20	0.26	0.36	0.29
Chemical Plants													
Sulfur Recovery	57.18	57.18	57.18	57.18	57.08	57.08	50.70	66.20	66.20	66.20	66.20	66.20	60.40
Sulfuric Acid	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00
Other Chemicals	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Petroleum Refining and Production													
Fluid Catalytic Crackers	52.07	52.07	52.07	52.07	52.07	52.07	52.07	52.07	52.07	52.07	52.07	52.07	52.07
Sour Water Strippers	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Delayed Cokers	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28
Misc. Refinery Process	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
Oil Field Production	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50
Misc. Stationary Sources													
Petroleum Coke Kilns	25.52	25.52	25.52	25.52	25.52	25.52	25.52	25.52	25.52	25.52	25.52	25.52	25.52
Glass Furnaces	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Metals Industries	8.78	8.78	8.78	8.78	8.78	8.78	8.78	8.78	8.78	8.78	8.78	8.78	8.78
Mineral Products	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sewage Treatment Digesters	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64
Other Industrial Processes	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Permitted Incinerators	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
MOBILE SOURCES													
Autos and Lt. Trucks-Surface	17.17	17.75	18.56	18.76	14.27	14.15	14.05	14.36	13.51	13.51	16.95	15.70	15.71
Autos and Lt. Trucks-Freeway	10.98	11.35	11.87	12.01	9.13	9.05	8.99	9.19	8.64	8.64	10.85	10.05	10.05
Heavy Duty Vehicles-Surface	10.18	10.50	10.94	11.05	10.99	10.88	10.80	10.99	10.35	10.34	10.71	9.90	10.64
Heavy Duty Vehicles-Freeway	6.51	6.72	7.00	7.07	7.03	6.96	6.91	7.03	6.62	6.61	6.85	6.33	6.80
Airport Operations	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06
Shipping Operations	10.13	10.13	10.13	10.13	10.13	10.13	10.13	10.13	10.13	10.13	10.13	10.13	10.13
Railroad Operations	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32
TOTAL	504.73	463.64	462.36	366.63	374.67	397.95	384.27	431.33	414.10	433.95	498.44	417.18	428.94

TABLE A2.15b

Major Off-Grid Emission Sources Included within the 1973 South Coast Air Basin Sulfur Oxides Modeling Inventory
(in short tons per day as SO_2)

STATIONARY SOURCES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Fuel Combustion													
Electric Utilities	60.19	45.46	57.94	39.18	53.62	64.68	54.07	58.97	45.38	59.69	91.75	66.46	58.20
Refinery Fuel	---	---	---	---	---	---	---	---	---	---	---	---	---
Other Interruptible Gas Customers	---	---	---	---	---	---	---	---	---	---	---	---	---
Firm Gas Customers	---	---	---	---	---	---	---	---	---	---	---	---	---
Chemical Plants													
Sulfur Recovery	---	---	---	---	---	---	---	---	---	---	---	---	---
Sulfuric Acid	---	---	---	---	---	---	---	---	---	---	---	---	---
Other Chemicals	---	---	---	---	---	---	---	---	---	---	---	---	---
Petroleum Refining and Production													
Fluid Catalytic Crackers	---	---	---	---	---	---	---	---	---	---	---	---	---
Sour Water Strippers	---	---	---	---	---	---	---	---	---	---	---	---	---
Delayed Cokers	---	---	---	---	---	---	---	---	---	---	---	---	---
Misc. Refinery Processes	---	---	---	---	---	---	---	---	---	---	---	---	---
Oil Field Production	---	---	---	---	---	---	---	---	---	---	---	---	---
Misc. Stationary Sources													
Petroleum Coke Kilns	---	---	---	---	---	---	---	---	---	---	---	---	---
Glass Furnaces	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
Metals Industries	41.46	41.46	41.46	41.46	41.46	41.46	41.46	41.46	41.46	41.46	41.46	41.46	41.46
Mineral Products	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90
Sewage Treatment Digesters	---	---	---	---	---	---	---	---	---	---	---	---	---
Other Industrial Processes	---	---	---	---	---	---	---	---	---	---	---	---	---
Permitted Incinerators	---	---	---	---	---	---	---	---	---	---	---	---	---
TOTAL	103.78	89.05	101.53	82.77	97.21	108.27	97.66	102.56	88.97	103.28	135.34	110.05	101.79

TABLE A2.16a

1974 Sulfur Oxides Emissions Within the 50 by 50 Mile Square Grid
(in short tons per day as SO_2)

STATIONARY SOURCES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Fuel Combustion													
Electric Utilities	166.24	119.19	101.05	77.73	97.16	113.19	111.03	84.23	127.98	148.83	197.60	215.11	130.04
Refinery Fuel	23.69	20.91	7.61	7.59	5.18	9.27	4.35	3.22	3.78	10.44	15.53	20.32	10.93
Other Interruptible Gas Customers	8.30	1.61	0.94	0.71	0.69	1.05	0.64	0.59	0.54	1.12	2.04	3.72	1.84
Firm Gas Customers	0.41	0.41	0.35	0.27	0.23	0.21	0.17	0.15	0.16	0.17	0.25	0.35	0.26
Chemical Plants													
Sulfur Recovery	63.22	63.22	63.22	63.22	63.22	63.22	25.84	25.84	25.84	25.84	25.84	25.84	44.37
Sulfuric Acid	10.20	3.12	3.12	3.12	3.12	3.12	3.12	3.12	3.12	3.12	3.12	3.12	3.72
Other Chemicals	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Petroleum Refining and Production													
Fluid Catalytic Crackers	45.48	45.48	45.48	45.48	45.48	45.48	45.48	45.48	45.48	45.48	45.48	45.48	45.48
Sour Water Strippers	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03
Delayed Cokers	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28
Misc. Refinery Processes	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
Oil Field Production	5.17	5.17	5.17	5.17	5.17	5.17	5.17	5.17	5.17	5.17	5.17	5.17	5.17
Misc. Stationary Sources													
Petroleum Coke Kilns	25.52	25.52	25.52	25.52	25.52	25.52	25.52	25.52	25.52	25.52	25.52	25.52	25.52
Glass Furnaces	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Metals Industries	8.76	8.76	8.76	8.76	8.76	8.76	8.76	8.76	7.40	7.40	7.40	7.40	8.31
Mineral Products	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sewage Treatment Digesters	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64
Other Industrial Processes	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Permitted Incinerators	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
MOBILE SOURCES													
Autos and Lt. Trucks-Surface	15.84	16.84	15.88	17.71	15.63	15.94	16.00	15.86	15.02	15.44	19.65	20.50	16.66
Autos and Lt. Trucks-Freeway	9.88	10.27	9.91	11.05	9.75	9.94	9.98	9.89	9.37	9.63	12.26	12.79	10.39
Heavy Duty Vehicles-Surface	11.20	11.65	11.25	12.49	12.65	12.95	13.03	12.95	12.27	12.66	12.53	13.11	12.40
Heavy Duty Vehicles-Freeway	6.99	7.27	7.02	7.79	7.89	8.08	8.13	8.08	7.65	7.90	7.81	8.18	7.74
Airport Operations	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17
Shipping Operations	9.38	9.38	9.38	9.38	9.38	9.38	9.38	9.38	9.38	9.38	9.38	9.38	9.38
Railroad Operations	2.87	2.87	2.87	2.87	2.87	2.87	2.87	2.87	2.87	2.87	2.87	2.87	2.87
TOTAL	421.31	359.83	325.69	307.02	320.86	342.31	297.63	269.27	309.71	339.13	400.61	427.02	343.24

TABLE A2.16b

Major Off-Grid Emission Sources Included within the 1974 South Coast Air Basin Sulfur Oxides Modeling Inventory
(in short tons per day as SO_2)

STATIONARY SOURCES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Fuel Combustion													
Electric Utilities	67.54	65.53	39.48	26.51	34.32	47.56	49.39	51.69	51.22	46.91	56.15	68.58	50.34
Refinery Fuel	---	---	---	---	---	---	---	---	---	---	---	---	---
Other Interruptible Gas Customers	---	---	---	---	---	---	---	---	---	---	---	---	---
Firm Gas Customers	---	---	---	---	---	---	---	---	---	---	---	---	---
Chemical Plants													
Sulfur Recovery	---	---	---	---	---	---	---	---	---	---	---	---	---
Sulfuric Acid	---	---	---	---	---	---	---	---	---	---	---	---	---
Other Chemicals	---	---	---	---	---	---	---	---	---	---	---	---	---
Petroleum Refining and Production													
Fluid Catalytic Crackers	---	---	---	---	---	---	---	---	---	---	---	---	---
Sour Water Strippers	---	---	---	---	---	---	---	---	---	---	---	---	---
Delayed Cokers	---	---	---	---	---	---	---	---	---	---	---	---	---
Misc. Refinery Processes	---	---	---	---	---	---	---	---	---	---	---	---	---
Oil Field Production	---	---	---	---	---	---	---	---	---	---	---	---	---
Misc. Stationary Sources													
Petroleum Coke Kilns	---	---	---	---	---	---	---	---	---	---	---	---	---
Glass Furnaces	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
Metals Industries	38.12	38.12	38.12	38.12	38.12	38.12	38.12	38.12	38.12	38.12	38.12	38.12	38.12
Mineral Products	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90
Sewage Treatment Digesters	---	---	---	---	---	---	---	---	---	---	---	---	---
Other Industrial Processes	---	---	---	---	---	---	---	---	---	---	---	---	---
Permitted Incinerators	---	---	---	---	---	---	---	---	---	---	---	---	---
TOTAL	107.79	105.78	79.73	67.76	74.57	87.81	89.64	91.94	91.47	87.16	96.40	108.83	90.59

categories of Figure A2.43. The emissions inventory created for air quality model use contains spatially resolved source strength data defined on the 50 by 50 mile grid for each of the 26 source types shown in Tables A2.14 through A2.16 for each month of the years 1972 through 1974. An itemization of large off-grid sources is also included.

One principal reason for compiling emissions on a source by source basis is to be able to display the spatial distribution of SO_x emission strength. Figures A2.45 through A2.47 summarize annual average SO_x emissions density for the years 1972, 1973 and 1974 respectively. It is seen that the largest SO_x emission source densities are located in a narrow strip along the coastline stretching from Los Angeles International Airport (near Lennox) on the north to Huntington Beach (opposite Santa Ana) on the south.

TOTAL SOX EMISSIONS FOR 1972 IN TCNS/DAY AS SO2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.C	0.1	0.1	0.1	0.2	0.1	0.1	3.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.1	0.1	0.1	0.1	0.2	0.1	0.2	0.2	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	1.6	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.1	0.1	0.2	0.2	0.4	0.3	0.3	0.3	0.2	0.2	1.9	0.1	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.1	0.2	0.0	0.2	0.1	0.1	0.1	1.7	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0
19	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.1	0.2	0.3	0.2	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
18	0.0	0.0	0.0	0.0	0.1	0.5	0.2	0.2	0.2	0.3	0.3	0.5	0.2	0.2	0.2	0.2	0.2	0.4	0.2	0.2	0.2	0.2	0.1	0.1	0.4
17	0.0	0.0	0.0	0.1	0.1	0.4	0.2	0.3	0.4	0.4	0.6	0.7	0.4	0.3	0.2	0.1	0.1	0.2	0.1	0.1	0.0	0.0	0.0	0.1	0.1
16	0.0	0.0	0.0	0.1	0.3	0.2	0.4	0.2	0.2	0.2	0.4	0.6	3.6	0.4	0.1	0.1	0.2	0.1	5.7	0.2	0.1	0.0	0.1	0.1	0.0
15	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.1	0.2	0.4	0.4	0.8	0.7	0.3	0.1	0.2	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.4	0.2	0.1	0.3	0.4	0.2	0.3	0.2	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.4	2.1	0.3	0.2	0.1	0.3	0.1	0.1	0.2	0.2	0.3	2.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	30.7	42.1	0.2	0.2	0.2	0.1	0.2	0.2	0.2	0.2	0.2	8.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.3	0.2	0.1	0.3	0.4	0.2	0.2	0.1	0.2	0.2	0.2	0.1	0.2	0.0	0.0	0.1
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.4	9.5	0.4	0.3	19.1	0.2	0.1	0.2	0.2	0.1	0.1	0.2	0.3	0.3	0.2	0.1	0.1	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	65.4	0.3	0.2	0.3	0.2	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	28.1	22.5	0.6	0.2	0.1	0.3	0.2	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.0
7	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	4.3	2.0	1.3	0.1	0.1	48.6	0.1	0.2	0.2	0.1	0.2	0.1	0.2	0.2	0.0
6	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.1	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.1	0.1	0.1	0.5	0.2	0.0
5	0.0	0.1	0.0	0.0	0.1	0.1	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.1	0.2	0.0	0.1
4	0.0	0.0	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.1
3	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.7	4.4	0.1	0.0	0.1	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0

RESEDA, BURBANK, GLENDALE, PASADENA, AZUSA, GLENDORA, WEST COVINA, WEST LA, LOS ANGELES, SANTA MONICA, LENNOX, LYNWOOD, TORRANCE, LONG BEACH, ANAHEIM, GARDEN GROVE, SANTA ANA

SOX
TONS/DAY
389.130

FIGURE A2.45

TOTAL SOX EMISSIONS FOR 1973 IN TONS/DAY AS SO2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.C	0.1	0.1	0.1	0.2	0.1	0.1	4.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.1	0.1	0.1	0.2	0.1	0.2	0.2	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	3.9	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.1	0.1	0.2	0.2	0.3	0.3	0.3	0.3	0.2	0.2	3.4	0.1	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.2	0.0	0.2	0.1	0.1	0.1	2.4	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0
19	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.2	0.3	0.2	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.1
18	0.0	0.0	0.0	0.0	0.1	0.5	0.2	0.2	0.2	0.3	0.3	0.5	0.2	0.2	0.2	0.2	0.2	0.4	0.2	0.1	0.2	0.1	0.1	0.1	0.5
17	0.0	0.0	0.0	0.0	0.1	0.4	0.2	0.3	0.3	0.4	0.5	0.6	0.3	0.3	0.2	0.1	0.1	0.2	0.1	0.1	0.0	0.0	0.0	0.1	0.1
16	0.0	0.0	0.0	0.1	0.2	0.2	0.3	0.1	0.2	0.2	0.4	0.6	3.5	0.4	0.1	0.1	0.2	0.1	5.7	0.2	0.1	0.0	0.1	0.1	0.0
15	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.1	0.2	0.3	0.3	0.8	0.7	0.3	0.1	0.2	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.3	0.2	0.1	0.3	0.4	0.2	0.2	0.2	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.5	5.0	0.3	0.2	0.1	0.2	0.1	0.1	0.2	0.2	0.3	2.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	43.0	0.3	0.1	0.1	0.2	0.1	0.2	0.2	0.2	0.2	0.2	7.6	0.0	0.0	0.1	0.1	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.3	0.2	0.1	0.2	0.4	0.2	0.2	0.1	0.1	0.2	0.2	0.1	0.1	0.0	0.0	0.1
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.3	12.6	0.4	0.3	20.1	0.2	0.1	0.1	0.2	0.1	0.1	0.2	0.3	0.3	0.2	0.1	0.1	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	68.8	0.3	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	25.0	22.4	0.6	0.2	0.1	0.3	0.2	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.0
7	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	7.7	1.8	1.3	0.1	0.1	101.5	0.1	0.2	0.1	0.1	0.1	0.1	0.2	0.1	0.0
6	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.1	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.1	0.1	0.1	0.5	0.2	0.0
5	0.0	0.1	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.1	0.2	0.0	0.1
4	0.0	0.0	0.1	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1
3	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.5	4.9	0.1	0.0	0.1	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0

SOX
TONS/DAY
428.945

FIGURE A2.46

TOTAL SOX EMISSIONS FOR 1974 IN TONS/DAY AS SO2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.1	0.1	0.1	0.2	0.1	0.1	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.1	0.1	0.1	0.1	0.2	0.1	0.2	0.2	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	2.4	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.1	0.1	0.2	0.2	0.4	0.3	0.3	0.3	0.2	0.2	2.6	0.1	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.2	0.0	0.1	0.1	0.2	0.0	0.2	0.1	0.1	0.1	2.5	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0
19	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.3	0.3	0.2	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
18	0.0	0.0	0.0	0.0	0.1	0.6	0.2	0.2	0.2	0.3	0.3	0.5	0.2	0.2	0.2	0.2	0.2	0.4	0.2	0.2	0.2	0.1	0.1	0.1	0.5
17	0.0	0.0	0.0	0.1	0.1	0.4	0.2	0.3	0.4	0.4	0.6	0.6	0.3	0.3	0.2	0.1	0.1	0.2	0.1	0.1	0.0	0.0	0.0	0.1	0.1
16	0.0	0.0	0.0	0.1	0.3	0.2	0.4	0.2	0.2	0.2	0.4	0.5	3.1	0.4	0.1	0.1	0.2	0.1	5.7	0.2	0.1	0.0	0.1	0.1	0.0
15	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.1	0.2	0.3	0.3	0.7	0.7	0.3	0.1	0.2	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.3	0.2	0.1	0.3	0.4	0.2	0.2	0.2	0.3	0.1	0.1	0.1	0.0	0.0	0.0	0.1	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.5	4.8	0.3	0.2	0.1	0.2	0.1	0.1	0.2	0.2	0.3	2.4	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	25.0	0.3	0.2	0.2	0.2	0.1	0.2	0.2	0.2	0.3	0.2	8.5	0.1	0.0	0.1	0.1	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.3	0.2	0.1	0.2	0.4	0.2	0.3	0.1	0.2	0.2	0.2	0.1	0.2	0.0	0.0	0.1
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.2	10.0	0.3	0.3	10.8	0.2	0.1	0.2	0.2	0.1	0.1	0.2	0.3	0.3	0.2	0.1	0.1	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	60.6	0.3	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	14.3	22.5	0.6	0.2	0.1	0.3	0.2	0.1	0.2	0.1	0.1	0.3	0.1	0.2	0.0
7	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	2.8	1.8	1.4	0.1	0.1	72.4	0.1	0.2	0.2	0.2	0.2	0.1	0.2	0.2	0.0
6	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.1	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.1	0.1	0.1	0.5	0.2	0.0
5	0.0	0.1	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.1	0.2	0.0	0.1
4	0.0	0.0	0.1	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.1	0.1	0.1
3	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.8	5.6	0.1	0.0	0.1	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0

RESEDA
BURBANK
GLENDALE
PASADENA
AZUSA
GLENDORA
WEST COVINA
WEST LA
LOS ANGELES
SANTA MONICA
LENNOX
LYNWOOD
TORRANCE
LONG BEACH
ANAHEIM
GARDEN GROVE
SANTA ANA

SOX
TONS/DAY
343.244

FIGURE A2.47

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(1) "Sulfur Balance - Los Angeles County Refineries - 1973".
(2) "Sulfur Balance - Los Angeles County Refineries - 1974".
(3) "Sulfur Recovery and Sulfuric Acid Plant Operations - Los Angeles County - 1973".
(4) "Sulfur Recovery and Sulfuric Acid Plant Operations - Los Angeles County - 1974".

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APPENDIX A3

ENERGY AND SULFUR BALANCE CALCULATIONS FOR THE SOUTH COAST AIR BASIN - 1973

A3.1 Introduction

This appendix describes the data sources and methods that were employed to compile an energy balance on the economy of the South Coast Air Basin for the year 1973. The purpose of this study was to determine the sources and sinks for sulfur-bearing fossil fuels within this air basin in a way that would assist estimation of sulfur oxides air pollutant emissions. Therefore, the energy balance is followed by sulfur balance calculations.

During the course of this discussion, it will become necessary to convert physical quantities of fuels (e.g. barrels, gallons, mcf) into energy units. A list of the conversion factors which were used in the development of this energy balance is given in Table A3.1. English engineering units are employed throughout this appendix since that is the currently accepted practice in the governmental and industrial community from whom the data used in this report were obtained.

The nature of energy resources as they enter the South Coast Air Basin will first be described. Then energy resources supplied to local petroleum refineries and electric utility generating stations will be transformed into a variety of finished petroleum products and electricity. Finished products reaching the end use consumption

TABLE A3.1

Heating Values and Conversion Factors

Fuel	Heating Value	Reference
Natural Gas	1060 BTU/ft^3	*1975 California Gas Report*
Crude Oil	5800 x 10^3 BTU/bbl	American Petroleum Institute (1972)
LPG		
Propane	3800 x 10^3 BTU/bbl	Environmental Protection Agency (1973)
Butane	4090 x 10^3 BTU/bbl	Environmental Protection Agency (1973)
Average	3950 x 10^3 BTU/bbl	(Used when no composition data available)
Natural Gasoline	4620 x 10^3 BTU/bbl	Bureau of Mines (1975c)
Digester Gas	600 BTU/ft^3	Frieling (1976)
Still Gas	990 BTU/ft^3	Bureau of Mines (1975c)
	6000 x 10^3 BTU/bbl	Bureau of Mines (1975c)
Refinery Gas (LPG & still gas mixture)	1300 BTU/ft^3	Zwiacher (1976)
Gasoline	5248 x 10^3 BTU/bbl	Bureau of Mines (1975c)
Diesel Fuel	5812 x 10^3 BTU/bbl	List (1971)
Jet Fuel	5683 x 10^3 BTU/bbl	List (1971)
Fuel Oils		
Distillate	5825 x 10^3 BTU/bbl	Bureau of Mines (1975c)
Residual	6287 x 10^3 BTU/bbl	Bureau of Mines (1975c)
Lubricants	6065 x 10^3 BTU/bbl	Bureau of Mines (1975c)
Asphalt	6636 x 10^3 BTU/bbl	Bureau of Mines (1975c)
Petroleum Coke	6024 x 10^3 BTU/bbl	Bureau of Mines (1975c)
Miscellaneous Petroleum Products	5800 x 10^3 BTU/bbl	(Based on energy content of crude oil)
Coal	12,000 BTU/lb	Bureau of Mines (1975c)
Electricity	3412 BTU/kwh	American Petroleum Institute (1972)
Steam	1200 BTU/lb	Bureau of Mines (1975c)

sector of the air basin's economy will be outlined, followed by an estimate of energy exports from the basin. The sulfur balance will follow from the energy balance in the same order. Throughout the discussion, the word "imports" will be used to indicate flows of energy (or sulfur) across the boundaries of the air basin and will be applied to both foreign and out-of-basin domestic sources. Similarly the term "exports" will be applied to flows out of the basin whether to foreign or domestic customers.

A3.2 Energy Sources

An estimate of the South Coast Air Basin's original energy supply is given in Table A3.2 for the year 1973. These data represent inflows of energy resources across the boundaries of the air basin, including locally produced oil and gas. All values given are in 10^{12} BTU's per year. Crude oil is seen to be the largest single energy source for the basin, followed by natural gas and imported fuel oils. A description of the methods used to estimate the quantities shown in Table A3.2 follows.

A3.2.1 Natural Gas Sources

All data on natural gas supplies were taken from the 1975 California Gas Report. Gas is received from both California and interstate suppliers. Natural gas from California sources is broken down into two components: direct purchases by the gas and electric utilities serving the basin, plus gas received for exchange. A gas exchange transaction represents gas submitted by its owner to a pipeline at one location followed by a counterbalancing withdrawal of gas from

TABLE A3.2

South Coast Air Basin Energy Sources-1973

	10^{12} BTU/year
Natural Gas	
California sources-utility purchase	67.7
-gas exchange	30.1
Interstate receipts	945.0
Purchases from other utilities	7.5
Less net injection to storage	-25.2
Subtotal	1,025.1
Crude Oil Plus Net Unfinished Oils	
Los Angeles & Ventura area oil fields	1,039.8
Other California crude oils	276.7
Interstate receipts of domestic oils	225.9
Foreign imports	639.9
Subtotal	2,182.3
Petroleum Product Imports	
Harbor receipts	
Gasoline (including natural gasoline)	69.6
Jet fuel	4.4
Distillate oil and kerosene	83.6
Residual oil	127.6
Petroleum coke	5.5
Lubricants and greases	12.3
Asphalt and asphalt materials	0.1
Other	4.6
Subtotal	307.7
Natural Gasoline & Natural Gas Liquids	20.9
Liquid Petroleum Gas	14.4
Digester Gas	2.6
Electricity Imports	
Generated out-of-basin by local utilities	
Nuclear	6.2
Hydro	27.2
Fossil fuel	
Oil	0.03
Natural gas	3.8
Coal	34.8
Purchases out-of-basin	25.3
Less out-of-basin sales	-13.1
Subtotal	84.2
Coal	
Coking coal	57.2
Miscellaneous	0.2
Receipts for export	0.0
Subtotal	57.4
TOTAL ENERGY SOURCES	3,694.6

the pipeline system at another location. Gas transferred through the utility systems serving the basin to San Diego and other areas of the state are included in the gas-supply totals of Table A3.2, and will be subtracted from the South Coast Air Basin's supply later as an "export".

Gas purchases by one utility company from another are not identifiable by interstate or intrastate origin. Purchases from other utilities shown in the energy supply tabulation include only those made by Pacific Lighting Companies. Purchases by Southern California Edison (SCE) from Pacific Gas and Electric (PG&E) for SCE's Coolwater power plant (located in the Mojave Desert) have not been included since that power plant site lies outside of the South Coast Air Basin. Those purchases were discussed in the PG&E section of the 1975 California Gas Report as "sendout to other steam electric plants, retail". All other utility to utility transactions reported by Los Angeles area utility companies represent purchases from Pacific Lighting and thus do not constitute a net flow of gas into the air basin's economy.

Changes in gas storage from one year to the next also take place. Storage change data were taken from the 1975 California Gas Report under the headings "underground and LNG storage injection" and "underground and LNG storage withdrawal". Depending on whether withdrawal exceeds injection or not, this activity could constitute a net gas source or sink in any given year. In 1973, injection exceeded withdrawal and the effect of the storage program was to reduce available gas supplies.

A3.2.2 Crude Oil Sources

A detailed survey of the South Coast Air Basin's crude oil supply was conducted for the year 1973, and is reported in Appendix A1 to this study. Data from that survey are the basis for the crude oil sources reported in Table A3.2. Crude oil sources have been grouped into local oil fields (i.e. oil produced at fields within the South Coast Air Basin and Federal leases off the coast of the air basin), other California oil fields (e.g. from the San Joaquin Valley and the central California coastal area), other domestic oils (from Alaska and the Four Corners area), and foreign crude oil. Sources of Los Angeles and Ventura area crude oil given in Table A3.2 include all production from those fields in 1973 (see Table A1.6). Net out-of-basin shipments of some of this locally produced crude oil will be subtracted from the energy balance later an an "export". All other crude oil volumes represent imports from out-of-basin sources as given in Table A1.10.

A3.2.3 Imported Petroleum Product Sources

Data on port receipts of refined petroleum products were obtained from Waterborne Commerce of the United States (Corps of Engineers, 1973). In those cases where harbor records do not distinguish between imports and exports, refined products were assumed to be shipped to sea from El Segundo and received at Huntington Beach, Ventura, Port Hueneme, and Carpenteria. Whenever a product classification used by the Corps of Engineers encompasses more than one product type, the entire energy content of imports in that classification was assigned to the most prominant product in the group.

No indication was found that significant quantities of refined petroleum products intended for civilian use were received in the South Coast Air Basin by means other than waterborne transit.

A3.2.4 Natural Gas Liquids* (NGL) and Liquified Petroleum Gas (LPG) Sources

Total production of these liquids at West Coast natural gas processing plants in 1973 is given by the Bureau of Mines (1974g, 1975e). West Coast import data likewise are available in the same publications. But scale factors needed to estimate transfers of LPG and NGL from West Coast suppliers to the South Coast Air Basin seem largely unavailable.

The California Energy Planning Council (1974) is able to supply an estimate of 1973 LPG and natural gasoline supplies for the entire state of California. They place total availability of natural gasoline at 20,000 bbl/day and LPG at 20,000 bbl/day. Natural gasoline appears to be used principally as a refinery feedstock. The refinery discussion to be presented later in this appendix indicates that 62% of the state's crude oil runs to refineries in 1973 occured in the South Coast Air Basin. Therefore, 62% of the available supply of natural

*Including natural gasoline.

gasoline in California in that year was assigned to the South Coast Air Basin.

LPG is used as a refinery fuel, for chemical plant feedstock, and for a variety of domestic and light industrial applications. Fifty percent of California's available LPG input was assigned to the South Coast Air Basin in 1973 on the basis of the ratio between basin population and the population of the state.

A3.2.5 Sources of Digester Gas

As part of the sewage sludge digestion process, methane-rich gases are produced. This digester gas is burned to power the sewage treatment plants, and is also sold for fuel to nearby industries and power plants. The volumes of digester gas produced by the Orange County Sanitation District, the City of Los Angeles' Hyperion Treatment Plant and the Los Angeles County Sanitation District's Harbor City plant were determined by conversations with treatment plant personnel (personal communications: Clark, 1976; Rojas, 1976; Frieling, 1976). The energy content of digester gas was given as 600 BTU/ft^3 (personal communication, Frieling, 1976).

A3.2.6 Sources of Imported Electricity

Southern California Edison Company (SCE), the Los Angeles Department of Water and Power (DWP), and the municipal power departments of Pasadena, Burbank, and Glendale are the utilities involved in importing electricity into the South Coast Air Basin. Data on quantities of electricity imported and generated by various methods were obtained from the annual reports of these utilities (Pasadena, 1974, 1975; Department of Water and Power, 1972a through 1975a, 1975b;

Southern California Edison, 1972a; 1973a; Southern California Edison, 1974). Additional data sources employed include the Federal Power Commission's (FPC) yearly reports on Statistics of Privately Owned Electric Utilities in the United States (Federal Power Commission, 1972a, 1973a, 1974a) and Statistics of Publicly Owned Electric Utilities in the United States (Federal Power Commission 1972b, 1973b, 1974b), plus the FPC's monthly reports on Electric Power Statistics (Federal Power Commission 1972c through 1975c).

Data available for the various utility companies were provided in different formats and required further processing before they could be combined to summarize electricity imports for the whole basin. Data for SCE were available on a calendar year basis in both the company's annual reports and the FPC yearly reports. For the other publicly owned utilities, data were provided only on a fiscal year basis. To adjust fiscal year data to a calendar year basis, the FPC monthly systems load data for each utility were examined to determine the load distribution between the two calendar years spanned by a given fiscal year. The factors shown in Table A3.3 were used to assign fiscal year data (for both electric generation and end use consumption) to given calendar years.

Nuclear power is imported to the air basin's economy from SCE operations at San Onofre. Data on nuclear power generation were taken from the SCE annual reports.

Hydroelectric power is produced by the DWP and SCE at installations at Hoover Dam and other sites. Data on total production of

TABLE A3.3

Factors Used to Adjust Electric Utility Fiscal Year Data to a Calendar Year Basis

Fiscal Year	Percentage of Fiscal Year Electric System Load Assigned to First and Second Half of Each Year							
	DWP		Pasadena		Glendale		Burbank	
	1st Half	2nd Half	1st Half	2nd Half	1st Half	2nd Half	1st Half	2nd Half
72-73	55.6	44.4	51.2	48.8	51.2	48.8	51.1	48.9
73-74	54.5	45.4	54.5	45.5	54.7	45.3	55.6	44.4

hydroelectric power were taken from the annual reports of these two utilities. The DWP pumped storage facility at Castaic was not included in the imported hydropower numbers on the energy balance. Electric power output from that reservoir will be considered as the result of in-basin hydroelectric generation to be described later in this appendix.

The DWP and SCE also have fossil fuel fired generating facilities located outside of the South Coast Air Basin. The DWP's out-of-basin plants are all coal fired; their electric production in fiscal years 1973-74 and 1974-75 is reported in the DWP's 1974-75 annual report. Coal fired electricity production for previous years was not reported separately in the DWP annual reports, but that information was obtained by personal communication with DWP staff (Nelson, 1976).

SCE's out-of-basin thermal generation includes coal fired plants plus the oil and gas fired plant at Coolwater in the Mojave Desert. Coal fired electricity production was reported separately in their 1973 annual statistical report. Gas and oil fired generation of electricity at Coolwater was estimated from PG&E's deliveries and curtailment of natural gas to the Coolwater plant (1975 California Gas Report) using the average heat rate from SCE's annual statistical report. Generation from natural gas at Coolwater was based on gas delivered, while gas deliveries curtailed were assumed to represent (on an equivalent BTU basis) the amount of oil that had to be burned instead.

Purchased power shown in Table A3.2 represents the sum of all purchases by electric systems from sources other than their own generating facilities. These purchases are assumed to come from out-of-basin generating plants. The quantity of sales between utilities of electricity generated within the basin could not be determined, but is estimated to be small in 1973. Data on purchases were taken from the FPC annual reports, with the following exception. Los Angeles DWP purchases were taken from their 10-year summary of operations published in 1975 (Department of Water and Power, 1975b).

Both the DWP and SCE provide electrical service to areas located outside of the South Coast Air Basin. The exact source of the electricity used to supply these customers is not known. In this energy balance, out-of-basin electricity consumption on these two utility systems has been subtracted from total out-of-basin electricity supply. The DWP services to Inyo and Mono Counties are reported for each year in the DWP 10-year summary (Department of Water and Power, 1975b). The SCE reports give no data on electricity use by geographic area. However, by comparing statistics on population, industrial employees, and number of manufacturing firms in the counties served by SCE, it was estimated that 92% of their residential and commercial sales, 98% of industrial sales, 10% of agricultural sales and 92% of "other" sales were for use within the South Coast Air Basin. Derivation of these scale factors will be explained when discussing electricity end use consumption. The remaining SCE electric use in each category was assigned to out-of-basin sales. Total SCE and DWP out-of-basin sales were then subtracted from out-of-basin sources to determine the net out-of-basin electricity supply shown on the energy input tabulation of Table A3.2.

A3.2.7 Sources of Coal

The 1973 Minerals Yearbook (Bureau of Mines, 1975e) indicates that coal use in California was confined almost entirely to coke and gas production during 1973. The Stanford Research Institute (1973) report Meeting California's Energy Requirements, 1975-2000 assigns all coal use in the state to Southern California. The principal recipient of coking coal in Southern California is a steel mill located within the bounds of the South Coast Air Basin. On that basis, all coal shipped to California for coke and gas production was assigned to the South Coast Air Basin.

The Bureau of Mines' Minerals Yearbook (1975e) also lists a very small amount of coal shipped to California for miscellaneous retail sales. Half of this retail coal sale has been assigned to the South Coast Air Basin (on the basis of basin population as a fraction of total state population).

A3.3 Energy Transformations Occurring Within the South Coast Air Basin

A3.3.1 Petroleum Refining

A3.3.1.1 Crude Oil and Other Raw Material Inputs to the Refining Process

Data on 1973 West Coast (PAD District V) refinery input feedstocks are available from the Bureau of Mines (1975c). Similar information on total 1973 California refinery feedstocks is given by the California Energy Planning Council (1974). These data are summarized in Table A3.4.

TABLE A3.4

1973 Refinery Input and Output
(in 10^{12} BTU's/year)

	PAD District V* (West Coast)	California	South Coast Air Basin	South Coast Air Basin Adjusted
Refinery Input Feedstocks (total)	4,372.2	3,510.6	2,174.3	
Crude & net unfinished oils	4,260.2	3,430.6	2,124.8	
LPG	28.2	14.1	8.7	
NGL (natural gasoline)	39.5	38.6	23.9	
(condensate)	16.5			
Other hydrocarbons	27.5	27.3	16.9	
Fuels Consumed (total)	470.6		219.9	
Natural gas	150.2		48.5	
Refinery gas	184.6		149.8	
LPG	13.4			
Residual & heavy distillate oil	31.1		11.8	
Middle distillate oil	6.9			
Petroleum coke	58.8			
Electricity	19.7		9.8	
Steam	5.9		unknown	
Refinery Output (total)	4,446.9	3,582.1	2,218.6	
Gasolines	1,759.6	1,393.3	863.0	
Jet fuels	490.1	362.2	224.3	
Distillate oils and kerosene	605.3	435.2	269.5 →	
light and mid distillates				126.9
heavy distillate & residual oils				581.2
Residual oils	835.5	708.2	438.6 →	
Petroleum coke	200.2			112.0
LPG-LRG	64.5			36.1
Lubricants	33.0			18.5
Asphalt & road oil	157.2			88.0
Still gas for fuel	193.7			108.4
Other hydrocarbons	107.8	683.2	432.2	60.3

*PAD District V includes the states of Alaska, Arizona, California, Hawaii, Nevada, Oregon and Washington.

The net supply of crude and unfinished oils available to South Coast Air Basin refineries in 1973 was established in Appendix A1 to this study (see Table A1.10). Crude and net unfinished oils processed by South Coast Air Basin refineries appear to account for about 62% of the crude oil and net unfinished oil supplied to all refineries in California in that year. That proportion of total South Coast Air Basin to total State crude oil input was used to scale the other non-crude oil refinery feedstocks given for all of California in Table A3.4 down to an estimate for the South Coast Air Basin.

A3.3.1.2 Refinery Fuel Use

Fuel use at refineries in PAD District V is reported by the Bureau of Mines (1975c). Fuel combustion by South Coast Air Basin refineries was calculated from a refinery fuel survey conducted by the Southern California Air Pollution Control District (SCAPCD) as described in Appendix A2 of this study. That local refinery survey covers all large refineries in the South Coast Air Basin, but at least two very small independent refiners are neglected. Therefore, total fuel use estimates for local refineries given in Table A3.4 will be a few percent too low.

Total refinery gas consumption reported to the SCAPCD by local refineries includes a mix of still gas and LPG. Oil use reported is for both residual and distillate fuels. In Table A3.4, these locally reported fuel combinations which overlap more than one Bureau of Mines fuel use category are shown by a single heating value estimate contained within a box which spans the equivalent combination of fuels reported by the Bureau of Mines. Electricity consumption by South Coast Air Basin refineries was scaled from PAD District V refinery electricity use in proportion to the ratio between South Coast Air Basin and PAD District V crude plus net unfinished oils feedstock inputs.

A3.3.1.3 Refinery Products

The product output of West Coast refineries in 1973 is available in considerable detail from the Bureau of Mines (1975c). The California Energy Planning Council (1974) reports 1973 California refinery production data for most liquid fuels plus a single miscellaneous refinery products category. A summary of these product data are given in Table A3.4.

Using crude oil input to refineries as our scaling factor, 62% of the total California refinery output of each product listed by the California Energy Planning Council (1974) was assigned to the South Coast Air Basin. Then the California Energy Planning Council's miscellaneous product category was subdivided further. Estimates of local refinery production of petroleum coke, LPG-LRG, lubricants, asphalt, still gas and other hydrocarbons were derived from the South Coast Air Basin's share of the state's miscellaneous products total in proportion to PAD District V refinery production of these items.

From a review of the quantity of heavy oils burned in the South Coast Air Basin, it became apparent that some of the product output listed as "distillate" by the Bureau of Mines was actually being blended into the heavy fuel oil pool. Therefore, an attempt was made to estimate the magnitude of this blending operation.

Distillate oils were subdivided into a light and middle distillates group, plus a heavy distillate group. The heavy distillate oils were then lumped with residual oil to form a single heavy fuel oil category. The quantity of heavy distillate oil produced in the South Coast Air Basin was estimated from a knowledge of the tonnage of sulfur contained in such oils leaving local refineries in 1973 as reported by the Southern California Air Pollution Control District (1976a), combined with an estimate of the weight percent sulfur in a Western Region Grade 4 fuel oil given by the Bureau of Mines (1972b). These revisions to the quantities of light and heavy fuel oils produced in South Coast Air Basin refineries are shown as an adjustment in Table A3.4.

A3.3.2 Generation of Electricity Within the South Coast Air Basin

Energy resources used to generate electricity within the South Coast Air Basin in 1973 are detailed in Table A3.5. These estimates are based on data from the sources cited during our previous discussion of electric power imports from outside of the basin. The quantity of electricity produced by combustion of various fuels was first determined from utility statistical reports. Then that electricity production by fuel type was combined with a knowledge of typical generating station heat rates to estimate total fuel input to the generating plant .

Thermal electric generation capacity is of two types: conventional steam boilers and internal combustion engines. With the

TABLE A3.5

Electricity Generation Within
the South Coast Air Basin - 1973

Fuel Burned	10^{12} BTU/year
Natural Gas	160.8
Heavy Fuel Oil	386.3
Light Distillate Oils	2.7
Digester Gas	0.3
SUBTOTAL	550.1
Electricity Generated	
Thermal Generating Plants	175.5
Hydroelectric	0.4
SUBTOTAL	175.9

exception of the City of Pasadena, all basin electric utilities employed internal combustion turbines to generate peaking power during 1973. Peaking unit utilization is reported in the FPC annual statistical reports, sometimes as "internal combustion engine" generation and sometimes as "other" generation. A light distillate fuel is assumed to be burned in these turbines.

Data on conventional steam electricity generation occurring within the South Coast Air Basin must be separated from statistics representing total conventional steam electric generation on each utility's entire system. In the case of DWP, this separation is readily identifiable in their annual reports. DWP's out-of-basin steam electric production is all coal-fired, while in-basin plants run on oil and gas. All 1973 conventional steam electric generation by the cities of Glendale, Burbank and Pasadena occurred within the air basin. SCE's in-basin steam electric generation for 1973 was determined by subtracting all coal-fired generation plus SCE's out-of-basin oil and gas fired generation from their total system steam electrical generation as given in their annual statistical reports. Estimation of SCE's out-of-basin oil and gas fired electricity generation was discussed previously in Section A3.2.6 of this survey. In-basin electricity generation at conventional steam plants by all utilities was then totaled for the year 1973.

Next, this in-basin electricity output from conventional generating stations was used to estimate related utility oil and gas requirements. The energy input required to generate the total steam electric output determined above was calculated using SCE's average heat rate, which was 9947 BTU's/KWH in 1973. The energy content of natural gas supplied to electric utilities in 1973 was calculated from gas deliveries to generating stations as reported in the 1975 California Gas Report. The remaining heat required to complete the total input to the steam electric generation process was assumed to be supplied by burning heavy fuel oil. These fuel use estimates derived from utility annual reports are very close to those obtained by adding up monthly fuel burning data from the air pollution control districts as described in Appendix A2 to this study. An important portion of the air quality modeling emission inventory has been confirmed.

Hydroelectric generation within the air basin occurs from DWP operations at the Castaic pumped storage reservoir. Data on operations at Castaic were obtained from the DWP's 10-year summary of operations (Department of Water and Power, 1975b).

A3.4 End Use Energy Consumption

Energy consumption patterns in the South Coast Air Basin are outlined for the year 1973 in Table A3.6. The term "energy consumption", as used here, has a very narrow meaning. The upper portion of Table A3.6 shows those energy resources which are actually expended for their heating value by their final customer within the air basin. Energy-bearing products, such as asphalt, which are consumed as a raw material instead of for their heating value are noted at the bottom of that table. Energy resources consumed while generating electricity

TABLE A3.6

South Coast Air Basin End Uses of Energy Resources-1973
(in 10^{12} BTU's/year)

	Electricity	Natural Gas	Crude and Unfinished Oils	NGL	LPG	Gasoline Including Aviation Gasoline	Jet Fuel	Light and Middle Distillate Fuel Oil	Residual and Heavy Distillate Fuel Oil	Petroleum Coke	Lubricants	Asphalt	Other Hydrocarbons	Coal	Digester Gas
CONSUMED IN BASIN AS ENERGY RESOURCE															
System uses; losses	28.8	20.5													
Residential/commercial	133.8	431.4			6.6			8.1	8.1					0.2	
Industrial (other than refinery)	71.2	153.9			1.0			15.6	19.5					57.2	2.3
Transportation (civilian)															
Motor vehicles					1.9	649.8		42.9							
Aircraft						0.5	17.3								
Railroads								10.7	0.1						
Ships								6.3	9.0						
Military						2.2	6.1	6.5	0.1						
Miscellaneous	21.9	8.7			3.0	—	—	14.5	0.6					—	—
Subtotal (energy dissipated)	255.7	614.5			12.5	652.5	23.4	104.6	37.4					57.4	2.3
CONSUMED AS A RAW MATERIAL*		18.6			8.4					pass through coke calcining process	to be determined by difference between known sources and exports				

*Or put to other non-energy resource use.

for resale or refining petroleum products for resale are excluded since they have been discussed previously as part of the energy transformation process. In addition, only those fuels sold to transportation vehicles which are actually burned within the mixed layer of the air basin will be considered as "consumed" within the air basin. Fuels leaving the basin in ship bunkers and aircraft fuel tanks will be considered later as "exports" once those vehicles have departed the air basin.

The following discussion is generally organized by the type of fuel involved. However, estimation of fuel use by the military poses some special problems which are best presented in a single discussion. Therefore estimation of military uses of all fuels will be postponed until the end of this section of the energy balance.

A3.4.1 Natural Gas Consumption

Natural gas sales data for the South Coast Air Basin were obtained from reports furnished to the California Air Resources Board (Wood, 1977) by the gas utilities serving the basin. Data from this source were in good agreement with the 1975 California Gas Report, but were considerably more detailed.

Data for 1974 were the most complete, showing sales to residential, commercial and industrial customers in the basin by both the Southern California Gas Company (the retail arm of Pacific Lighting Companies in the area) plus the gas utility of the City of Long Beach. For 1973, complete data were available from Long Beach, but only total firm and non-refinery interruptible sales were obtained for the

Southern California Gas Company service area. Therefore 1973 Southern California Gas Company sales in both firm and interruptible categories were apportioned among residential, commercial and industrial customers using the same proportions as apparent in their 1974 sales data. The industrial gas quantities shown in Table A3.6 include both firm and interruptible gas combustion by industries other than oil refineries. This should not be confused with the "industrial interruptible" gas total given in the 1975 California Gas Report.

Current feedstock use of natural gas in Southern California was reported by the California Public Utilities Commission (1975). It was assumed that all such use was in the South Coast Air Basin and that the magnitude given for 1975 would apply reasonably well to the year 1973. An amount of natural gas equal to this feedstock use was subtracted from total deliveries to industrial customers, and was then assigned to the raw materials use category. The remaining non-refinery industrial gas deliveries were assumed to be burned for fuel.

Natural gas deliveries classified as "special producer exchange and payback" and "oil company exchange and payback" in the 1975 California Gas Report were totaled. Then these exchange gas volumes were added to gas utility retail sales to South Coast Air Basin refineries as reported by the Southern California Gas Company and the City of Long Beach (Wood, 1977). Total natural gas combustion at South Coast Air Basin refineries was outlined in Table A3.4. Known gas combustion at refineries was subtracted from the available exchange gas plus refinery retail gas purchases. The remainder of the available exchange gas was assigned to the Miscellaneous Fuel category. Some of this exchange gas was delivered to non-refinery petroleum company operations and may have been burned to generate heat used to stimulate production in old oil fields. Other exchange gas may have gone into feedstock use. Data needed to more clearly define the appropriate sector for use of this exchange gas is unavailable to us.

Additional quantities of natural gas are consumed as part of the gas distribution systems' operation. These system uses and losses are taken from the unaccounted for net inventory change and fuel use totals given for the Southern California Gas Company and the City of Long Beach in the 1975 California Gas Report.

A3.4.2 Electricity End Use Consumption

Data on electricity uses within the City of Los Angeles were obtained from the DWP's 1975 ten-year statistical report (Department of Water and Power, 1975b). FPC annual statistics on publicly owned utilities (Federal Power Commission, 1972b, 1973b, 1974b) were used to detail electricity use for Pasadena, Burbank and Glendale through the end of the 1973-74 fiscal year. Fiscal year data were converted to a calendar year basis using the procedures discussed previously when explaining Table A3.3.

Electricity use by sector within the SCE system was obtained from their annual reports. These data covered the entire SCE system and not just the South Coast Air Basin. To scale SCE's electricity sales down to the South Coast Air Basin, the basin was compared to the total SCE service area using county by county statistics from the California Statistical Abstract (California, State of, 1974). It was estimated that the in-basin portion of SCE's service area contained 92% of SCE's total population served, 98% of its manufacturing customers, and 98% of the industrial employees within its service territory. Therefore, it was assumed that 92% of SCE's residential, commercial and "other" (principally municipal) sales, and 98% of their industrial sales could be assigned to the basin. Sales classified as agricultural, municipal or "other" were assigned to the miscellaneous sector of the energy balance.

All electric utilities report some sales for resale. These sales have been apportioned emong consuming sectors by the following methods. About 35% of SCE's sales for resale are delivered to the City of Vernon (Southern California Edison, 1972b), which is a heavily industrial area. Thus one third of SCE's total sales for resale were assigned to industrial activities in Vernon. The remainder of SCE's sales for resale plus the sales for resale by other utilities were divided among all the consuming sectors in proportion to total in-basin direct sales by sector for all participating utilities.

A3.4.3 Petroleum Product Consumption

A3.4.3.1 Motor Vehicle Gasoline

Sales of motor gasoline in California are given by the Ethyl Corporation (1974) for both regular and premium grades. California gasoline sales in 1973 are also listed by the Bureau of Mines (1975e). The Bureau of Mines data show slightly higher motor gasoline sales than given by Ethyl Corporation. That is not too surprising since Ethyl Corporation describes their data base as representing "oil refiners manufacturing over 95% of the U.S. requirements" for motor gasoline. In this study, Bureau of Mines data will be used to estimate total motor gasoline sales in California. The ratio of premium grade to regular grade sales will be taken from the Ethyl Corporation survey.

Fifty percent of the State's population resides in the South Coast Air Basin. Therefore 50% of the State's total sales of motor gasoline in 1973 were assigned to the South Coast Air Basin. A portion of these gasoline sales were allocated to military uses as will be discussed shortly. The remainder of the total was assigned to consumption by the civilian transportation sector. It was assumed that a net balance exists between gasoline arriving in vehicle fuel tanks and gasoline leaving in the fuel tanks of cars and trucks departing the boundaries of the South Coast Air Basin.

A3.4.3.2 Jet Fuel and Aviation Gasoline End Use Consumption

The Federal Aviation Administration (1973a, 1974a) reports yearly activity at airports having a FAA-operated control tower. These data are reported as "operations" by air carriers, air taxis, general aviation aircraft and military aircraft. An "operation" is either a landing or a take-off. Civilian aircraft operations will be discussed here, while an accounting of military aircraft operations at civilian airports will be postponed until the military fuel use section of this study.

FAA yearly activity reports are compiled on a fiscal year basis. In order to construct calendar year 1973 air traffic estimates, data from FY73 and FY74 were averaged. An additional adjustment to the FAA data is needed to account for a number of small airports in the basin which are without an FAA-operated control tower. A summary of operations at three such independently operated airports was obtained from conversations with airport personnel (Compton Airport Personnel, 1976; Whiteman Airport Personnel, 1976; San Fernando Airport Personnel, 1976). Rough estimates of traffic at the remaining small airports were then made. The total number of operations estimated for non-FAA airports was found to be about 10% of the total general aviation operations at FAA-controlled airports. All operations at these smaller airports were assumed to be in the general aviation category. Thus the number of general aviation operations reported for FAA airports was increased by 10% to achieve a basin-wide total for both FAA and non-FAA airports.

The Environmental Protection Agency (1973) has published data on fuel use per landing and take-off cycle (LTO) for various engine and aircraft types. A landing and take-off cycle represents all fuel used by an aircraft from its descent below an altitude of 3,500 feet through its landing, ground operations, take-off, and subsequent climb to an altitude of 3,500 feet. There are thus two FAA reported operations for every landing and takeoff cycle.

Aircraft fuel consumed in the basin was computed from the EPA landing and takeoff cycle data plus the following assumptions. All general aviation aircraft were assumed to have one engine, and its fuel use was taken to be the average of use reported for a Teledyne and a Lycoming engine. For air taxis, it was assumed that 30% had one piston engine, 65% had two piston engines and 5% had one turbo-prop engine. Fuel use by air carriers is given for jumbo jets, long-range jets (707 or DC-8), and medium range jets. It was assumed that all air carrier operations at airports other than Los Angeles International (LAX) and Ontario were medium range jets. This assumption was confirmed for Orange County Airport (Orange County Airport Personnel, 1976) and is thus probably true of other small regional airports. The distribution of aircraft types using Ontario airport was obtained by communication with personnel at that airport (Ontario Airport Personnel, 1976). The Department of Airports (1976) of the City of Los Angeles provided an air carrier operations breakdown by aircraft type for LAX in the year 1975. A similar distribution of airport operations by aircraft type was available for 1970 at LAX (Los Angeles Air Pollution Control District, 1971). The percentage distribution of air carrier traffic between jumbo, long range and medium range jets was obtained for 1973 by linear interpolation between the available data sets. For the purpose of computing fuel use by air carriers, it was further assumed that there were an average of 4 engines per jumbo jet, 4 engines per long range jet, and 2.6 engines per medium range jet.

A3.4.3.3 Residual and Distillate Fuel Oil End Use Consumption

Sales of both residual and distillate oil in the State of California in 1973 are reported in the Fuel Oil Sales, Annual series of the Bureau of Mines (1974h). Data from this source are classified into sales for "heating", industrial use (with oil company use listed separately), railroads, ship bunkering, on and off-highway diesel vehicles, plus military, utility and miscellaneous uses. These data were used to construct fuel oil consumption estimates for the residential/commercial, industrial, civilian transportation and miscellaneous sectors of the energy balance. Fuel oils used by oil refineries and utilities have been discussed previously and military fuel oil consumption will be treated at a later point in this survey. As was the case with our previous discussion of energy sources, kerosene use has been lumped with light and middle distillate fuel oil consumption. Also, in line with our attempt to include heavy distillate oil along with residual oil, any Grade 4 fuel oil sales which were explicitly detailed in the Bureau of Mines data base were transferred from the distillate oils category to form a residual plus heavy distillate oil category.

Adequate statistics upon which to base a division of total California oil use between the South Coast Air Basin and the rest of the state seem unavailable. Likewise, separation of fuel oil use into residential, commercial and industrial categories must proceed on the basis of partially supported assumptions. At the state level, it will be assumed that the Bureau of Mines "heating oil" use represents oil used solely by residential, commercial and institutional customers. Oil listed as "industrial use (excluding oil company use)" will be assumed to provide both industrial process heat and any incidental space heating at non-petroleum industry industrial sites. It may well be the case that some "heating" oils are also consumed by industry, but we have no data from which to estimate how large that fraction might be.

The Stanford Research Institute (1973) study allocates 40% of the state's residential and commercial oil use and 64% of "industrial" oil use to Southern California.* Using county population data from the California Statistical Abstract (California, State of, 1974). it was determined that the South Coast Air Basin has approximately 83% of the population of Southern California. Thus 33% (i.e. 0.40 x 0.83 = 0.33) of the state total "heating oils" use was assigned to the South Coast Air Basin's residential and commercial fuel use sector.

Fuel oil is burned by industry when natural gas supplies have been interrupted. On the basis of Southern California Gas Company industrial gas sales data provided for each air basin in Southern California (Wood, 1977), plus San Diego Gas and Electric and Long Beach City gas system data given in the 1975 California Gas Report, it was estimated that 75% of the non-refinery industrial heating demand in Southern

*By SRI's definition, Southern California is that part of the state not served by PG&E.

California was in the South Coast Air Basin. Therefore, it was assumed that industrial oil use in the South Coast Air Basin by facilities other than oil refineries could be taken as 48%, (i.e. 0.64 x 0.75 = 0.48) of California "industrial oil use (excluding oil company use)" as given by the Bureau of Mines (1974h).

Estimates of industrial fuel oil consumption at refineries in the South Coast Air Basin were entered into the energy balance during our previous discussion of the energy transformation sector.

The Bureau of Mines' (1974h) Fuel Oil Sales, Annual series reports miscellaneous uses of distillate and residual fuel oil, including on-highway and off-highway diesel oil use. On-highway diesel fuel use will be assigned to the transportation sector.

On the basis of truck registration data, which are reported by county for 1972 in the 1974 California County Factbook (Carey, 1974), it was found that about 40% of the State's trucks were registered in the South Coast Air Basin. Therefore, 40% of the State's on-highway diesel fuel used was assigned to the South Coast Air Basin.

All other miscellaneous oil uses (including off-highway diesel oil use) reported by the Bureau of Mines (1974h) will be placed in the Miscellaneous Consumption sector of the energy balance. On the basis of the ratio of basin population to the State's population, 50% of such miscellaneous oil use in California was assigned to the South Coast Air Basin in 1973.

Consumption of fuel oil sold to railroads was assumed to be proportional to track mileage. Railroad track mileage in the South

Coast Air Basin was measured on United States Geological Survey 7-1/2 minute topographic maps and was estimated as 1842.3 miles. A total California track mileage of 8,446 miles was obtained from the Federal Railway Administration (1976). Track mileage in the basin is thus estimated to be 21.6% of the state total. Therefore, 21.6% of the fuel oil sales to railroads in California, as reported by the Bureau of Mines (1974h), were apportioned to consumption within the South Coast Air Basin.

Fuel oil consumed by ships can be divided into three modes of ship operation: dockside use, use while under way inside the port area and near the port entrance, and use while under way in the shipping lanes which parallel the shoreline of the South Coast Air Basin. Each of these modes of operation will be discussed separately. The methodology employed to estimate fuel oil use is based on EPA's Guide for Compiling a Comprehensive Emission Inventory (Environmental Protection Agency, 1972).

Computation of dockside fuel use generally followed the EPA's suggested method. The number of vessels entering each port in the air basin was obtained from Waterborne Commerce of the United States (Corps of Engineers, 1973). It was assumed that only vessels with draft greater than eighteen feet burned fuel while docked in port. Fuel consumption was taken as 660 gallons per vessel per day for distillate oil users and 1900 gallons per day for residual oil users. EPA's suggested assumption of an average three days of dockside fuel burning per vessel arrival was checked against the total number of vessels entering Long Beach and Los Angeles Harbors yearly, and the daily report of vessels in the harbor ("Ship Movements", 1973-1976).

An average dockside retention time of three days was found to be a reasonable estimate. In order to compute dockside fuel use, the total vessel population must be separated into distillate and residual fuel oil users. This was done on the basis of the relative proportion of residual oil to distillate oil sales for bunker fuel in the Los Angeles area. Data on bunker fuel sales to ships engaged in foreign commerce are given by the Bureau of the Census (1974). The Los Angeles Customs District was found to account for 77.4% of the residual oil and 69.8% of the distillate oil sold at California ports to vessels engaged in foreign commerce. These fractions of the California foreign trade total were used to scale California sales of bunker fuel for all purposes, as reported by the Bureau of Mines (1974h), down to the South Coast Air Basin level. The ratio of distillate oil fueled ships to residual oil fueled ships in the harbor was next obtained from estimated bunker fuel sales after weighting the sales data to reflect the lower fuel consumption rate of the smaller distillate fueled ships.

At Los Angeles and Long Beach Harbors, areas inside the breakwater were added to a port entrance zone in order to create a transition area between fuel use at the docks and fuel use in the shipping lanes. From shipping lane maps, it was estimated that an approach distance of 20 miles would be considered as within the port and its entrance zone for each vessel entering that port. For vessels with less than an eighteen foot draft, fuel used in transiting that zone was calculated at the rate prescribed for distillate oil users by the Environmental Protection Agency (1972). Vessels with greater than 18 foot draft were assumed to enter and leave the port under power of two tugboats, each with a fuel consumption rate the same as that for vessels with less than 18 foot draft. An additional 4000 distillate-fueled vessels per year with less than 18 foot drafts were added to the traffic through the port and its entrance areas as an estimate of the domestic fishing fleet traffic which is not included in the waterborne commerce reports of the Corps of Engineers (1973).

The length of the coastal shipping lanes which parallel the shore of the South Coast Air Basin was measured from the National Oceanic and Atmospheric Administration's West Coast California-San Diego to Santa Rose Island map (undated). The number of ships transiting the shipping lanes in each direction was determined from a sampling of "Ship Movements" reports (1973-1976). Those reports list the origin and destination of ships arriving in and departing from Los Angeles area harbors. Fuel consumption per vessel-mile was taken from data presented by the Environmental Protection Agency (1972). Ships with drafts of 18 feet or less were assigned to distillate oil use. Larger ships were divided between distillate and residual oil use in the same proportions as described for dockside fuel use.

A3.4.3.4 Petroleum Coke Consumption

In view of the high sulfur content of petroleum coke, it is doubtful that any is burned for fuel legally in the South Coast

Air Basin. Therefore, use of petroleum coke as a fuel will be neglected. Petroleum coke is also used as a feedstock by the petroleum coke calcining industry. However, it appears that most calcined petroleum coke is subsequently exported from the basin. Net consumption of petroleum coke within the South Coast Air Basin will be neglected.

A3.4.3.5 Asphalt, Lubricants and Other Hydrocarbons

Asphalt, lubricants and other hydrocarbons are used as industrial raw materials or are put to other non-combustion related uses. Since they are not burned as fuel, their sulfur oxides emission potential is low and their fate will not be explored extensively. Use of these non-fuel petroleum products will be later estimated by difference between refinery production and net harbor exports of such materials.

A3.4.4 Liquified Petroleum Gas and Natural Gas Liquids End Use Consumption

The Bureau of Mines series Liquified Petroleum Gas Sales, Annual (Bureau of Mines, 1974i) lists sales of LPG in California for residential and commercial, industrial, internal combustion, miscellaneous and utility uses. Thirty-three percent of the residential and commercial LPG use in the state was assigned to the South Coast Air Basin on the same basis as developed when discussing residential and commercial heating oil use. Fifty percent of the internal combustion and miscellaneous uses were allocated to the basin on the basis of the ratio of basin population to total state population. These internal combustion uses were assigned to the transportation sector of the energy balance; however, LPG use in stationary engines is also possible. The 1975 California Gas Report shows no use of LPG as a standby supply for gas utilities in the Los Angeles area in 1973. Therefore, no LPG from the state total for utility use was assigned to the South Coast Air Basin in that year.

The industrial category being considered in the end use consumption sector of this energy balance excludes fuel use by oil refineries. Therefore, use of LPG as a refinery fuel must be separated from the Bureau of Mines data including all industrial uses. This is difficult to accomplish because locally available refinery fuel data lump still gas use with LPG-LRG use. Therefore, a means other than use of the Bureau of Mines data was sought for estimation of non-refinery industrial LPG consumption. On the basis of information gathered during the industrial fuel use survey of Appendix A2 to this report, it was found that only about 0.53×10^{12} BTU's per year of LPG were used for fuel by major non-refinery industrial interruptible gas customers within a 50 by 50 mile square laid over the center of metropolitan Los Angeles and Orange Counties. Therefore, it will be assumed that non-refinery industrial fuel uses of LPG in the entire South Coast Air Basin amounted to about 1×10^{12} BTU's per year in 1973, rounded up to one significant figure.

Sales of liquified petroleum gases and ethane for petrochemical feedstocks in 1973 are reported by the Bureau of Mines (1974i). Data given are for the entire west coast region of the United States, with each State's feedstock total concealed in order to make it difficult to estimate chemical feedstock use (a trade secret). For lack of any better scale factor, LPG and ethane use as a raw material will be scaled to the South Coast Air Basin from the west coast total in proportion to the fraction of west coast crude oil and net unfinished oils supplied to the South Coast Air Basin refineries, as given in Table A3.4 Ethane has been separated from LPG (propane and butane) in our classification scheme and is included within the "other hydrocarbons" category of the energy balance.

Natural gasoline and other natural gas liquids are primarily used as a feedstock material for petroleum and chemical processes. Their direct use as a fuel in the South Coast Air Basin is assumed to be zero. Since estimated refinery feedstock use of natural gasoline about equals the South Coast Air Basin's estimated supply, no further sinks for natural gasoline will be sought.

A3.4.5 Coal Utilization

The coal supplied to the South Coast Air Basin in 1973 was outlined in detail in the energy sources section of this energy balance. Waterborne commerce data on South Coast Air Basin coal shipments for that year (Corps of Engineers, 1973) show negligible coal exports in 1973. Therefore, we will assume that all coal brought into the South Coast Air Basin for use in gas and coke production was consumed within the basin's industrial sector in 1973. The small amount of coal imported for retail sale will be assumed to be burned in the residential/commercial sector.

A3.4.6 Digester Gas Consumption

Digester gas supplied to electric utilities was outlined in the energy transformation section of this survey. At least one Los Angeles area refinery occasionally receives digester gas for fuel, but air pollution control district records show little actual refinery use of digester gas in 1973. The difference between digester gas production and sales to refineries and utilities represents digester gas combustion at sewage treatment plants. Much of this digester gas performs useful work while powering sewage treatment plant equipment. Excess digester gas is flared.

A3.4.7 Military Fuel Consumption

Fuel consumption by military activities in the basin is difficult to determine. The results reported here are subject to considerable uncertainty. However, data do seem sufficient to indicate that energy consumption in the basin's military sector is relatively small for all uses except aviation and marine fuels. Therefore, effort needed to characterize fuel use precisely was expended only for aviation and marine refueling operations.

Fuel combustion in 1974 by stationary sources at March and Norton Air Force Bases was obtained from the regional office of the Environmental Protection Agency (Rhea, 1976). The principal fuel burned was natural gas. Since stationary source fuel burning data on several large military installations in the basin were unavailable from EPA, it was decided that no attempt would be made to unbundle military natural gas and electricity use from the totals given in the basin's residential/commercial, industrial and miscellaneous energy use categories.

The Bureau of Mines (1974h) reports yearly "sales" by state of distillate and residual oil for military use. These data include oil which the military imports into the state for its own use. The largest single use of distillate oil in the civilian sector was seen to be for on- and off-highway vehicle fuel. Therefore, it was assumed that military distillate oil should be apportioned to the South Coast Air Basin in a manner consistent with likely vehicle use patterns. Military distillate fuel use in the South Coast Air Basin was scaled from the state totals in proportion to the fractions of the State's total military personnel at work in the basin as given by the 1970 census.

The 1970 Census of Population for California places total armed forces strength in California at about 346 thousand persons in 1970 (Bureau of the Census, 1973a; difference between total state labor force and civilian labor force). The special report on Journey to Work of the 1970 Census of Population (Bureau of the Census, 1973b) places armed forces personnel working in Ventura, Orange, Los Angeles Riverside and San Bernardino Counties at 69 thousand persons in 1970. These county totals unfortunately include portions of Los Angeles, Riverside and San Bernardino Counties which lie in the desert outside of the air basin. Data are not readily available which permit subtraction of military personnel based in the desert from those county totals. However, two other factors serve to reduce the amount by which the 69,000 person armed forces total for those counties might overestimate military personnel working in the South Coast Air Basin. First, there are a number of persons in the armed forces living in these counties who were not included in the totals for those working within the county limits because they did not report their place of assignment to the census takers. Secondly, none of the military personnel stationed in Santa Barbara County were included in the previous local totals because the vast majority of Santa Barbara County military personnel are assigned to areas outside of the South Coast Air Basin boundaries. It is judged that the 69 thousand persons total obtained from the five-county summation is a reasonable estimate of armed forces personnel working in the South Coast Air Basin in 1970. That estimate implies that the air basin contained about 20% of the military personnel working in the state at the time of the last census. Thus, 20% of the distillate oil used by the military in California in 1973 was apportioned to the South Coast Air Basin.

The principal use of residual oil by the military in California was assumed to be for bunkering of Naval vessels. Personnel at the Long Beach naval station's fuel depot were contacted. They indicated that a significant amount of a residual type oil referred to as Navy Special grade was loaded aboard naval vessels at Long Beach in 1973. However, heavy oil bunkering of naval vessels at Long Beach has since ceased, and personnel familiar with the details of the 1973 operations were not available for interview. When pressed to make an estimate for 1973, personnel at the fuel depot said that a guess that Long Beach accounted for 20% of California naval fuel bunkering in 1973 would be reasonable. That estimate coincided very closely with the fraction of California military personnel at work in the basin. Therefore, 20% of the California residual fuel use by the military was assigned to the South Coast Air Basin in 1973. Our previous estimate of residual oil burned by civilian ships in the South Coast Air Basin was compared to fuel loaded aboard civilian ships as deduced in the forthcoming export section of this energy balance. It was found that residual fuel oil burned by ships within the air basin and offshore shipping lanes totaled about 10% of residual oil bunker fuel sales to those ships from basin fuel depots. Therefore residual oil burned by naval ships in the South Coast Air Basin was taken as 2% (i.e. 10% of 20%) of total California uses of residual fuel oil by the military. Most of the residual oil loaded aboard naval ships in the South Coast Air Basin will be shipped out of the basin in vessel fuel tanks, as detailed in the forthcoming export section of this energy balance.

Total domestic motor gasoline procurement by the military in 1972 is given by Mutch (1973). This level of total domestic use was assumed to hold for 1973 as well. It was next assumed that California military gasoline consumption constituted the same fraction of total domestic military gasoline use as was apparent from the ratio of California to total United States domestic military distillate oil use given by the Bureau of Mines (1974h). Then 20% of the military motor vehicle gasoline sales total constructed for the State of California was assigned to the South Coast Air Basin on the same basis as discussed previously for distillate oils.

Military and civilian air traffic at military airports is reported periodically by the Federal Aviation Administration (FAA). The closest reporting period to 1973 was for calendar year 1974 (Federal Aviation Administration, 1974b). Military air traffic at South Coast Air Basin civilian airports in 1973 and 1974 was determined from the previously described documents on flight operations at airports with FAA-operated control towers (Federal Aviation Administration, 1973a, 1974a). Then aircraft operations at military airports in 1974 (Federal Aviation Administration, 1974b) were scaled to 1973 using the ratio of 1973 to 1974 military operations apparent at the civilian airports for which data for both years were available. Military and civilian operations at military airports were added to military operations at FAA-operated airports to obtain a 1973 South Coast Air Basin total for military-related air traffic.

The Federal Aviation Administration (1976) was able to provide a description of the different types of aircraft in use by the military at bases in the South Coast Air Basin. Flight operations at each air field were then distributed among these aircraft types in what seemed to be a reasonable, although arbitrary manner. Fuel consumption during operations below 3500 feet in altitude was then computed using the same procedures as for civilian aircraft.

A3.5 Exports

A summary of energy resource exports from the South Coast Air Basin for the year 1973 is given in Table A3.7. Fuels are exported from the basin by a number of methods. Pipelines carry natural gas to nearby service areas. Petroleum products are piped

TABLE A3.7

South Coast Air Basin Energy Exports-1973

	10^{12} BTU/year
Natural Gas	
Out-of-basin sales to Pacific Lighting customers	90.2
Sales to San Diego Gas & Electric	91.2
Exchange with out-of-basin utility	5.4
Subtotal	181.6
Crude Oil - Net	
Los Angeles and Ventura oil shipped to sea less estimated return flows of that oil at other South Coast Air Basin ports	57.5
Petroleum Product Exports	
Harbor exports	
Gasoline	47.9
Jet fuel	17.4
Distillate oil and kerosene	89.7
Residual oil	155.1
Petroleum coke	109.4
Lubricants and greases	20.0
Asphalt and asphalt materials	16.5
LPG	0.2
Other	5.1
Subtotal	461.3
Overland transport	
Arizona and southern Nevada	
Gasoline	90.5
Jet fuel	21.8
Light & middle distillate oil	52.9
Residual oil	27.9
Inland to southern California	
Gasoline	104.2
Subtotal	297.3
Exported in transport mode fuel tanks	
Transportation (civilian)	
Aviation gasoline	3.8
Jet fuel	100.2
Distillate bunker fuel	2.7
Residual bunker fuel	84.7
Military	
Aviation gasoline	~0
Jet fuel	11.3
Residual bunker fuel	1.3
Subtotal	204.0
TOTAL INVENTORIED EXPORTS	1,201.7

to Arizona, Nevada and San Diego. Crude oil and refined petroleum products are exported from local harbors, and other liquid fuels leave the air basin in the tanks of ships and aircraft. It is likely that significant quantities of petroleum products are shipped overland by pipeline, tank car and tank truck to other areas of California. With the exception of gasoline, these overland exports are difficult to quantify and will be neglected. Hence, the total exports identified in the energy balance tabulations of Table A3.7 are likely to be below actual export levels.

A3.5.1 Natural Gas Exports

Exports of natural gas from the basin represent deliveries by the Pacific Lighting Companies to San Diego Gas and Electric and to their own customers in the San Joaquin Valley, South Central Coast, and Southeast Desert Air Basins. Deliveries to San Diego were obtained from the 1975 California Gas Report, while the remaining data came from reports supplied to the California Air Resources Board by local gas utilities (Wood, 1977).

The 1975 California Gas Report also outlines exchange transactions in which California source gas is delivered through the Pacific Lighting System to PG&E. This utility to utility exchange is represented as a net export from the energy supply available to gas utilities serving the South Coast Air Basin.

A3.5.2 Crude Oil Exports (Net)

The crude oil exports listed in Table A3.7 represent locally produced oil shipped to sea less return flows of that local oil to other South Coast Air Basin ports. These net exports were determined from data presented in Appendix A1 to this survey. Total Los Angeles and Ventura area crude oil remaining in the basin as given in Table A1.10 was subtracted from Los Angeles and Ventura area crude oil production given in Table A1.6 to obtain an estimate of net crude oil exports.

A3.5.3 Refined Petroleum Products Exported by Ship

Data on exports of refined petroleum products from local harbors were obtained from Waterborne Commerce of the United States (Corps of Engineers, 1973). Where the direction of flow was not indicated, refined products were assumed to be shipped to sea from El Segundo and received at Huntington Beach, Ventura, Port Hueneme and Carpenteria. In cases where a product classification used by the Corps of Engineers encompassed more than one product type, the entire energy content of imports in that classification was assigned to the most prominant product in the group.

A3.5.4 Refined Petroleum Products Exported by Overland Transport

Shipments of California refinery products to Arizona and Nevada are reported for 1974 by the California Energy Planning Council (1974). Lacking additional data, these exports were assumed to represent 1973 as well. All fuel sent to Arizona and to the Las Vegas area was assumed to come from South Coast Air Basin refineries.

From population distribution data for the Reno and Las Vegas areas (Rand McNally, 1973), it was estimated that Southern Nevada surrounding Las Vegas constituted 68.9% of that state's population. Therefore, all of Arizona's and 68.9% of Nevada's refined petroleum product imports from California were taken to be exported overland from Los Angeles.

By examination of port records for San Diego, it was observed that relatively little gasoline was received in that location by ship. Review of pipeline maps given by McCaslin (1974), shows a refined product pipeline proceeding from Los Angeles to the San Diego area. It was therefore considered likely that most of the gasoline needs of Southern California outside of the South Coast Air Basin were being met by overland shipments from Los Angeles. While data on intrastate refined product pipeline, tank car, and tank truck transportation are unavailable to us, it should be possible to estimate gasoline demand in the remainder of Southern California on the basis of population served. County population statistics given in the California Statistical Abstract (California, State of, 1974) were reviewed. It was concluded that between 8% and 12% of California's population lay in areas of Southern California outside of the South Coast Air Basin which were probably supplied with gasoline from the stocks available in Los Angeles. Since some transport of gasoline to San Diego by ship appears to occur, our estimate for the fraction of California's population supplied with gasoline by overland transport from Los Angeles refineries will be held to the low side of the above population range. Therefore 8% of California's total gasoline production, as given in Table A3.4 was assigned to overland export to other parts of California from the Los Angeles basin.

Estimation of overland export of other refined petroleum products to Southern California areas outside of the South Coast Air Basin will not be attempted. There are substantial receipts of fuel oils at San Diego County harbors which would indicate that much of the fuel oil supply exported from Los Angeles to other parts of the state has already been counted when we outlined waterborne exports. Unless a detailed energy balance were performed on San Diego, an overland transport estimate for fuel oils based on population alone would run a significant risk of double counting much of the fuel oil which appears to move in waterborne commerce. Because of the lack of this intrastate overland export estimate, most petroleum categories in the energy "balance" are expected to show a slight net surplus of products for which the ultimate consumer is unknown.

A3.5.5 Fuels Exported in the Tanks of Transportation Vehicles

Long range transportation vehicles (ships and airplanes) carry fuel supplies in their tanks which are far in excess of that burned while in the vicinity of their refueling terminals. Jet fuel and bunker fuel sales exceed combustion within the confines of the South Coast Air Basin. This difference represents a net fuel export from the air basin's energy economy.

Estimation of residual and distillate fuel oil sales for ship bunkering was described briefly during our previous discussion of fuel combustion by ships. Distillate and residual fuel oils sold in California for civilian ship bunkering (Bureau of Mines, 1974h) were apportioned to the South Coast Air Basin in proportion to the Los Angeles Customs District's fraction of total California sales of each of these fuels to ships engaged in foreign commerce (Bureau of the Census, 1974). Then net exports of fuel contained in ship bunkers were obtained by subtracting our previous in-basin fuel combustion estimates for ships from total bunkering sales of each oil type.

In a previous discussion of military oil use, it was estimated that naval bunkering at Los Angeles and Long Beach harbors in 1973 accounted for 20% of total California residual oil "sales" to the military as given by the Bureau of Mines (1974h). Our fuel combustion estimate for naval ships was subtracted from our estimate of bunker fuel supplied to the military in the South Coast Air Basin to obtain a net estimate for naval bunker fuel exported from the South Coast Air Basin in ship fuel tanks.

Total demand for aviation gasoline and jet fuel in the West Coast district of the United States (PAD District V) is given by the Bureau of Mines (1975e). The Bureau of Mines (1975e) also lists West Coast shipments of aviation fuels for both military and commercial use. Data on total shipments and demand are in reasonable agreement. Therefore, West Coast Aviation gasoline and jet fuel demand figures were apportioned between military and civilian uses in the relative proportions indicated by shipments of fuels to military and civilian customers.

Federal Aviation Administration (FAA) statistics are available on the number of aircraft operations at civilian and combined use airports on the West Coast of the United States (Federal Aviation Administration, 1973a). From these sources, it was estimated that 26.6% of the West Coast Air Carrier Operations took place at South Coast Air Basin airports. Therefore, 26.6% of the civilian aviation jet fuel sales on the West Coast were assigned to the South Coast Air Basin. In a similar manner, it was found that 34.6% of the air taxi plus general aviation activity on the West Coast took place at South Coast Air Basin airports. Thus 34.6% of West Coast civil aviation gasoline demand was assigned to local airports. From data on military aircraft operations at military airports (Federal Aviation Administration, 1974b) plus military traffic at civilian airports (Federal Aviation Administration, 1973a), it was estimated that 9.1% of the military flight operations in the West Coast region of the United States occurred at South Coast Air Basin airports and military bases. Therefore, 9.1% of West Coast military jet fuel and aviation gasoline supplies were assigned to the South Coast Air Basin. Net fuel exports in the tanks of all aircraft were then determined by difference between South Coast Air Basin aviation fuel demand and our previous estimates of in-basin aviation fuel combustion. About 15% of the civilian jet fuel and about 35% of the military jet fuel supplied to aircraft at local airports is estimated to be burned within the air basin.

A3.6 The Energy Balance

Table A3.8 summarizes the energy balance on the South Coast Air Basin for the year 1973. A total of nearly 3700 x 10^{12} BTU's of energy resources entered the air basin's economy in that year. The ultimate fate of that energy supply is also apparent from Table A3.8.

- 15% of the energy supply is lost in transformation processes such as petroleum refining and electricity generation;
- 48% is expended for its heating value within the air basin by a final consumer of energy products;
- 4% of the energy content of the basin's energy resource base is tied-up in products that are used as industrial raw materials; and
- 33% of the energy supply passing through the air basin's economy is subsequently exported.

If all discrepancies between sources and sinks for various energy products are added regardless of sign, the total discrepancy is less than 5% of the gross energy input to the basin. On an aggregate basis, the energy balance actually balances with less than a 1% net surplus.

The degree to which the energy balance actually balances for individual product types is more variable, but still is considered to be acceptable. Three of the five largest energy flows in the system, (i.e. natural gas, electricity and heavy fuel oil) balance to within less than a 1% discrepancy between sources and sinks. The gasoline

TABLE A3.8

South Coast Air Basin Energy Balance--1973 (10^{12} BTUs per year)

	Electricity	Natural Gas	Crude and Unfinished Oils	NGL	LPG	Still Gas for Fuel	Gasoline	Jet Fuel	Light and Middle Distillate Fuel Oil	Residual and Heavy Distillate Fuel Oil	Petroleum Coke	Lubri-cants	Asphalt and Road Oil	Other Hydro-carbons	Coal	Digester Gas	TOTAL
SOURCES																	
Resource base: imports plus local crude oil and natural gas production	97.3	1050.3	2182.3	20.9	14.4		69.6	4.4	83.6	127.6	5.5	12.3	0.1	4.6	57.4	2.6	3732.9
Adjustments: change in gas storage; out-of-basin electric use	-13.1	-25.2	—	—	—		—	—	—	—	—	—	—	—	—	—	-38.3
Subtotal	84.2	1025.1	2182.3	20.9	14.4		69.6	4.4	83.6	127.6	5.5	12.3	0.1	4.6	57.4	2.6	3694.6
TRANSFORMATION SECTOR																	
Refinery feedstock (-)			-2124.8[a]	-23.9	-8.7									-16.9[b]			-2174.3
Refinery fuels (-)	-9.8	-48.5				-149.8				-11.8							-219.9
Refinery production(+)					36.1	108.4	863.0	224.3	126.9	581.2	112.0	18.5	88.0	60.3			2218.7
Utility fuels (-)		-160.9							-2.7	-386.3						-0.3	-550.2
Utility production (+)	179.9	—	—	—	—	—	—	—	—	—	—	—	—	—		—	179.9
Subtotal	170.1	-209.4	-2124.8	-23.9		-14.0	863.0	224.3	124.2	183.1	112.0	18.5	88.0	43.4		-0.3	-545.8
CONSUMED IN BASIN AS ENERGY RESOURCE																	
System uses; losses	-28.8	-20.5															-49.3
Residential/commercial	-133.8	-431.4			-6.6				-8.1	-8.1					-0.2		-588.2
Industrial (other than refinery)	-71.2	-153.9			-1.0				-15.6	-19.5					-57.2	-2.3[a]	-320.7
Transportation (civilian)					-1.9		-650.3	-17.3	-59.9	-9.1							-738.5
Military							-2.2	-6.1	-6.5	-0.1							-14.9
Miscellaneous	-21.9	-8.7			-3.0		—	—	-14.5	-0.6					—	—	-48.7
Subtotal	-255.7	-614.5			-12.5		-652.5	-23.4	-104.6	-37.4					-57.4	-2.3	-1760.3
CONSUMED AS A RAW MATERIAL[c]		-18.6			-8.4						pass through	-10.8[a]	-71.6[a]	-42.9[a]			-152.3
EXPORTS																	
As a commodity (by ship)			-57.5		-0.2		-47.9	-17.4	-89.7	-155.1	-109.4	-20.0	-16.5	-5.1			-518.8
As a commodity (overland)		-186.8[d]					-194.7	-21.8	-52.9	-27.9							-484.1
In transport mode fuel tanks		—	—		—		-3.8	-111.5	-2.7	-86.0	—	—	—	—			-204.0
Subtotal		-186.8	-57.5		-0.2		-246.4	-150.7	-145.3	-269.0	-109.4	-20.0	-16.5	-5.1			-1206.9
SUMMARY																	
Total sources (+ flows)	277.2	1050.3	2182.3	20.9		158.9	932.6	228.7	210.5	708.8	117.5	30.8	88.1	64.9	57.4	2.6	
Total sinks (- flows)	-278.6	-1054.5	-2182.3	-23.9		-179.6	-898.9	-174.1	-252.6	-704.5	-109.4	-30.8	-88.1	-64.9	-57.4	-2.6	
Absolute difference	-1.4	-4.2	(a)	-3.0		-20.7	33.7	54.6	-42.1	4.3	8.1	(a)	(a)	(a)		(a)	29.3
Difference as % of sources	-0.51%	-0.40%	(a)	-14.35%		-13.03%	3.61%	23.87%	20.0%	0.61%	6.89%	(a)	(a)	(a)		(a)	
Difference as % of total energy resources	-0.04%	-0.11%		-0.08%		-0.56%	0.91%	1.48%	-1.14%	0.12%	0.22%						0.79%

Notes: (a) Obtained by difference
(b) May include some natural gas
(c) Or put to other non-energy resource use
(d) Includes exchange with out-of-basin utility

summary balances to within 4% and the crude oil supply balances by virtue of the fact that refinery input was determined by difference between crude oil supply and exports. In addition, the petroleum coke summary balances with only a 7% surplus. That is considered to be good agreement given that petroleum coke production had to be scaled in two stages from a West Coast refinery total. The unaccounted-for petroleum coke may well have been lost in coke calcining processes which have not been investigated for their effect on product "shrinkage".

Major percentage discrepancies between individual product sources and sinks occur in the light and middle distillate fuel oil categories including both jet fuel and light fuel oil. These two product lines share overlapping hydrocarbon boiling ranges. Kerosene heating oil has much the same composition as certain jet and turbine fuels. Our estimated surpluses of jet fuel and deficiency of light and middle distillate heating oil are of corresponding magnitude and opposite sign. These two discrepancies could well be self-cancelling. The source of the estimation error is not readily apparent from the highly aggregated data on refinery output which are at our disposal. For the purpose of the forthcoming sulfur balance, jet fuel and light fuel oils must be merged because available data on refinery sulfur output are given only for both product streams combined. If the source of the jet fuel surplus and light fuel oil deficit lies in the refinery output estimate made for each fuel, that problem alone will not affect the forthcoming sulfur balance's accuracy.

The energy balance also shows an excess of LPG and NGL consumption above known supply. This problem is felt to arise from an inadequate knowledge of the sources of supply for these materials. LPG is the product of natural gas processing plants and refinery processes. Harbor receipts show that negligible quantities of liquified gases were imported into the South Coast Air Basin in 1973 by waterborne commerce. Refinery gas consumption for fuel appears to include virtually all potential local refinery LPG production. Therefore, it seems likely that LPG sufficient to meet residential, commercial, industrial, and feedstock demand may have been imported into the basin by intrastate overland transportation modes. If that were the case, a significant source of LPG supply would not be identifiable in our commerce statistics and would have been omitted from the energy balance. A similar situation is thought to mask NGL supply: it is either included within crude oil statistics, lumped with unidentified hydrocarbons or moved overland within California in a way that does not easily stand out in the intrastate commerce records. Since the sulfur content of LPG and NGL is very low, this discrepancy between LPG and NGL supply and consumption will not jeopardize the forthcoming sulfur balance.

Turning our attention to product supplies and uses, it is seen that crude oil is the principal energy input to the basin, accounting for 59% of the original energy supply. Natural gas is in second place with about 28% of the total energy supply. Imported refined petroleum products and imported electricity follow in order of importance to the gross energy resource base of the basin.

From Tables A3.8 and A3.4 it is seen that estimated refinery feedstocks and gross product yield are in good agreement on a net energy content basis. However, in order to obtain this transformation of feedstocks into products, fuels were consumed with an energy content equal to about 10% of gross refinery product output. The ratio of fuel use to product energy content is about the same for the South Coast Air Basin and for all refineries located in the Western United States. However, South Coast Air Basin refineries appear to depend much more heavily on refinery gases for fuel than is typical of refineries in the West Coast Region (PAD District V) as a whole.

The principal refinery product in the South Coast Air Basin is gasoline, which accounts for 39% of total refinery product output on an energy content basis. The next largest refinery product stream consists of heavy fuel oil. The principal customer for this heavy fuel oil is a second stage of the energy transformation sector: the electric utility industry.

Electric utilities consumed 550.2×10^{12} BTU's of fossil fuel within the South Coast Air Basin in 1973. Electricity generated from that fuel consumption amounted to 179.9×10^{12} BTU's for an overall conversion efficiency of 33%. Seventy percent of that electricity was generated by combustion of heavy fuel oil. If a typical refinery energy loss of 10% is associated with preparation of the fuel oils used by utilities, then the overall efficiency of generating electricity using liquid petroleum products falls even further.

The largest energy demand in the end use consumption sector is for transportation fuels, principally gasoline. Gasoline accounts for roughly one third of the total energy used in the air basin by final product customers. Residential and commercial customer demand for natural gas is second in magnitude, followed by industrial natural gas use and residential/commercial electricity demand.

Energy exports from the basin consist almost entirely of refinery products, plus natural gas in transit to other parts of the state. Net refinery product exports (i.e. exports less imports) have an energy content equal to about 30% of that of the initial crude oil runs to local refineries. That raises on interesting observation about the nature of trade patterns in the Southwest. For many years, persons living in areas outside of Los Angeles have complained that Los Angeles is exporting air pollution by locating some electric generating stations serving Los Angeles in desert areas to the east of the basin. As can be seen from Table A3.8, 33% of the electricity supply for the South Coast Air Basin comes from sources outside of the basin. From Table A3.2 it is seen that about half of that imported electricity is generated by fossil fuel fired steam plants located outside the air basin. However, it is also now apparent that a fairly large fraction of the emissions caused by petroleum refining in Los Angeles are incurred within the South Coast Air Basin for the benefit of final product customers located elsewhere, principally in San Diego, Arizona and Nevada. It is obvious that the energy economies of all of Southern California, Arizona and Southern Nevada are so interdependent that the question of "exporting pollution" when siting a major energy transformation facility such as a power plant or refinery becomes nearly meaningless.

A3.7 An Introduction to the Sulfur Balance

In order to convert the energy balance into a sulfur balance for the South Coast Air Basin, data on the sulfur content of fuels must be combined with a knowledge of industrial process activities. For fuels supplied to combustion sources, a knowledge of the quantity of sulfur in fuels is usually sufficient to completely determine sulfur received and atmospheric sulfur oxides emissions. For certain industrial processes, sulfur enters the facility in a variety of raw materials and leaves the factory in a large number of joint products, plus solid wastes, liquid wastes and atmospheric emissions. In the following sections of this survey, the sulfur content of fuels will first be determined from Bureau of Mines fuel analyses and other sources. Then industrial process data from the detailed emission inventory of Appendix A2 of this study will be combined with the fuel sulfur content information in order to compile the desired sulfur balance on the South Coast Air Basin.

A3.8 Sulfur Flows Entering the South Coast Air Basin in 1973

The quantities of sulfur accompanying energy resources entering the South Coast Air Basin in 1973 are shown in Table A3.9. Values given in that table are in thousands of pounds of sulfur per day. Comparison of each portion of the sulfur balance (of which Table A3.9 forms a part) to the atmospheric emissions given in

TABLE A3.9

South Coast Air Basin Sulfur Sources-1973

	1000 lbs Sulfur per Day
Natural Gas	
California sources-utility purchase	0.05
-gas exchange	0.02
Interstate receipts	0.73
Purchases from other utilities	0.01
Less net injection to storage	-0.02
Subtotal	0.79
Crude and Unfinished Oils	
Los Angeles Basin & Ventura area total production, plus South Coast Air Basin receipts from out-of-basin sources	3,942.5
Petroleum Product Imports	
Harbor receipts	
Gasoline (including natural gasoline)	4.40
Jet fuel	0.31
Distillate oil and kerosene	29.45
Residual oil	77.70
Petroleum coke	16.11
Lubricants and greases	(small)
Asphalt and asphalt materials	(small)
Other	(probably small)
Subtotal	127.97
Liquid Petroleum Gas	0.01
Digester Gas	0.63
Coal	
Coking coal	91.41
Miscellaneous	0.32
Subtotal	91.73
Elemental Sulfur (Harbor Receipts)	0.06
Sulfuric Acid (Harbor Receipts)	0.00
TOTAL INVENTORIED IMPORTS	4,163.69

TABLE A3.10

Sulfur Content of Fuels

FUEL	Fuel Sulfur Content (wt% unless otherwise stated) 1972	1973	1974	1000 lbs Sulfur(a) per 10^{12} BTUs For Year 1973	API Gravity	Reference
Gasoline						
Regular	0.072	0.056	0.048	27.72	59.0	Bureau of Mines (1972f through 1975f)
Premium	0.042	0.037	0.050	18.37	58.5	Bureau of Mines (1972f through 1975f)
Average	0.057	0.047	0.049	23.10		
Jet Fuels						
Jet A Commercial	0.048	0.045	0.054	22.47	42.9	Bureau of Mines (1973a through 1975a)
JP-5 Military	0.037	0.096	0.065	48.27	41.7	Bureau of Mines (1973a through 1975a)
Diesel Transportation Fuels						
T-T (trucks and trailers)	0.218	0.230	0.265	116.45	36.7	Bureau of Mines (1972d through 1974d)
R-R (railroads)	0.352	0.359	0.315	184.72	34.0	Bureau of Mines (1972d through 1974d)
S-M (stationary and marine)	0.160	0.320	0.320	165.15	33.5	Bureau of Mines (1972d through 1974d)
Fuel Oils						
Utility light distillate turbine fuel		0.05		24.03	42.0	See Appendix A2
#2 Distillate	0.217	0.247	0.230	126.27	34.7	Bureau of Mines (1972b through 1974b)
#6 Residual (high sulfur)	1.79	1.58	1.64	875.32	10.6	Bureau of Mines (1972b through 1974b)
#6 Residual (low sulfur)	0.40	0.40	0.40	209.23	19.0	See Appendix A2
Power plant residual (low sulfur)	0.420	0.439	0.436	222.25	24.0	See Appendix A2
Gaseous Fuels						
Refinery gas	10(b)	6(b)	6(b)	6.59		See Appendix A2
Digester gas	600(c)	600(c)	600(c)	89.0		Estimate (Rojas, 1976)
Natural gas	0.3(d)	0.3(d)	0.3(d)	0.283		Environmental Protection Agency (1973)
Solid Materials						
Coal		0.7		583.3		Bureau of Mines (1975e)
Petroleum coke		1.61		1069.1		Estimate; see text

(a) Note that 10^3 lbs sulfur/10^{12} BTU is equivalent to tons of $SO_2/10^{12}$ BTU.
(b) In grains per 100 ft^3.
(c) In ppm H_2S (digester gas sulfur content varies widely from plant to plant; this is an intermediate value from among a survey of several plants).
(d) in lbs/10^6 ft^3.

Appendix A2 is facilitated by the fact that combustion of a fuel supply containing one thousand pounds of sulfur per day results in one ton per day of SO_x emissions (stated as SO_2). Sulfur flows in Table A3.9 may thus be viewed as potential SO_x emissions in units of short tons per day as SO_2.

Sulfur flows into the air basin were determined from the energy balance plus estimates of the sulfur content of fuels. The sulfur content of energy resources consumed in the South Coast Air Basin is shown in Table A3.10. A description of how the sulfur inflows of Table A3.9 were developed from the energy balance follows.

A3.8.1 Crude and Net Unfinished Oils

In Appendix A1 to this study, the sulfur contained in crude oil entering South Coast Air Basin refineries was estimated for the year 1973. That appendix forms the basis for the sulfur flows in crude-type oils entering the South Coast Air Basin as shown in Table A3.9. Estimates of sulfur contained in all crude oils produced in the Los Angeles and Ventura area oil fields are taken from production data given in Table A1.6. All sulfur accompanying local oil production is entered as a sulfur source in Table A3.9. Sulfur accompanying net out-of-basin shipments of some of this locally produced oil will be subtracted from the sulfur balance later as an export. The sulfur content given for all other crude oil flows represents only the net receipts of sulfur from outside the boundaries of the air basin, not the total sulfur production in the oil fields of origin. Sulfur received in foreign and domestic oil imports is detailed in Table A1.10.

A3.8.2 Refined Petroleum Product Sulfur Content

The procedure used for determining the inflows of sulfur in each of the refined petroleum product streams was the same for all product types. The weight percent sulfur content of each fuel was determined from Bureau of Mines reports or other records. A representative sulfur content for the year 1973 was entered in Table A3.10. Representative sulfur content data for 1972 and 1974 were also recorded for the sake of comparison. Then the sulfur content per 10^{12} BTU's of fuel energy content was computed for each fuel using the energy content data of Table A3.1, the weight percent sulfur data of Table A3.10, and the fuel density implied by the API gravity of the samples from which the sulfur analysis was taken. The results of those calculations are shown in Table A3.10 for the year 1973. Then these sulfur contents per 10^{12} BTU's were applied to the energy imports given in Table A3.2 in order to obtain the total flux of sulfur entering the air basin in imported fuels.

A description of the source of the fuel sulfur content data follows, along with notes on any further assumptions which were made.

A3.8.2.1 Gasoline Sulfur Content

The sulfur content of gasoline was reported for summer and winter seasons of each year by the Bureau of Mines (1972f through 1975f). Samples are reported for 17 geographic regions of the country, of which Southern California forms one region. Data shown in Table A3.10 were obtained from these Bureau of Mines Southern California gasoline analyses after having adjusted their seasonal reports to a calendar year basis. Calendar year averages for 1973, for example, are based on the following weighing factors: Winter 1972-73, 25%; Summer 1973, 50%; Winter 1973-74, 25%. A weighted average sulfur content for all gasolines has been calculated using the relative proportions of regular and premium grade sales for California in 1973 as given by Ethyl Corporation (1974).

A3.8.2.2 Jet Fuel Sulfur Content

The sulfur content of jet fuel is reported on an annual basis by the Bureau of Mines (1973a through 1975a). Data for Type A commercial and JP-5 military fuels were used to calculate the sulfur content of jet fuels burned by the civilian transportation and military sectors, respectively. Imported jet fuels entering the basin were treated as being 87% commercial grade and 13% military type, in proportion to the relative quantities of jet fuel delivered locally to each of these customers in 1973 (i.e. burned plus exported in fuel tanks).

A3.8.2.3 Light and Middle Distillate Fuel Oil Sulfur Content

Data on the sulfur content of distillate fuel oil used for residential, commercial and industrial purposes was taken from the Grade 2 fuel oil summary for the Western Region of the United States given by the Bureau of Mines (1973b) in their burner fuel oils series. The sulfur content of diesel fuel used by trucks, railroads, and marine diesel engines is also reported by the Bureau of Mines (1973d). Data given in that source were used to calculate the sulfur content of distillate fuels used in the transportation sector of the energy balance. Imported distillate fuel oils probably span a variety of grades and uses. This mixed pool of imported distillate oil was characterized as being 23% Grade 2 (all stationary sources), 61% type TT (trucks), 10% type RR (railroad), and 6% type SM (maritime). Those quantities were taken in proportion to an analysis of total distillate oil deliveries to local customers as estimated in the energy balance sector of this study.

A3.8.2.4 Residual and Heavy Distillate Fuel Oil Sulfur Content

Heavy fuel oil sulfur content varies considerably depending on the sulfur content of the crude oil from which it was refined. The maximum fuel sulfur content permitted for stationary combustion sources in the South Coast Air Basin in 1973 was 0.5% sulfur by weight. From data developed in the detailed inventory of Appendix A2 to this study, it was found that the 1973 average sulfur content of electric utility fuel was 0.43% sulfur by weight. Most industrial residual fuel oil recorded in that survey had a sulfur content of about 0.40%. The sulfur content of residual fuel oil produced from Los Angeles Basin crude oils is much higher than 0.5%. Hence, it is expected that the sulfur content of much of the residual oil exported from the basin will be much higher than that burned locally. The Bureau of Mines (1973b) places typical Western Region Grade 6 residual oil sulfur content at 1.58% by weight in 1973. That value will be adopted as an average for all high sulfur oil uses in 1973. It is worth noting, however, that the reported average sulfur content of Western Region residual oils is not very stable, and that significantly higher sulfur content levels were reported for both 1972 and 1974.

The demand for imported residual oil was probably generated by a need for power plant fuel that would meet local emission control requirements. Therefore, imported residual fuel oil was treated as having a sulfur content like that of power plant fuels for the purposes of calculating the sulfur inflows of Table A3.9.

A3.8.2.5 Petroleum Coke Sulfur Content

Data on the sulfur content of petroleum coke are unavailable from the Bureau of Mines. On the basis of the sulfur flows leaving local refineries in petroleum coke daily (Southern California Air Pollution Control District, 1976a) plus our estimate of the energy content of local coke production, it was estimated that petroleum coke contained about 1.61% sulfur by weight. That estimate is higher than the 1.4% sulfur reported by local coke calciners to Hunter and Helgeson (1976), but lower than we would expect for a production weighted average of petroleum coke made from high sulfur California crude oils. In the absence of comprehensive survey information on coke sulfur content, our estimate should be viewed with caution.

A3.8.2.6 Asphalt, Lubricating Oils and Other Hydrocarbons

Of this group of miscellaneous products, only asphalts and road oils are expected to have a high sulfur content. Imports of asphalt products into the basin are negligible. Although the imports of lubricants and petrochemical feedstocks are higher, their sulfur content is low. Therefore, sulfur inflows into the air basin in these miscellaneous products are thought to be small and will be neglected.

A3.8.3 Digester Gas Sulfur Content

Digester gas is apparently not a uniform product. Sulfur content estimates obtained from various treatment plant operators range from 70 ppm H_2S up to 600 ppm H_2S (Rojas, 1976; Frieling, 1976; Clark, 1976). A sulfur content of 600 ppm H_2S was used as an upper limit to the sulfur contained in digester gas when constructing this sulfur balance. Since only small quantities of this fuel are burned in the basin, an extremely precise estimate of digester gas sulfur content is unnecessary.

A3.8.4 Natural Gas, LPG and NGL Sulfur Content

Based on Environmental Protection Agency (1973) emission factor data, the nationwide sulfur content of natural gas is about 0.3 lbs/mmcf. The sulfur content of natural gas is so low that no attempt was made to further refine EPA's nationwide estimate. As by-products of natural gas production, the sulfur content of LPG and NGL is similarly very low. Lacking any additional data, the sulfur content per 10^{12} BTU's estimated for natural gas will be assumed to approximate that for LPG and NGL as well.

A3.8.5 Coal Sulfur Content

Virtually all of the coal entering the South Coast Air Basin is destined for coke production. The only western coal mining districts listed by the Bureau of Mines (1975e) as having production for coke plants sufficient to meet the basin's import needs are in Utah and southern Colorado. The southern Colorado mines produced coking coal with a sulfur content of 0.6% sulfur by weight. The Utah mines coking coal was 0.8% sulfur by weight. Therefore, an average sulfur content for South Coast Air Basin coal receipts was taken as 0.7% sulfur by weight.

A3.9 Sulfur Flows in the Energy Transformation Sector

A3.9.1 Petroleum Refining

The Southern California Air Pollution Control District (1976a) has prepared a sulfur balance on Los Angeles County oil refineries for the year 1973, as shown in Table A3.11. Since these data were obtained directly from the refineries involved, they are assumed to represent sulfur flows far more accurately than could be estimated from regional commerce statistics such as are available from the Bureau of Mines. Therefore the APCD refinery sulfur balance will be used as the basis for characterizing the distribution of sulfur between the large number of products leaving South Coast Air Basin refineries.

Use of the APCD refinery sulfur balance places some constraints on the product categories which may be treated separately as they leave the refineries in our sulfur survey. The APCD study classifies refined products by boiling range rather than by intended use. Jet fuel, utility turbine fuel and kerosene heating oil, for instance, would all be included under the category "light distillates". Therefore, in order to make the APCD survey compatible with our energy balance, the number of separately identified products must be reduced. The sulfur flows contained in the APCD's light distillates and middle distillates categories will be merged and assumed to

TABLE A3.11

1973 Sulfur Balance
Los Angeles County Refineries plus Refinery-Owned
Sulfur Recovery Plants
(Summarized from APCD Format)

Line number ( ) and process stream	Sulfur (1000 lbs/day)
Sulfur in feed	
(1) virgin crudes	3,088.09
(2) reduced crudes	396.43
(3) purchased gas fuel	0.22
(4) misc	216.15
TOTAL SULFUR IN	3,700.89
Sulfur in Products	
(5) fuel gas	0.07
(6) LPG-LNG	0.13
(7) gasoline	81.88
(8) light distillates	35.09
(9) middle distillates	100.56
(10) heavy distillates	177.09
(11) fuel oils	575.03
(12) crudes	149.18
(13) coke	332.11
(14) sulfur	1,769.24
(15) misc	216.97
Total sulfur out in products	3,437.35
Sulfur to Atmosphere	
(16) fuel gas	2.49
(17) fuel oil	9.19
(18) industrial processes (summation)	53.77*
(19) from sulfur plant	61.68
Total sulfur to atmosphere	127.13
Sulfur in Liquid Waste	
(20) total sulfur in liquid waste	134.95
TOTAL SULFUR OUT	3,699.41

*corrected for addition error in APCD table.

represent the combined total of the sulfur contained in jet fuel plus light and middle distillate heating, turbine, and diesel oils. Similarly, the APCD sulfur flows contained in heavy distillate oils will be combined with their fuel oil (residual oil) totals to form a heavy fuel oil category. Petroleum refinery products (other than petroleum coke) which are destined for non-fuel use will be grouped into a miscellaneous products total. Finally, in line with our practice developed in the energy balance, the sulfur contained in topped crude and other unfinished oils output of the refineries will be subtracted from gross refinery input feedstocks in order to show as feedstocks only the net fresh feed to the refinery complex. Refinery fuels burned will be separated from other refinery input feedstock.

In addition to the refinery sulfur balance, the APCD has developed a sulfur balance on the sulfur recovery and sulfuric acid plants associated with local refineries, as shown in Table A3.12. Some of these sulfur recovery operations are owned by oil refineries and their product output is shown as sulfur on both the sulfur plant balance and the refinery balance. In other cases, sulfuric acid produced at refinery-owned acid plants is included within the miscellaneous products category of the refinery balance. However, several refineries do not operate their own sulfur recovery or acid plants. Instead H_2S and acid sludge are sent to separately operated chemical plants for further processing. In some cases, this H_2S is included within the "sulfur" product output of the refinery balance. In other cases, either H_2S or sulfuric acid produced must appear in the miscellaneous

TABLE A3.12

1973 Sulfur Balance
All Sulfur Recovery and Sulfuric Acid Plants
Associated with Los Angeles County Refineries

Line number ( )* and process stream	Sulfur (1000 lbs/day)
Sulfur in feed	
(21) hydrogen sulfide burned	1,980.4
(22) acid sludge burned	363.4
(23) sulfur burned	420.8
TOTAL SULFUR IN	2,764.6
Sulfur in products	
(24) elemental sulfur	1,720.74
(25) sulfuric acid	959.40
(26) other	5.80
Total sulfur in products	2,685.94
Sulfur to atmosphere	
(27) total sulfur to atmosphere	81.46
TOTAL SULFUR OUT	2,767.4

*Continued from Table A3.11.

products category in order for the refinery sulfur balance to actually balance.

In order to place all refinery operations on a common basis, an attempt was made to unbundle the sulfur recovery plants from the refinery sulfur balance. This task is rendered rather difficult by the fact that the APCD sulfur balance data were aggregated to a basin-wide level before public release in order to conceal proprietary information on each sulfur plant's product output. Individual refinery/ sulfur plant relationships were obscured to the point where it is difficult to determine where the feedstock materials entering the sulfuric acid production process (Table A3.12) appear on the refinery balance (Table A3.11). Therefore some assumptions were made. It was assumed that refineries produced at least as much H_2S as the sulfur recovery and acid plants burned in 1973. That H_2S quantity received by sulfur recovery and acid plant operations exceeds the total of "sulfur" produced and "sulfur plant emissions" given in the refinery balance of Table A3.11. It was therefore assumed that the remainder of the sulfur as H_2S needed to meet indicated sulfur recovery and acid plant H_2S intake appears as either H_2S or sulfuric acid in the miscellaneous refinery products total of Table A3.11. The sulfur contained in the miscellaneous products category of the refinery balance was reduced accordingly. In place of "sulfur", "sulfur plant emissions", and the acid plant production portion of the miscellaneous products total, a single refinery product called "H_2S" was created. This reformatted version of the refinery sulfur balance is given in Table A3.13, along with appropriate notes showing the correspondence between that table and Tables A3.11 and A3.12. It was further assumed that acid sludge appearing on the sulfur recovery and acid plant balance was not included as a product in the refinery balance. That seems reasonable since the acid sludge appears to be recycled process acid from the refineries and not a direct product of the sulfur contained in the oil being refined. Many of the ambiguities in the relationship between acid plant operation and the refinery sulfur balance could be resolved from APCD files if the production information on individual plants were not confidential.

A3.9.2 Electric Utility Fuel Combustion

The sulfur content of electric utility heavy fuel oil was determined in Appendix A2 as 0.43% sulfur by weight in 1973. Light fuel oils used by utility internal combustion engines averaged about 0.05% sulfur in that year. Virtually all sulfur entering electric generating stations in fuel is released to the atmosphere in the form of sulfur oxides air pollutant emissions, as indicated in Table A3.14.

A3.10 Sulfur Flows in the End Use Consumption Sector

Fuels burned in the end use consumption sector of the energy balance release virtually all of their sulfur to the atmosphere in the form of sulfur oxides air pollutant emissions. Emission factors from Table A3.10 were used to convert the energy units of Table A3.6 into the sulfur flow statement shown in Table A3.15. In most cases, the appropriate choice of emission factor is apparent from Tables A3.6 and A3.10. Grade 2 distillate oil sulfur content was used to

TABLE A3.13

Reformatted Sulfur Balance on Los Angeles Refineries - 1973
(Excluding acid plant and sulfur recovery operations)

	Sulfur (1000 lbs/day)	Notes:
Refinery Input including all fuels burned		
Net input feedstock	3,551.49	Refinery balance lines (1)+(2)+(4)-(12)
Refinery fuels consumed		
Natural gas	0.04	Calculated from energy balance & % sulfur in fuel
Still gas and LPG	2.45	Refinery balance line (16) less natural gas above
All fuel oils	9.19	Refinery balance line (17)
TOTAL SULFUR IN	3,563.17	
Refinery Output including refinery fuel		
Still gas and LPG	2.65	Refinery balance lines (5)+(6)+still gas and LPG burned
Gasoline	81.88	Refinery balance line (7)
Jet fuel; light and middle distillate oil	135.65	Refinery balance lines (8)+(9)
Residual and heavy distillate oil	761.31	Refinery balance lines (10)+(11), plus fuel oil burned line (17)
Petroleum coke	332.11	Refinery balance line (13)
Miscellaneous products	67.49	Refinery balance lines (14)+(15)+(19) less H_2S to sulfur and acid plants from sulfur plant balance line (21)
H_2S to sulfur recovery and acid plants	1,980.40	Sulfur recovery plant balance line (21)
Sulfur to atmosphere		
Fuel combustion	11.68	Refinery balance lines (16)+(17)
Industrial processes excluding sulfur recovery and sulfuric acid	53.77	Refinery balance lines (18)+(19)
Liquid wastes	134.95	Refinery balance line (20)
TOTAL SULFUR OUT	3,561.89	

TABLE A3.14

Sulfur Emissions from Electricity Generation
Within the South Coast Air Basin - 1973

Fuel Burned	Thousands of pounds of sulfur per average day
Natural Gas	0.12
Heavy Fuel Oil	235.22
Light Distillate Oils	0.18
Digester Gas	0.07
Subtotal	235.59
Emissions to the Atmosphere	235.59

TABLE A3.15

Sulfur Flows in the Energy Resources Used by Final Consumers in the South Coast Air Basin - 1973

(in 1000's lbs sulfur per day)

END USE CONSUMPTION SECTOR	Natural Gas	LPG	Gasoline	Jet Fuel	Light and Middle Distillate Fuel Oil	Residual and Heavy Distillate Fuel Oil	Petroleum Coke Calcining	Coal	Digester Gas	Sulfur Sufficient to Balance Raw Materials Processing Losses	Solid Wastes	Atmospheric Emissions: Industrial Process	Atmospheric Emissions: Fuel Burning
Sulfur from Fuel Combustion in Basin													
System uses; losses	-0.016												0.016
Residential/commercial	-0.334	-0.005			-2.80	-4.64		-0.32					8.10
Industrial (other than refinery)	-0.119	-0.001			-5.40	-11.18		-91.41	-0.56		50.05		58.62
Transportation (civilian)													
Motor vehicles		-0.001	-41.12		-13.69								54.81
Aircraft			-0.03	-1.07									1.10
Railroads					-5.42	-0.06							5.48
Ships					-2.85	-21.58							24.43
Military			-0.14	-0.81	-2.07	-0.24							3.26
Miscellaneous	-0.007	-0.002	—	—	-4.63	-0.34		—	—		—		4.98
Subtotal (from fuels)	-0.48	-0.01	-41.29	-1.88	-36.86	-38.04		-91.73	-0.56		50.05		160.80
ADJUSTMENT FOR EFFECT OF RAW MATERIALS PROCESSING INDUSTRIES	-0.01	-0.01					-25.52			-17.69		43.21	

Note: '-' indicates sulfur in.
'+' indicates sulfur out.

calculate distillate oil sulfur emissions by residential/commercial and industrial customers. Military and miscellaneous distillate oil demands were assumed to be principally for vehicle diesel engine fuel. Heavy bunker oil combustion by civilian and military ships was calculated as if high sulfur fuel oil were used. All remaining heavy oil uses within the basin were inventoried at 0.40% sulfur in the fuel.

Use of coking coal in the largest steel mill in the Los Angeles area must be treated as a special case in our sulfur balance. Sulfur is released to the atmosphere from both the coal being fed to the mill's coke ovens, and from the sintering of sulfur-bearing ores. Furthermore, some of the fuel sulfur reaching the mill's furnaces is captured by the use of slag mixtures and eventually becomes part of a solid waste product. In order to separate iron ore sulfur released from fuel sulfur released, an attempt was made to construct a sulfur mass balance on the steel mill's sinter plant. That effort failed when the balance showed much more sulfur lost from the process than Hunter and Helgeson's (1976) stack tests would indicate is going to the atmosphere. Without the ability to retest the plant or to acquire further process information, the sulfur oxides emissions from Appendix A2 to this report will be accepted as representing sulfur released to the atmosphere from the entire steel mill. Those emissions will be subtracted from estimated fuel sulfur input in coal, and the remaining fuel sulfur will be assumed to be tied-up in slag solid wastes. The atmospheric emissions presented in this manner will be within reason, but the sulfur contained in iron ore will not show explicitly on the basin's sulfur balance and the quantity of sulfur captured in solid wastes will be too low.

Construction of a sulfur balance on the raw materials processing industries in Los Angeles could become very complicated. A number of industrial processes exist which release sulfur from mineral products and scrap being processed rather than from the fuel being burned. The total quantity of mineral products, scrap batteries, fluxes, coloring agents and the like charged to these processes in 1973 is unknown to us because production rate information of this type is confidential and will not be released by the local APCD. Instead, our sulfur balance will include adjustments for the effect of the reported atmospheric emissions from these industrial processes. These adjustments are shown at the bottom of Table A3.15. Sulfur in energy products which are consumed as a feedstock by industrial processes is shown as a negative entry in that table. Industrial process emissions to the atmosphere are shown as a positive flow. These emissions estimates are taken from Tables A2.15a and A2.15b. They represent the sum of emissions from coke calcining kilns, glass furnaces, secondary metals furnaces, other minerals industries, incinerators, oil field production operations, chemical plants other than sulfur recovery and sulfuric acid plants, and miscellaneous industrial processes.

A3.11 Sulfur Exported from the South Coast Air Basin

Sulfur contained in fuels exported from the South Coast Air Basin in 1973 is summarized in Table A3.16.

A3.11.1 Natural Gas Sulfur Exported

Sulfur leaving the basin in natural gas was estimated from the energy exports given in Table A3.7. The sulfur content assumed for that natural gas is given in Table A3.10.

A3.11.2 Net Crude Oil Sulfur Exported

The sulfur content of net crude oil exports from local oil fields was estimated from data in Appendix A1, Tables A1.6 and A1.10. Sulfur exported in crude oil was taken as sulfur produced in oil from Los Angeles Basin and Ventura area fields less the sulfur content of local oil production kept for processing in local refineries (i.e. production less refinery receipts).

A3.11.3 Sulfur Contained in Refined Petroleum Products Exported from Local Harbors

The energy content of refined product exports from local harbors is shown in Table A3.7. The sulfur content of these products is given in Table A3.10. Many of these exported product streams contain fuels of varying sulfur content. As was the case with our imported refined products, some assumptions must be made about the product mix represented by "jet fuel", distillate oil and residual oil. Jet fuel was taken to be 87% commercial type and 13% military type, as was assumed in our discussion of jet fuel imports. Distillate oil sulfur content was estimated from a blend of distillate oil types,

TABLE A3.16

South Coast Air Basin Sulfur Exports-1973

	1000 lbs Sulfur per Day
Natural Gas	
Out-of-basin sales to Pacific Lighting customers	0.07
Sales to San Diego Gas & Electric	0.07
Exchange with out-of-basin utility	0.004
Subtotal	0.14
Crude Oil - Net	
Los Angeles and Ventura oil shipped to sea less estimated return flows of that oil at other South Coast Air Basin ports	121.8
Petroleum Product Exports	
Harbor exports	
Gasoline	3.03
Jet fuel	1.23
Distillate oil and kerosene	31.60
Residual oil	302.57
Petroleum coke	320.44
Lubricants and greases	(small)
Asphalt and asphalt materials	∿40.0
LPG	∿ 0
Other	(small)
Subtotal	698.87
Overland transport	
Arizona and southern Nevada	
Gasoline	5.73
Jet fuel	1.54
Light and middle distillate oil	18.64
Residual oil	16.99
Inland to southern California	
Gasoline	6.59
Subtotal	49.49
Exported in transport mode fuel tanks	
Transportation (civilian)	
Aviation gasoline	0.24
Jet fuel	6.17
Distillate bunker fuel	1.22
Residual bunker fuel	203.12
Military	
Aviation gasoline	0.00
Jet fuel	1.49
Residual bunker fuel	3.12
Subtotal	215.36
Raw Materials	
Elemental sulfur (harbor export)	1.67
TOTAL INVENTORIED EXPORTS	1,087.33

in the same proportions as assumed for imports in Section A3.8.2.3 of this survey.

Residual fuel oils shipped from local harbors principally consist of high sulfur oils destined for other ports where burning higher sulfur oil is within legal limits. However, a substantial quantity of low sulfur residual oil is apparently also shipped in coastal commerce from harbors in the Los Angeles area to fuel power plants located elsewhere on the California coast. Examination of our fuel oil import records at Huntington Beach, Port Hueneme, Carpenteria and Ventura showed residual oil imports from domestic sources equal to about 25% of the gross South Coast Air Basin residual oil shipments to sea. While all of that oil received may not have come from South Coast Air Basin refineries, there is similarly no lack of other non-South Coast Air Basin power plants along the California coast to which low sulfur fuel might be shipped by sea. Therefore it seemed reasonable to estimate that about 25% of the residual oil exported to sea from local harbors was of the low sulfur power plant fuel oil variety. All remaining heavy oil exports were assumed to represent disposal of high sulfur fuel oil refined from crude oil which will not meet local sulfur content limits.

A significant quantity of sulfur leaves the air basin by ship in petroleum coke and asphalt. The sulfur content of petroleum coke was estimated in Table A3.10. The sulfur content of asphalt is not known to us but is probably not too much different than that of petroleum coke.

If that were the case, about 40 thousand pounds of sulfur would leave the basin daily in exported asphalt. However, since actual data on the sulfur content of asphalt is not available, an export estimate for it will not be entered into the sulfur balance. Instead, all miscellaneous hydrocarbons (except petroleum coke) which are not ultimately used for fuel will be considered to have an unknown sink from which their sulfur content is not released to the atmosphere.

A3.11.4 Sulfur Contained in Petroleum Products Exported by Overland Transportation Modes

The energy content of fuels shipped out of the basin by overland transport modes is shown in Table A3.7. Jet fuel and distillate oils exported were assumed to be mixtures of the fuel types used in the South Coast Air Basin in the proportions indicated for imports in sections A3.8.2.2 and A3.8.2.3 of this survey. Based on conversations with personnel at the air pollution control agencies for the State of Arizona (Rowe, 1977) and Clark County (Las Vegas), Nevada (Neeler, 1977), it was found that power plants in those areas burned low sulfur fuel oil. Therefore, residual oil exports to Arizona and Southern Nevada were inventoried at the sulfur content given in Table A3.10 for South Coast Air Basin low sulfur power plant fuel.

A3.11.5 Sulfur Exported in the Fuel Tanks of Long Range Transportation Vehicles

The energy content of fuels leaving the South Coast Air Basin in aircraft and ship fuel tanks is detailed in Table A3.7. Sulfur flows associated with those energy exports were inventoried using factors presented in Table A3.10. Distillate bunker fuels were taken to be Type SM diesel fuel. Residual bunker fuel was assumed to be of the high sulfur fuel oil variety.

A3.11.6 Raw Material Exports

Harbor records given in Waterborne Commerce of the United States (Corps of Engineers, 1973) show a small amount of elemental sulfur exported from South Coast Air Basin harbors. That sulfur export has been entered in Table A3.16. Other quantities of sulfur or sulfuric acid may leave the air basin by overland transportation modes, but data on those shipments are unknown to us.

A3.12 The Sulfur Balance

Table A3.17 summarizes the sulfur balance on the South Coast Air Basin for the year 1973. An estimated total of 4.2 million pounds of sulfur per day was tracked through the basin's economy. Over ninety percent of that sulfur input originally accompanied crude oil.

The estimated fate of that sulfur supply is also given in Table A3.17:

- Nearly half of the sulfur was captured at sulfur recovery and sulfuric acid plants;
- Approximately one quarter of the sulfur was exported from the basin in finished petroleum products;
- 4.4% of the sulfur supply found its way into solid or liquid wastes;
- At least 14% of the sulfur was emitted to the atmosphere in the form of 586.51 tons per day of sulfur oxides air pollutants (stated as SO_2); and

TABLE A3.17

South Coast Air Basin Sulfur Balance - 1973
(1000's lbs sulfur per day)

	Natural Gas	Crude Oil; Unfinished Oils & Other Refinery Feedstocks	LPG and Still Gas for Fuel	Gasoline	Light and Middle Distillates & Jet Fuel	Residual and Heavy Distillate Fuel Oil	Petroleum Coke	Misc. Petroleum Products	Coal	Digester Gas	Hydrogen Sulfide	Sulfur	Acid Sludge	Sulfuric Acid	Misc. Indus. Raw Materials Sufficient to Balance Process Losses	Solid or Liquid Waste	Atmospheric Emissions: Industrial Process	Atmospheric Emissions: Fuel Burning	TOTAL
SOURCES																			
Resource base: imports plus local crude oil and natural gas production	0.81	3942.5	0.01	4.40	29.76	77.70	16.11	small	91.73	0.63		0.06			17.69				
Adjustments: change in gas storage	-0.02																		
Subtotal	0.79	3942.5	0.01	4.40	29.76	77.70	16.11		91.73	0.63		0.06			17.69				4181.38
TRANSFORMATION SECTOR																			
Refinery																			
Feedstock sulfur		-3551.5																	
Fuel sulfur	-0.04		-2.45			-9.19													
Products and wastes			2.65	81.88	135.65	761.31	332.11	67.49			1980.4		363.4	-363.4		134.95	53.77	11.68	
Sulfur Recovery and Sulfuric Acid																			
Feedstock sulfur											-1980.4	-420.8	-363.4						
Products and wastes								5.80				1720.7		959.4			81.46		
Electric Utilities																			
Fuel sulfur	-0.12				-0.18	-235.22				-0.07								235.59	
Subtotal	-0.16	-3551.5	0.20	81.88	135.47	516.90	332.11	73.29		-0.07	0	1299.90	0	596.0		134.95	135.23	247.27	1.47
END USE CONSUMPTION SECTOR																			
(Fuel Combustion in Basin)																			
System uses; losses	-0.02																	0.02	
Residential/commercial	-0.33		-0.005		-2.80	-4.64			-0.32									8.10	
Industrial (other than refinery)	-0.12		-0.001		-5.40	-11.18			-91.41	-0.56						50.05		58.62[a]	
Transportation (civilian)			-0.001	-41.15	-23.03	-21.64												85.82	
Military				-0.14	-2.88	-0.24												3.26	
Miscellaneous	-0.01		-0.002		-4.63	-0.34												4.98	
Subtotal	-0.48		-0.01	-41.29	-38.74	-38.04			-91.73	-0.56						50.05		160.80	0.00
ADJUSTMENT FOR EFFECT OF RAW MATERIALS PROCESSING INDUSTRIES	-0.01		-0.01				-25.52								-17.69		43.21[b]		-0.02
EXPORTS																			
As a commodity (by ship)	-0.07	-121.8	~0	-3.03	-32.83	-302.57	-320.44					-1.67							
As a commodity (overland)	-0.07			-12.32	-20.18	-16.99						unknown							
In transport mode fuel tanks				-0.24	-8.88	-206.24													
Subtotal	-0.14	-121.8	~0	-15.59	-61.89	-525.80	-320.44					-1.67							-1047.33
SINK FOR MISC. NON-FUEL RESOURCES WHOSE ULTIMATE CUSTOMER WILL NOT BE SOUGHT								-73.29				-1298.29		-596.0					-1967.58
SUMMARY																			
Total sources (+ flows)	0.81	3942.5	2.66	86.28	165.41	839.01	348.22	73.29	91.73	0.63	1980.4	1720.76	363.4	959.4	17.69	185.00	586.51		
Total sinks (- flows)	-0.81	-3673.3	-2.47	-56.88	-100.81	-808.25	-345.96	-73.29	-91.73	-0.63	-1980.4	-1720.76	-363.4	-959.4	-17.69				
Absolute difference	0	269.2	0.19	29.40	64.60	30.76	2.26						0						393.41
Difference as % of sources	0	+6.8%	+7.1%	34.1%	39.1%	3.7%	0.65%												
Difference as % of total sulfur input of 4181.38 thousand lbs/day	0	6.4%	~0%	0.70%	1.54%	0.74%	0.05%										14.0%		

Notes: (a) This fuel burning total includes 41.36 thousand pounds of sulfur per day from combined fuel burning and industrial processes activities at Kaiser Steel.

(b) These industrial process emissions include

misc. chemical industries	0.09
oil field production	4.50
petroleum coke kilns	25.52
glass furnaces	2.23
metals industries	8.88
minerals industries	1.90
other industrial processes	0.02
incinerators	0.07

• The fate of 9.4% of the sulfur supply remains undetermined. In contrast to the energy balance, the sulfur balance at first glance does not appear to balance closely. The explanation for that problem, however, seems fairly straightforward.

The largest discrepancy between sulfur supply and consumption lies in the crude oil column of Table A3.17. While supply exceeds known crude oil sulfur consumption by only 6.8%, that 6.8% difference is applied to two very large sulfur flows. One reason for this gap between estimated supply and demand lies in the fact that the APCD survey used to estimate sulfur intake by refineries did not include at least two small refineries which accounted for about 1% of the basin's daily crude oil demand in 1973. Refinery sulfur intake and output should be about 1% higher than shown if more complete data were available on those small refineries. The remaining five to six percent surplus of crude oil sulfur supplied probably represents an overestimate of either crude oil intake or crude oil sulfur content as part of the study conducted in Appendix A1 to this report. Considering the difficulty in estimating the origin of some of the crude oils received in the basin, that small percentage disagreement will be considered nearly unavoidable. Provided that the APCD refinery sulfur balance is correct, any overestimate of crude oil sulfur supply from Appendix A1 will not affect the rest of the sulfur flows shown in Table A3.17, nor will it inflate any atmospheric emissions estimates. With the crude oil sulfur discrepancy set aside, the remainder of the sulfur balance balances to within about 3%.

Turning to individual product streams, we note that the sulfur balances on the heavy petroleum products appear reasonable. Petroleum coke sulfur balances to within less than a 1% surplus, and heavy fuel oil balances to within 3.7%. Those two products account for about 28% of the total sulfur in the system.

Heavy fuel oil combustion in the basin is the largest single source of sulfur oxides air pollutant emissions, accounting for just under half of total emissions to the atmosphere. It is therefore reassuring to obtain a fairly close sulfur balance on supply and use for this product.

Petroleum coke is produced almost exclusively for export from the basin. Significant emissions to the atmosphere come from the petroleum coke calcining industry (25.22 tons/day as SO_2; see adjustment for raw materials processing or Appendix A2). In that process, coke is carbonized in preparation for manufacturing electrodes.

At the lightest product end of the sulfur balance, results also seem acceptable. Natural gas and refinery gases (LPG and still gas) contain practically no sulfur even though they accounted for a third of the basin's total energy supply in 1973.

In spite of the fact that the energy balance on gasoline closed almost exactly, the fate of 34% of the sulfur distributed in gasoline in 1973 remains undetermined. The apparent explanation is that the

Bureau of Mines gasoline grab samples for that year were not representative of a production weighted average of local refinery products. Consider the following evidence to that effect.

Table A3.18 shows refinery sulfur output in gasoline for the years 1973 and 1974 as reported by refineries to the local air pollution control district. An estimate of the weight percent sulfur in gasoline implied by those refinery reports has been made for comparison with Bureau of Mines data. As can be seen, the refinery reports to the APCD closely follow the Bureau of Mines sulfur samples in 1974. For 1973, however, either the Bureau of Mines samples are far too low, or the APCD sulfur balance is too high.

Since local refineries would be unlikely to overstate the total tonnage of sulfur distributed in gasoline by 47%, one tends to suspect the Bureau of Mines data. The Bureau of Mines appears to take grab samples of gasoline from a large number of refiners. These samples are first averaged for each refiner and then each refiner is weighted equally when computing the Southern California average gasoline sulfur content. However two of the eighteen refineries in the South Coast Air Basin accounted for about 40% of local refinery capacity in 1973. Unless the sulfur content of gasoline from the basin's large refineries is weighted by their market share, the Bureau of Mines would not be able to compute a gasoline pool average sulfur content with any accuracy unless all gasoline samples were of about the same sulfur content. Bureau of Mines test results show wide variance in gasoline sulfur content between refineries. One therefore suspects

TABLE A3.18

Comparison of Bureau of Mines Gasoline Sulfur Content Data to the Sulfur Content of Gasoline Estimated from Refinery Reports to the Southern California APCD

Calendar Year	Sulfur distributed in gasoline (1000's lbs/day)[(a)]	Sulfur distributed as weight percent of gasoline production (approximate)[(b)]	Average Weight Percent Sulfur in gasoline as implied by Bureau of Mines[(c)]
1973	81.88	0.070%	0.047%
1974	55.89	0.048%	0.049%

(a) Based on refinery reports to the Southern California Air Pollution Control District (1976a).

(b) Based on an approximate gasoline production rate for local refineries of 450 thousand barrels per day in both years (estimated from Table A3.3).

(c) See Table A3.10.

that their average sulfur content values could be quite a bit in error if used to represent a gasoline pool average.

Unlike the discrepancy in the crude oil sulfur balance, the gasoline sulfur surplus probably represents a real uncertainty in the basin's atmospheric emissions estimates for 1973. Most gasoline produced in local refineries is actually burned in the basin. If the 1973 gasoline sulfur content were 47% higher than reported by the Bureau of Mines, then atmospheric emissions from gasoline combustion would have been close to 60 tons per day (as SO_2) instead of 41 tons per day as calculated from Table A3.17.

A similar problem may have occurred with estimation of light and middle distillate fuel oil sulfur content in 1973. The average sulfur content of distillate oil products shown in Table A3.10 was given by the Bureau of Mines for the entire Western Region of the United States. Since several Southern California refineries handled very high sulfur crude oil, it would not be too suprising if Southern California distillate oil sulfur content were above the Western Region average. However, given the large variety of distillate oil products and the fact that our energy balance on these oils did not close exactly, it is not possible to pinpoint the nature of the imbalance in the distillate oil sulfur pool.

One of the most striking features of the sulfur balance is the relatively high degree of desulfurization of petroleum products that was already occurring at Los Angeles area refineries in 1973. Roughly half of the sulfur entering those refineries was captured as elemental sulfur or sulfuric acid, rather than leaving the refinery in products or waste discharges.

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APPENDIX A4

PLUME RISE CALCULATIONS

A4.1 Introduction

In order to characterize the local concentration effects of pollutant emissions from any source, it is necessary to estimate the source's effective stack height. Source effective stack height is the elevation above ground level at which a buoyant plume ceases to rise further into the atmosphere and instead equilibrates with its surroundings. Effective stack height can be thought of as having two component parts: an increment due to the physical stack height which is built into the source, and an increment due to plume rise above the physical stack.

Plume rise in a stratified atmosphere is a complex phenomenon, depending on the physical characteristics of the effluent gases and ambient meteorological conditions. The purpose of this appendix is to present a compilation of relevant stack characterisitics for major SO_x sources in the South Coast Air Basin and to estimate plume rise from a representative set of sources at one set of reference atmospheric conditions. The results of these calculations will be used to establish typical physical stack heights and plume rise behavior for each source class in the emission inventory of Appendix A2 to this study. Then a method will be suggested for dynamically allocating effective stack height as a function of source class and wind speed within a simple emissions/air quality model. It is unrealistic to think that data are available sufficient to calculate plume rise accurately for all sources under all meteorological conditions. But an approach is developed which at least will distinguish sources with tall effective stacks from those emitting near ground level.

A4.2 Data Sources

The following stack parameters are required in order to calculate the plume rise from any source using Briggs' (1971) method: the physical stack height, the stack diameter, and the temperature and velocity of the exhaust gases. Several data sources were employed to obtain these parameters for the most significant sulfur oxides sources in the South Coast Air Basin.

The Federal Power Commission (Thomas, 1976) supplied the required stack parameters for the electrical power plants in the basin. These data are reported by the utilities on FPC Form 67 for 50%, 75%, and 100% of full power plant load. In a few cases the stack gas exit velocity was simply estimated rather than measured by the utility. Occasionally it was necessary to calculate the exit velocity from the exhaust gas volumetric flow rate when only the latter was reported.

Stack data on many industrial plants came from measurements made by Hunter and Helgeson (1976) as part of a sulfur oxides source test program conducted for the South Coast Air Basin. Those source tests covered a number of the larger industrial facilities in the basin. Hunter (1975) provided stack data for various refinery fluid catalytic cracking (FCC) units, sulfur recovery plants, sulfuric acid plants, coke calcining kilns, glass furnaces, and various metallurgical operations. In some cases, particularly where sources were baghouse-controlled, measurements of exit velocity and effective stack diameter were unavailable, but at least the physical stack height is known.

For several additional sulfur oxides sources, stack data were obtained by personal communication with plant personnel.

A4.3 Calculation Methods

Plume rise is a function of the flux of buoyant force carried by the stack gases. For a buoyant plume of about the same specific heat capacity and molecular weight as air, this flux, divided by Π and the mean atmospheric density, is given by

$$F = g \frac{\Delta T}{T_s} v_s r^2 \qquad \text{(A4.1)}$$

where

g = gravitational constant

ΔT_s = temperature difference, $T_{stack} - T_{ambient}$

T_s = the absolute temperature of the stack gases

v_s = stack exit velocity

r = stack radius

F has dimensions of $(\text{length})^4/(\text{time})^3$ and is related to Q_H, the heat flux of the plume. For an emission source located near sea level, the conversion formula is:

$$Q_H = F/(4.3 \times 10^{-3}) \qquad (A4.2)$$

with Q_H in cal/sec and F in ft^4/sec^3.

Plume rise (ΔH) was calculated according to the semi-empirical formulas proposed by Briggs (1971) for the final height of rise through a neutral or unstable atmosphere, using:

$$\Delta h = 1.6 \frac{F^{1/3}}{U} (10\ H_s)^{2/3} \qquad \text{for } Q_H \geq 47.8 \times 10^5 \text{ cal/sec} \qquad (A4.3)$$

$$\Delta h = 1.6 \frac{F^{1/3}}{U} (1.56\ F^{2/5} H_s^{\ 3/5})^{2/3} \qquad \text{for } Q_H < 47.8 \times 10^5 \text{ cal/sec} \qquad (A4.4)$$

where H_s is the physical stack height and U is the ambient wind speed.

Example calculations shown in Table A4.1 give plume rise, ΔH, for each source for which stack data were obtained. These calculations were made for one set of typical atmospheric conditions, and provide a basis for visualizing relative differences in source plume buoyancy. Results shown in Table A4.1 assume a wind speed of 6.2 mph (2.76 m/sec) and an ambient temperature of 64.4°F (18°C), which are average values for downtown Los Angeles (National Oceanic and Atmospheric Administration, 1974). In order to compute source effective stack height above ground level, plume rise, ΔH is added to source physical stack height, H_s.

TABLE A4.1

Stack Data Buoyancy Flux (F), Heat Flux, (Q_H), and Plume Rise (ΔH) for South Coast Air Basin Sulfur Oxides Sources
(calculated for neutral stability, ambient temperature = 64.4°F, wind speed = 6.2 mph)

Fuel Combustion Sources

Electric Utilities

Generating Station	Unit Number	Plant Load	Physical Stack Height H_s (ft)	Stack Volumetric Flow Rate (SCFM)	Stack Exhaust Temperature T_s (°F)	Stack Diameter (ft)	Exhaust Gas Velocity V_s (FPS)	Briggs F (ft^4/sec^3)	Heat Flux Q_H (10^5 cal/sec)	Plume Rise ΔH (ft)	Data Source
El Segundo	#1&2	full	200	450,000	290	12	66.3	22974	53.4	794	FPC
		75%		337,500	280		49.7	16681	38.8	673	FPC
		half		225,000	270		33.1	10739	25.0	517	FPC
	#3&4	full	200	854,000	235	14	92.4	35564	82.7	919	FPC
		75%		640,000	205		69.3	22974	53.4	794	FPC
		half		427,000	193		46.2	14266	33.2	613	FPC
Redondo	#1,2,3	full	200	363,000	323	14	39.2	20300	47.2	757	FPC
		75%		272,000	306		29.4	14540	33.8	620	FPC
		half		181,000	300		19.6	9527	22.2	481	FPC
	#4	full	200	181,000	323	14	19.6	10150	23.6	500	FPC
		75%		136,000	306		14.7	7270	16.9	409	FPC
		half		91,000	300		9.8	4764	11.1	317	FPC
	#5&6	full	200	505,000	274	12	74.5	24508	57.0	812	FPC
		75%		379,000	255		55.9	17166	39.9	685	FPC
		half		253,000	236		37.3	10594	24.6	513	FPC
	#7&8	full	200	1,291,000	230	17	94.8	52603	122.3	1047	FPC
		75%		968,000	204		71.1	34560	80.4	910	FPC
		half		646,000	180		47.4	19794	46.0	746	FPC
Long Beach	#1&2	full	247.5	500,000	300	16	42	26665	62.0	962	FPC
		75%		375,000	250		32	17132	39.8	745	FPC
		half		250,000	220		20	9373	21.8	519	FPC
	#3	full	247.5	250,000	290	16	21	12937	30.1	629	FPC
		75%		187,000	240		16	8220	19.1	479	FPC
		half		125,000	210		10	4451	10.4	332	FPC
	#4	full	247.5	520,000	320	16	44	29529	68.7	995	FPC
		75%		390,000	260		33	18360	42.7	776	FPC
		half		260,000	220		21	9841	22.9	534	FPC
Los Alamitos	#1&2	full	200	469,000	274	12	69.1	22731	52.9	791	FPC
		75%		370,000	265		54.5	17372	40.4	690	FPC
		half		262,000	258		38.6	11990	27.9	552	FPC
	#3&4	full	200	819,000	258	14	82.6	34923	81.2	913	FPC
		75%		655,000	252		66.1	27309	63.5	841	FPC
		half		491,000	227		49.6	18407	42.8	714	FPC
	#5&6	full	201.5	1,157,000	255	17	84.9	52325	121.7	1050	FPC
		75%		983,350	250		72.2	43636	101.5	989	FPC
		half		809,820	179		65.9	27325	63.5	846	FPC
Scattergood	#1&2 (common stack)	full	300	543,000	308	20	59.5	60393	140.5	1436	FPC
		75%		430,000	282		48.2	45233	105.2	1304	FPC
		half		300,000	253		30.4	25732	59.8	1081	FPC
	#3	full	300	1,200,000	278	23.5	60	76722	178.4	1556	FPC
		75%		970,000	253		49	57263	133.2	1411	FPC
		half		650,000	230		31	32870	76.4	1173	FPC
Valley	#1&2	full	250	362,000	350	12.5	52	22919	53.3	921	FPC
		75%		295,000	314		42.4	17091	39.7	747	FPC
		half		190,000	220		27.3	7809	18.2	467	FPC
	#3&4	full	250	532,000	314	15	52.5	30474	70.9	1013	FPC
		75%		382,000	285		37.6	20041	46.6	821	FPC
		half		266,000	265		26.2	13049	30.3	635	FPC

Table A4.1 (Continued)

Generating Station	Unit Number	Plant Load	Physical Stack Height H_s (ft)	Stack Volumetric Flow Rate (SCFM)	Stack Exhaust Temperature T_s (°F)	Stack Diameter (ft)	Exhuast Gas Velocity V_s (FPS)	Briggs F (ft^4/sec^3)	Heat Flux Q_H (10^5 cal/sec)	Plume Rise ΔH (ft)	Data Source
Harbor	#1&2	full	247	243,200	338	8.7	77.5	16090	37.4	717	FPC
		75%		172,500	302		54.8	10347	24.1	550	FPC
		half		116,400	284		38	6792	15.8	427	FPC
	#3,4,5	full	247	365,000	339	9.7	89	23024	53.5	915	FPC
		75%		282,000	309		67	16041	37.3	715	FPC
		half		209,000	281		51	11221	26.1	577	FPC
Haynes	#1&2	full	240	585,000	260	13.2	75.5	28590	66.5	965	FPC
		75%		445,000	236		57.5	19761	46.0	801	FPC
		half		321,000	212		41.4	12675	29.5	614	FPC
	#3a,b #4a,b	full	240	302,500	263	10.5	62	15021	34.9	680	FPC
		75%		232,500	252		47.8	11108	25.8	567	FPC
		half		162,500	235		33.4	7231	16.8	438	FPC
	#5&6	full	240	777,000	251	18.5	50.1	36001	83.7	1042	FPC
		75%		510,000	234		32.8	21947	51.0	883	FPC
		half		412,000	209		27.6	16334	38.0	715	FPC
Burbank	Magnolia #1,2,3	full	66	34,500(4)	375	5.5(5)	24	2160	5.0	127	FPC
		75%		25,500(4)	340		18(4)	1501	3.5	102	FPC
		half		17,000(4)	310		12(4)	926	2.2	76	FPC
	Magnolia #4	full	150	164,856(4)	315	10.0(5)	35	9054	21.0	416	FPC
		75%		123,637(4)	300		26(4)	6448	15.0	339	FPC
		half		82,425(4)	290		17(4)	4173	9.7	261	FPC
	Olive #1	full	109	120,600(4)	360	8	40	7383	17.2	324	FPC
		75%		90,450(4)	330		30(4)	5164	12.0	261	FPC
		half		60,300(4)	290		20(4)	3080	7.2	192	FPC
	Olive #2	full	109	120,600(4)	245	8	40	5246	12.2	264	FPC
		75%		90,450(4)	240		30(4)	3853	9.0	219	FPC
		half		60,300(4)	235		20(4)	2514	5.8	170	FPC
Glendale	#1a,b 2	full	60	85,000(4)	300(4)	6	40(5)	3571	8.3	165	FPC
		75%		62,000(4)	275(4)		36(5)	2971	6.9	148	FPC
		half		45,000(4)	250(4)		27(5)	2033	4.7	118	FPC
	#3	full	80	92,000(4)	300(4)	6	54(5)	4821	11.2	222	FPC
		75%		70,000(4)	275(4)		41(5)	3383	7.9	179	FPC
		half		48,000(4)	250(4)		28(5)	2108	4.9	135	FPC
	#4	full	100	160,000(4)	300(4)	8	53(5)	8412	19.6	338	FPC
		75%		122,000(4)	250(4)		40(5)	5354	12.5	258	FPC
		half		88,000(4)	220(4)		29(5)	3398	7.9	196	FPC
	#5	full	100	160,000(4)	180(4)	8	53(5)	4901	11.4	245	FPC
		75%		122,000(4)	160(4)		40(5)	3158	7.3	188	FPC
		half		88,000(4)	150(4)		29(5)	2084	4.8	146	FPC
Pasadena	Broadway #1&2	full	120	190,000	371	10	40	11806	27.5	446	FPC
		75%		137,000	320		29	7602	17.7	342	FPC
		half		93,000	276		20	4600	10.7	253	FPC
	Broadway #3	full	140	174,000	211	5	74	3234	7.5	218	FPC
		75%		134,000	187		57	2160	5.0	171	FPC
		half		92,000	132		39	891	2.1	101	FPC
	Glenarm #14,15	full	86	78,660	370	6	24	2545	5.9	155	FPC
		75%		57,000	352		17	1734	4.0	123	FPC
		half		39,520	309		12	1099	2.6	94	FPC
	Glenarm #16,17	full	81	103,500	354	5.5	25	2152	5.0	137	FPC
		75%		75,000	310		18	1389	3.2	106	FPC
		half		52,000	295		12	887	2.1	81	FPC
Huntington Beach	#1	full	203	1,203,000	275	17.3	85.6	58726	136.6	1097	FPC
		75%		917,000	255		65.3	41679	96.9	978	FPC
		half		621,000	230		44.2	25399	59.1	829	FPC
	#2	full	203	1,207,000	250	17.3	85.9	53764	125.0	1065	FPC
		75%		919,000	230		65.5	37639	87.5	946	FPC
		half		622,000	210		44.3	23050	53.6	803	FPC

Table A4.1 (Continued)

Generating Station	Unit Number	Plant Load	Physical Stack Height H_s (ft)	Stack Volumetric Flow Rate (SCFM)	Stack Exhaust Temperature T_s (°F)	Stack Diameter (ft)	Exhaust Gas Velocity V_s (FPS)	Briggs F (ft^4/sec^3)	Heat Flux Q_H (10^5 cal/sec)	Plume Rise ΔH (ft)	Data Source
Mandalay	#1	full	200	1,081,482	229(4)	17.3	77	44044	102.4	987	FPC
		75%		840,426	216(4)		60	32217	74.5	889	FPC
		half		599,370	202(4)		43	21400	49.8	776	FPC
Etiwanda	#1&2	full	176	384,000	265	12	57	18169	42.3	673	FPC
		75%		292,000	245		43	12690	29.5	543	FPC
		half		196,000	225		29	7833	18.2	406	FPC
	#3&4	full	199	861,000	260	14	93	39616	92.1	949	FPC
		75%		650,000	235		70	26943	62.7	835	FPC
		half		440,000	210		48	16356	38.0	664	FPC
Highgrove	#1&2	full	70	108,000	334	8.2	34	6210	14.4	244	FPC
		75%		83,000	318		26	4559	10.6	203	FPC
		half		56,000	302		17	2851	6.6	153	FPC
	#3&4	full	99	150,000	312	10	32	8211	19.1	332	FPC
		75%		115,000	296		24	5882	13.7	272	FPC
		half		78,000	238		17	3382	7.9	195	FPC
San Bernardino	#1	full	130	10,810	285	10	2.3	545	1.3	73	FPC
		75%		8,730	263		1.9	418	1.0	62	FPC
		half		5,440	240		1.2	241	0.6	45	FPC
	#2	full	130	10,510	285	10	2.2	521	1.2	71	FPC
		75%		7,890	263		1.7	374	0.9	58	FPC
		half		5,250	240		1.1	221	0.5	42	FPC
Ormond Bench	#1&2 (gas)	full	237	2,080,000	251	22	91	92474	215.1	1415	FPC
		75%		1,688,000	225		74	67177	156.2	1272	FPC
		half		1,130,000	203		50	40472	94.1	1074	FPC
	#1&2 (oil)	full	237	1,728,000	255	22	76	78455	182.4	1339	FPC
		75%		1,222,000	229		54	49950	116.2	1152	FPC
		half		864,000	206		38	31283	72.8	986	FPC
Large Interruptible Gas Customers											
UCLA boilers (5 stacks)			45	30,000	500	4.5	31	4372	10.2	166	c
UCLA boiler (1 stack)			45	40,000	500	5	34	5920	13.8	199	c

Table A4.1 (Continued)

Source Type	Physical Stack Height H_s (ft)	Stack Volumetric Flow Rate (SCFM)	Stack Exhaust Temperature T_s (°F)	Stack Diameter (ft)	Exhaust Gas Velocity V_s (FPS)	Briggs F (ft^4/sec^3)	Heat Flux Q_H (10^5 cal/sec)	Plume Rise ΔH (ft)	Data Source
Chemical Plants									
Sulfur Recovery Plants									
ARCO	200	25,200	1140	5.5	54	8785	20.43	458	KVB
Champlin	50	3,720	1130	2.8	30	1261	2.93	82	KVB
Douglas	60	2,843	850	2.2	29	673	1.56	61	KVB
Gulf	100	36,738	147	4	36	627	1.46	71	KVB
Mobil	150	35,700	1100	6.5	70	15707	36.5	578	KVB
Standard (3 stacks)	150	8,100	120	2.4	32	141	0.33	34	KVB
Texaco	160	9,912	190	1.6	100	396	0.92	65	KVB
Union (2 stacks)	171	-	120	5.0	20	383	0.89	66	a
Powerine	100			(exhausts through FCC unit stack; see below)				215	
Sulfuric Acid Plants									
Standard Oil	150	16,400	160	4	26	513	1.19	74	KVB
Collier	80	26,736	85	3.1	60	174	.41	30	KVB
Stauffer #3	200	18,524	130	3.4	37	380	.88	70	KVB
Petroleum Refining and Production									
Fluid Catalytic Crackers									
ARCO (each of two)	89	108,000	430	6	100	11830	27.5	396	KVB
Gulf	101	51,441	450	5	73	6187	14.4	282	KVB
Mobil (each of two)	100	110,600	600	9	59	19317	44.9	557	KVB
Powerine	100	32,410	440	7.9	19	3958	9.2	215	KVB
Shell	100	143,651	520	10.3	57	22490	52.3	497	KVB
Standard	150	195,500	730	13.5	51	41590	96.7	794	KVB
Texaco (each of two)	181	136,500	485	9.1	64	18871	43.9	696	KVB
Union	140	91,500	1640	10.3	72	45848	106.6	788	KVB
	140	110,200	750	9.5	59	24136	56.1	637	KVB
Misc. Petroleum Industry Equipment									
ARCO odor incinerator (FLARE)	130	16,200	1580	5.5	45	8090	18.8	367	KVB
Misc. Stationary Sources									
Petroleum Coke Kilns									
Great Lakes #2,3,4	150	13,700	1400	13.5	55	57581	133.9	1261	KVB
Glass Furnaces									
Anchor Hocking #3	75 (2)	15,054	850	6	22	3800	8.8	187	KVB
Ball #1	60	26,877	680	6.5	28	5110	11.9	204	KVB
Brockway	58	27,800	630	5.2	46	5163	12.0	203	KVB
Glass Containers 1	72	13,000	160	3.1	37	439	1.0	50	KVB
Glass Containers 2	72	23,000	540	4.2	52	3490	8.1	175	KVB
Latchford A	120	12,100	720	4.0	37	2631	6.1	181	KVB
Latchford B	80	5,240	560	4.0	13	808	1.9	76	KVB
Latchford C	100	11,443	720	3.8	34	2182	5.0	151	KVB
Latchford D	68	10,500	800	3.1	54	2424	5.6	137	KVB
Owens Illinois (Vernon) 23A	82	15,000	740	3.5	61	3366	7.8	180	KVB
Owens Illinois (Vernon) 23B	94	16,363	760	4.5	38	3510	8.2	195	KVB
Owens Illinois (Vernon) 23C	69	7,000	680	4.50	17	1487	3.5	103	KVB
Owens Illinois (Vernon) 23D	58	8,000	652	3.46	32	1619	3.8	101	KVB
Reichhold	80	3,860	1420	2.42	52	1757	4.0	121	KVB
Thatcher #1	40	14,000	900	4.21	43	3746	8.7	144	KVB
Thatcher #2	80	15,000	590	3.42	54	2529	5.9	150	KVB
Thatcher #3	70	15,000	600	3.42	54	2553	5.9	143	KVB
Metals									
(a) Primary Metals (steel mill)									
Kaiser Fontana									
Sinter plant (2)	300	129,000	240	7.5	80	9031	21.0	548	KVB
Coke ovens A-E (5)	225	58,800	450	16	8.5	7376	17.2	432	KVB
Coke ovens F-G (1)	250	45,000	450	16	6.5	5641	13.1	384	KVB
Open hearth 1-9 (8)	175	40,600	500	4.5	80	5881	13.7	341	KVB

Table A4.1 (Continued)

	Physical Stack Height H_s (ft)	Stack Volumetric Flow Rate (SCFM)	Stack Exhaust Temperature T_s (°F)	Stack Diameter (ft)	Exhaust Gas Velocity V_s (FPS)	Briggs F (ft^4/sec^3)	Heat Flux Q_H (10^5 cal/sec)	Plume Rise ΔH (ft)	Data Source
(b) Secondary Metals (lead furnaces)									
RSR-Quemetco									
Reverb	60	11,700	510	note(3)	note(3)	-	-	-	KVB
Cupola	60	6,410	240	note(3)	note(3)	-	-	-	KVB
NL Industries									
Cupola	50								
Cupola	50								
Mineral Products									
Crestlite (aggregate kiln)	25	46,000	130	8	15	3865	9.0	122	KVB
Sewage Treatment Plant Digesters									
Hyperion Sewage Treatment Plant (7 stacks)	35	6,700	600	1	142	1013	2.3	62	b

Notes

Key to Data Sources

(1) KVB: Hunter, 1975
FPC: Thomas, 1976
a: Jones, 1976
b: Rojas, 1976
c: UCLA, 1976

(2) assumed
(3) baghouse
(4) estimated by utility
(5) calculated
- not available

A4.4 Generalization of Plume Rise Calculations

The plume rise calculations given in Table A4.1 provide a basis for visualizing the relative buoyancy of plumes from various sources for which stack data were available. Most major SO_x sources in the basin are represented in that table. However, there are literally thousands of emission sources in the Los Angeles basin for which stack data are unavailable. In order to progress with air quality modeling calculations, some assumptions must be made which will assign a physical stack height and plume rise to each source in the airshed.

The approach taken here will be to use the data from sources for which the stack parameters are known to assign a typical stack height and plume rise behavior to all members of a single source class. Since the source classes defined in Appendix A2 to this study are based on similarity of equipment type, the use of source class averaged plume rise behavior should be a reasonable and practical approach.

Physical stack height and plume rise above the physical stack is summarized for each source class of our emission inventory in Table A4.2. Values given are for the same set of reference atmospheric conditions as in Table A4.1. The range of values apparent for sources analyzed in Table A4.1 is stated, along with a choice of typical values to represent the source class as a whole. Typical values given in Table A4.2 are usually the arithmetic mean of the stack heights and plume rises calculated for members of each source class in Table A4.1. In those cases where no data are available in Table A4.1 upon which to

TABLE A4.2

Stack Height and Plume Rise for Individual Source Classes

(estimated at reference conditions: neutral stability; ambient temperature 64.4°F; wind speed 6.2 mph)

	Number of Cases Examined in Table A4.1	Notes	Range of Physical Stack Heights (ft)	Typical Physical Stack Height Adopted H_s (ft)	Range of Plume Rise Calculated at Reference Conditions (ft)	Typical Plume Rise Adopted at Reference Conditions ΔH (ft)	Effective Stack Height Adopted at Reference Conditions $H_s + \Delta H$ (ft)
Stationary Sources							
Fuel Combustion							
Electric Utilities at 75% of Full Load							
Large Generating Units (H > 150 ft)	28		176–300	225	409–1411	822	1047
Small Generating Units (H ≤ 150 ft)	16		60–150	102	58–342	189	291
Refinery Fuel Burning	—	(b)		100		180	280
Other Interruptible Gas Customers (Large)	2		45	45	166–199	182	227
Firm Gas Customers	—	(c)		12		24	36
Chemical Plants							
Sulfur Recovery Plants	9		50–200	127	61–578	181	308
Sulfuric Acid Plants	3		80–200	143	30–74	58	201
Other Chemicals	—	(c)		35		70	105
Petroleum Refining and Production							
Fluid Catalytic Crackers	9		89–181	122	282–794	540	662
Sour Water Strippers	—	(d)		130		367	497
Delayed Cokers	—	(d)		130		367	497
Miscellaneous Refinery Processes	—	(d)		130		367	497
Oil Field Production	—	(c)		20		72	92
Miscellaneous Stationary Sources							
Petroleum Coke Calcining Kilns	1		150	150	1261	1261	1411
Glass Furnaces	17		40–120	75	50–204	147	222
Secondary Metals Industries (On-Grid)	4	(a)	50–60	55		110	165
Sewage Treatment Plant Digesters	1		35	35	62	62	97
Other Industrial Processes	—	(c)		35		70	105
Permitted Incinerators	—	(c)		35		70	105
Primary Metals Industries (Off-Grid Steel Mill)	4		175–300	238	341–548	426	664
Mineral Products Industries (Off-Grid)	1		25	25	122	122	147
Mobile Sources							
Autos and Light Duty Trucks	—	(b)		1		2	3
Heavy Duty Vehicles	—	(b)		12		24	36
Airport Operations	—	(b)		20		40	60
Shipping Operations	—	(b)		90		180	270
Railroad Operations	—	(b)		18		36	54

Notes: (a) Physical stack height known; plume rise assumed.

(b) Physical stack height estimated by observation of members of that source class; plume rise assumed.

(c) Physical stack height and plume rise assumed.

(d) Based on data for one refinery flare given in Table A4.1.

base a stack parameter characterization for a given source class, an assumed value has been entered in Table A4.2 based on a qualitative impression of the size of the sources involved.

The plume rise values given in Tables A4.1 and A4.2 are for a single set of reference atmospheric conditions. An air quality modeling exercise which attempted to treat every source in detail could, on the basis of stack parameters given in Table A4.1, recompute effective stack height at each time of day for each source. Changes in power plant load with time of day could be factored into the plume rise calculations. Adjustments for changing wind speed and atmospheric temperature could be made. If greater information were available on atmospheric temperature structure, more complex plume rise formulas could be adopted which incorporate corrections for changing atmospheric stability. However, for the long time period which we intend to simulate (three years), and the large number of sources involved (several thousand), inclusion of such great detail is not practical within a small computing budget. Instead, the following approach seems reasonable.

The plume rise formulas of equations A4.3 and A4.4 are strict inverse functions of ambient wind speed, U, and only weakly depend on changes in buoyancy flux, F. Fortunately, ambient wind speed data are readily available at each hour of the day. Therefore, a practical approach to dynamically allocating source effective stack height would seem to be as follows:

$$H(t,i) = H_s(i) + \frac{U_{ref}}{U(t)} \cdot \Delta H_{ref}(i) \qquad \text{(A4.5)}$$

The effective source height, $H(t,i)$, at time t for source class i will be taken as that source's typical physical stack height, $H_s(i)$, plus that source's plume rise at reference conditions scaled by the ratio of reference wind speed to the actual wind speed at time t.

REFERENCES FOR APPENDIX A4

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