APPENDIX B

Population Data, Normalized Growth Factors, and Normalized Total Production Indices

SECTION 3 - ASSESSING AIR POLLUTANT EMISSIONS

List of Tables

Appendix B

(continued)

SECTION 3 - ASSESSING AIR POLLUTANT EMISSIONS

List of Tables

Appendix B

(continued)

From Dept. of Finance
Report 75 E-2,
October 28, 1975

TABLE 2. TOTAL POPULATION OF CALIFORNIA COUNTIES, JULY 1, 1970 TO JULY 1, 1975

County	July 1, 1970	July 1, 1971	July 1, 1972	July 1, 1973	July 1, 1974	July 1, 1975
Alameda	1,072,700	1,088,100	1,094,400	1,089,100	1,087,300	1,086,600
Alpine[1]	500	500	600	700	800	800
Amador[1]	11,900	12,800	12,800	13,800	14,700	15,100
Butte	102,500	104,500	108,900	111,700	114,100	116,900
Calaveras	13,700	13,900	14,400	14,900	15,500	16,100
Colusa	12,400	12,400	12,300	12,400	12,600	12,800
Contra Costa[1]	557,400	562,900	567,600	573,600	578,300	584,900
Del Norte	14,600	15,000	15,100	15,200	15,300	15,600
El Dorado[1]	44,100	46,400	49,700	52,500	55,700	59,200
Fresno[1]	413,800	422,100	427,900	432,100	439,500	447,100
Glenn	17,500	17,600	17,900	18,300	18,600	18,900
Humboldt	100,100	100,900	102,200	103,800	104,900	104,400
Imperial[1]	74,500	76,300	77,100	79,600	82,100	84,100
Inyo[1]	15,600	16,300	16,400	16,800	16,600	16,900
Kern	330,700	335,500	336,300	337,300	337,900	342,800
Kings[1]	66,700	67,000	68,400	69,200	68,000	68,200
Lake	19,800	21,000	22,300	23,300	24,200	25,500
Lassen	16,900	17,000	17,500	17,500	17,700	18,700
Los Angeles	7,047,100	7,071,200	6,988,900	6,966,200	6,955,500	6,970,000
Madera	41,600	42,600	43,200	43,700	45,100	46,200
Marin	207,000	209,200	211,500	214,100	211,500	213,800
Mariposa	6,100	6,500	6,900	7,500	7,900	8,200
Medocino	51,300	52,300	52,900	55,300	56,900	57,600
Merced	105,000	107,900	111,500	111,700	115,100	117,000
Modoc	7,500	7,700	7,900	7,900	8,200	8,100
Mono[1]	4,100	4,800	5,800	6,600	6,800	7,300
Monterey	247,700	255,000	253,300	255,400	261,600	266,400
Napa	79,400	80,500	82,800	84,400	86,900	88,600
Nevada[1]	26,500	27,100	28,700	30,400	31,900	33,900
Orange	1,431,600	1,471,000	1,526,700	1,592,300	1,653,500	1,694,900
Placer[1]	78,000	79,400	81,400	84,800	87,900	90,000
Plumas	11,700	12,000	12,500	13,200	13,600	14,000
Riverside	461,400	474,000	488,500	501,600	514,200	526,600
Sacramento[1]	636,600	645,700	661,000	670,300	682,600	687,400
San Benito	18,300	18,500	18,700	18,900	19,200	19,700
San Bernardino[1]	685,200	689,500	690,500	691,400	694,600	698,300
San Diego[1]	1,366,900	1,388,400	1,419,800	1,472,200	1,527,700	1,571,700[2]
San Francisco	712,100	709,000	695,800	692,800	679,200	667,700
San Joaquin	292,000	293,600	296,500	296,800	298,500	302,000
San Luis Obispo	106,400	108,500	112,300	117,200	122,000	127,800
San Mateo	557,200	559,900	560,900	565,500	568,900	571,100
Santa Barbara	265,700	268,700	272,400	275,000	279,200	281,300
Santa Clara	1,072,400	1,093,600	1,122,000	1,146,900	1,169,400	1,190,000
Santa Cruz	124,500	128,600	137,300	141,200	145,000	148,400
Shasta	78,000	79,200	80,600	83,900	86,200	87,700
Sierra	2,400	2,400	2,500	2,500	2,500	2,600
Siskiyou	33,200	33,500	34,000	34,600	34,800	34,900
Solano	172,400	178,100	180,900	179,700	181,200	184,000
Sonoma	206,400	210,900	221,400	231,400	238,800	242,800
Stanislaus	195,700	198,900	199,800	204,600	207,800	212,400
Sutter[1]	42,100	42,800	43,200	44,300	45,200	46,000
Tehama	29,600	29,900	30,100	30,700	31,600	31,800
Trinity	7,600	8,000	8,500	8,900	9,300	9,600
Tulare	189,100	194,000	196,700	199,600	202,600	207,700
Tuolumne[1]	22,300	23,000	23,700	24,800	25,400	26,000
Ventura[1]	381,400	389,800	404,200	415,200	427,000	438,200
Yolo[1]	92,700	93,400	96,300	97,200	98,600	101,700
Yuba[1]	44,400	45,700	45,600	44,500	44,300	45,000
California	20,026,000	20,265,000	20,419,000	20,647,000	20,882,000	21,113,000[2]

[1] Estimates have been adjusted to reflect the results of a special census.

[2] Numbers do not include 17,777 refugees living at Camp Pendleton, San Diego County, on July 1, 1975. This temporary population is expected to be relocated by the end of the year.

TABLE B.3.2

TOTAL POPULATION OF CALIFORNIA COUNTIES, PROJECTED 1980-1995
Series D-100

County	1980 Series D-100	1985 Series D-100	1990 Series D-100	1995 Series D-100
Alameda- - - - - -	1,143,800	1,194,800	1,251,200	1,305,500
Alpine - - - - - -	700	800	900	1,200
Amador - - - - - -	18,100	20,400	22,400	24,000
Butte- - - - - - -	129,400	143,000	156,800	170,000
Calaveras- - - - -	18,800	21,100	23,100	24,700
Colusa - - - - - -	12,500	12,900	13,500	14,300
Contra Costa - - -	652,800	715,200	780,900	844,700
Del Norte- - - - -	16,400	17,700	19,100	20,600
El Dorado- - - - -	64,200	76,100	87,700	96,100
Fresno - - - - - -	477,200	513,500	550,900	586,400
Glenn- - - - - - -	19,100	20,300	21,300	22,000
Humboldt - - - - -	108,300	114,400	121,100	127,600
Imperial - - - - -	86,300	94,100	101,800	108,800
Inyo - - - - - - -	19,900	22,400	24,700	26,700
Kern - - - - - - -	365,200	386,000	406,300	424,400
Kings- - - - - - -	69,500	74,400	80,000	85,300
Lake - - - - - - -	28,200	31,600	34,100	36,500
Lassen - - - - - -	20,300	22,000	23,200	24,100
Los Angeles- - - -	6,963,200	7,122,900	7,346,800	7,591,600
Madera - - - - - -	49,600	54,000	58,400	62,300
Marin- - - - - - -	233,200	249,200	265,400	280,200
Mariposa - - - - -	9,300	10,700	12,000	13,200
Mendocino- - - - -	65,100	73,000	79,500	85,500
Merced - - - - - -	126,300	138,900	151,400	162,500
Modoc- - - - - - -	8,100	8,400	8,700	9,000
Mono - - - - - - -	10,500	13,100	14,900	16,600
Monterey - - - - -	299,000	329,800	362,100	396,500
Napa - - - - - - -	101,600	113,800	126,600	139,200
Nevada - - - - - -	37,200	42,100	46,700	51,000
Orange - - - - - -	1,970,500	2,233,900	2,465,300	2,647,500
Placer - - - - - -	109,500	125,000	137,600	148,900
Plumas - - - - - -	15,400	17,100	18,400	19,600
Riverside- - - - -	596,900	676,700	755,500	825,800
Sacramento - - - -	753,600	820,400	884,900	944,200
San Benito - - - -	21,000	23,000	25,100	27,100
San Bernardino - -	765,100	836,400	913,800	995,100
San Diego- - - - -	1,801,300	2,022,400	2,242,300	2,449,500
San Francisco- - -	661,100	653,500	653,700	655,100
San Joaquin- - - -	330,200	352,500	375,000	396,600
San Luis Obispo- -	147,500	164,300	181,000	197,300
San Mateo- - - - -	593,100	616,300	637,500	653,800
Santa Barbara- - -	305,800	333,700	361,900	388,300
Santa Clara- - - -	1,342,800	1,487,800	1,614,300	1,721,700
Santa Cruz - - - -	177,200	203,400	227,800	252,200
Shasta - - - - - -	98,200	108,100	117,400	125,500
Sierra - - - - - -	2,700	2,800	3,000	3,200
Siskiyou - - - - -	38,200	41,100	43,300	45,000
Solano - - - - - -	198,400	220,800	249,400	283,600
Sonoma - - - - - -	300,500	349,300	395,400	438,700
Stanislaus - - - -	235,400	256,700	278,300	296,500
Sutter - - - - - -	49,900	54,700	59,500	63,700
Tehama - - - - - -	34,500	37,100	39,400	41,000
Trinity- - - - - -	10,500	11,900	12,900	13,400
Tulare - - - - - -	224,300	245,500	267,300	288,400
Tuolumne - - - - -	32,200	36,100	39,500	42,200
Ventura- - - - - -	523,300	612,100	704,400	791,000
Yolo - - - - - - -	118,800	133,000	147,300	161,100
Yuba - - - - - - -	47,300	50,800	55,300	59,500
The State- - - - -	22,659,000	24,363,000	26,098,000	27,726,000

From California Department of Finance Report 74 P-2, June 1974

TABLE B.3.3

TOTAL POPULATION OF CALIFORNIA COUNTIES, PROJECTED 1980-1995

SERIES E-0

County	1980 Series E-0	1985 Series E-0	1990 Series E-0	1995 Series E-0
Alameda	1,121,500	1,148,100	1,171,700	1,188,000
Alpine	600	600	600	600
Amador	17,200	18,100	18,600	18,900
Butte	124,900	131,100	136,700	141,500
Calaveras	18,000	18,700	19,200	19,500
Colusa	12,300	12,400	12,600	12,700
Contra Costa	639,400	681,400	721,600	756,600
Del Norte	15,900	16,700	17,400	17,800
El Dorado	60,800	66,300	70,800	74,600
Fresno	466,800	491,600	515,900	537,600
Glenn	18,700	19,200	19,400	19,400
Humboldt	105,700	109,100	112,400	115,100
Imperial	84,400	90,000	95,500	100,100
Inyo	19,400	20,900	21,900	22,500
Kern	357,900	372,600	385,500	394,600
Kings	67,700	70,500	73,200	75,600
Lake	27,000	28,400	29,100	29,700
Lassen	19,800	20,500	20,700	20,700
Los Angeles	6,674,500	6,574,700	6,571,100	6,569,100
Madera	47,800	50,400	52,600	54,400
Marin	228,900	239,100	248,600	256,600
Mariposa	8,900	9,100	8,900	8,500
Mendocino	62,900	66,600	69,000	70,800
Merced	123,000	130,900	137,900	143,800
Modoc	8,000	8,100	8,100	8,100
Mono	9,700	10,500	10,600	10,600
Monterey	290,900	309,400	328,600	346,900
Napa	98,300	103,300	107,500	111,200
Nevada	35,700	36,700	35,900	34,900
Orange	1,900,500	2,063,600	2,194,900	2,299,500
Placer	104,400	110,300	115,100	118,700
Plumas	14,900	15,600	15,700	15,600
Riverside	580,200	632,100	681,300	725,500
Sacramento	736,000	777,500	816,600	849,900
San Benito	20,500	21,600	22,600	23,600
San Bernardino	741,400	783,900	825,900	862,800
San Diego	1,750,600	1,905,800	2,044,400	2,159,500
San Francisco	651,400	635,700	621,900	610,000
San Joaquin	322,000	335,700	348,300	359,500
San Luis Obispo	141,300	149,900	156,600	162,800
San Mateo	583,700	597,900	609,400	615,900
Santa Barbara	298,900	313,600	326,500	337,400
Santa Clara	1,309,200	1,399,200	1,482,400	1,547,200
Santa Cruz	170,500	181,000	187,200	193,000
Shasta	95,000	100,000	103,500	105,800
Sierra	2,600	2,600	2,600	2,600
Siskiyou	37,300	38,800	39,500	39,900
Solano	192,900	205,900	219,200	232,000
Sonoma	287,200	313,600	335,000	355,200
Stanislaus	226,400	237,700	248,100	257,100
Sutter	48,200	50,600	52,300	53,600
Tehama	33,700	34,700	34,900	34,900
Trinity	10,100	10,600	10,700	10,600
Tulare	218,600	232,400	245,600	257,400
Tuolumne	30,400	31,700	31,600	31,300
Ventura	497,700	550,200	601,600	643,300
Yolo	114,500	121,600	128,000	133,700
Yuba	46,300	48,200	50,000	51,300
The State	21,933,000	22,757,000	23,573,000	24,250,000

From California Department of Finance Report 74 P-2, 1974

TABLE B.3.4

EXAMPLE CALCULATION FOR POPULATION GROWTH FACTORS

The procedure for projecting emission from certain source categories requires population growth factors for future years. These growth factors are calculated using the values given for base year populations (Table B.3.1 or other references) and future year population projections. As an example, the population growth factors for Orange County are developed below using a base year of 1973 and Series D-100 population projections.

SERIES D-100 POPULATION GROWTH FACTORS

Orange County

Year	Future Years						
	1973	1974	1975	1980	1985	1990	1995
Population	1,592,300[a]	1,653,500[a]	1,694,900[a]	1,970,500[b]	2,233,900[b]	2,465,300[b]	2,647,500[b]
Growth Factors	1.000[c]	1.038[c]	1.064[c]	1.238[c]	1.402[c]	1.548[c]	1.663[c]

[a] From Table B.3.1

[b] From Table B.3.2

[c] 19XY Growth Factor = (19XY Population/1973 Population)

TABLE B.3.5

FRESNO COUNTY - Fresno SMSA

SERIES 'C' GROWTH INDICES

(NORMALIZED TO 1973)

	1970	1971	1972	1973	1974	1975	1980	1985	1990	1995	2000
AGRICULTURE	99	99	100	100	100	101	101	105	109	118	128
FORESTRY & FISHERIES	100	100	100	100	100	100	100	100	100	100	100
MINING											
METAL	100	100	100	100	100	100	100	100	100	100	100
CRUDE PETROLEUM & NATURAL	121	114	107	100	94	88	90	92	97	101	105
NONMETALLIC, EXCEPT FUELS	94	96	98	100	102	104	131	149	167	199	238
CONTRACT CONSTRUCTION	92	95	97	100	103	105	120	143	171	210	257
MANUFACTURING	84	89	94	100	106	113	139	170	206	254	313
FOOD & KINDRED PRODUCTS	86	90	95	100	105	111	131	152	176	205	239
TEXTILE MILL PRODUCTS	95	97	98	100	102	104	126	148	173	205	243
APPAREL & OTHER FABRIC PR	83	88	94	100	106	113	145	180	223	277	344
LUMBER PRODUCTS & FURNITU	83	88	94	100	106	113	136	162	192	229	274
PAPER & ALLIED PRODUCTS	80	86	93	100	108	116	157	205	267	350	458
PRINTING & PUBLISHING	93	95	97	100	103	105	124	147	175	213	260
CHEMICALS & ALLIED PRODUC	70	79	89	100	113	127	181	243	325	438	591
PETROLEUM REFINING	63	74	86	100	117	136	182	222	276	340	419
PRIMARY METALS	86	90	95	100	105	111	130	149	169	193	222
FABRICATED METALS & ORDNA	89	92	96	100	104	108	142	184	236	306	395
MACHINERY, EXCLUDING ELEC	81	87	93	100	107	116	147	183	228	287	361
ELECTRICAL MACHINERY & SU	96	97	99	100	101	103	112	148	196	254	329
MOTOR VEHICLES & EQUIPMEN	71	80	89	100	112	125	172	208	252	309	380
TRANS. EQUIP., EXCL. MTR.	135	122	110	100	91	82	53	59	65	71	77
OTHER MANUFACTURING	90	93	97	100	104	107	132	163	201	249	309
POPULATION (SERIES C-150)	96	98	99	100	102	103	112	122	133	145	157

SERIES 'E' GROWTH INDICES

(NORMALIZED TO 1973)

	1970	1971	1972	1973	1974	1975	1980	1985	1990	1995	2000
AGRICULTURE	96	97	99	100	101	103	110	117	125	132	140
FORESTRY & FISHERIES	100	100	100	100	100	100	100	100	100	100	100
MINING											
METAL	100	100	100	100	100	100	100	100	100	100	100
CRUDE PETROLEUM & NATURAL	100	100	100	100	100	100	101	101	102	102	103
NONMETALLIC, EXCEPT FUELS	92	94	97	100	103	106	121	137	154	171	190
CONTRACT CONSTRUCTION	90	93	96	100	104	107	127	149	173	200	229
MANUFACTURING	89	93	96	100	104	108	129	152	178	207	239
FOOD & KINDRED PRODUCTS	93	95	98	100	102	105	117	130	144	158	173
TEXTILE MILL PRODUCTS	88	92	96	100	104	109	132	158	188	222	259
APPAREL & OTHER FABRIC PR	85	90	95	100	105	111	141	178	220	270	328
LUMBER PRODUCTS & FURNITU	88	92	96	100	104	108	131	157	187	219	255
PAPER & ALLIED PRODUCTS	86	90	95	100	105	110	140	174	214	261	314
PRINTING & PUBLISHING	90	93	97	100	104	107	126	148	171	196	224
CHEMICALS & ALLIED PRODUC	87	91	96	100	105	109	135	165	200	239	283
PETROLEUM REFINING	92	95	97	100	103	105	119	133	149	165	181
PRIMARY METALS	94	96	98	100	102	104	114	124	134	144	155
FABRICATED METALS & ORDNA	86	90	95	100	105	110	135	174	214	260	314
MACHINERY, EXCLUDING ELEC	89	93	96	100	104	107	128	150	175	201	231
ELECTRICAL MACHINERY & SU	82	88	94	100	107	114	154	205	268	345	439
MOTOR VEHICLES & EQUIPMEN	87	91	95	100	105	110	136	167	203	243	290
TRANS. EQUIP., EXCL. MTR.	100	100	100	100	100	100	100	100	100	100	100
OTHER MANUFACTURING	87	91	95	100	105	110	136	167	202	243	288
POPULATION (SERIES E-0)	96	98	99	100	102	103	108	114	119	124	129

TABLE B.3.6

KERN COUNTY - Bakersfield SMSA

SERIES 'C' GROWTH INDICES

(NORMALIZED TO 1973)

	1970	1971	1972	1973	1974	1975	1980	1985	1990	1995	2000
AGRICULTURE	95	97	99	100	101	103	110	114	119	129	140
FORESTRY & FISHERIES	100	100	100	100	100	100	100	100	100	100	100
MINING											
METAL	100	100	100	100	100	100	100	100	100	100	100
CRUDE PETROLEUM & NATURAL	90	93	96	100	104	108	118	128	139	151	164
NONMETALLIC, EXCEPT FUELS	99	99	100	100	100	101	116	134	154	179	209
CONTRACT CONSTRUCTION	73	81	90	100	111	123	152	188	231	290	365
MANUFACTURING	82	88	94	100	107	114	143	173	212	260	320
FOOD & KINDRED PRODUCTS	93	95	98	100	103	105	125	147	173	204	241
TEXTILE MILL PRODUCTS	100	100	100	100	100	100	100	100	100	100	100
APPAREL & OTHER FABRIC PR	78	85	92	100	109	118	154	196	246	318	399
LUMBER PRODUCTS & FURNITU	70	79	89	100	112	126	171	215	262	328	398
PAPER & ALLIED PRODUCTS	100	100	100	100	100	100	100	100	100	100	100
PRINTING & PUBLISHING	83	88	94	100	106	113	140	171	200	261	327
CHEMICALS & ALLIED PRODUC	75	82	91	100	110	121	156	204	264	344	449
PETROLEUM REFINING	82	88	94	100	107	114	135	159	187	223	264
PRIMARY METALS	92	95	97	100	103	106	118	133	152	174	199
FABRICATED METALS & ORDNA	79	85	92	100	108	117	157	192	236	293	363
MACHINERY, EXCLUDING ELEC	84	89	94	100	106	112	138	171	210	261	324
ELECTRICAL MACHINERY & SU	72	81	90	100	111	124	196	257	332	434	568
MOTOR VEHICLES & EQUIPMEN	100	100	100	100	100	100	100	100	100	100	100
TRANS. EQUIP., EXCL. MTR.	69	78	89	100	113	128	166	195	229	273	324
OTHER MANUFACTURING	85	90	95	100	106	111	146	187	238	304	388
POPULATION (SERIES C-150)	98	99	100	100	100	102	109	117	125	132	139

SERIES 'E' GROWTH INDICES

(NORMALIZED TO 1973)

	1970	1971	1972	1973	1974	1975	1980	1985	1990	1995	2000
AGRICULTURE	96	97	99	100	101	103	110	117	125	132	140
FORESTRY & FISHERIES	100	100	100	100	100	100	100	100	100	100	100
MINING											
METAL	100	100	100	100	100	100	100	100	100	100	100
CRUDE PETROLEUM & NATURAL	96	98	99	100	101	102	108	114	120	126	132
NONMETALLIC, EXCEPT FUELS	92	95	97	100	103	105	119	134	150	166	183
CONTRACT CONSTRUCTION	88	92	96	100	104	109	133	160	191	226	264
MANUFACTURING	89	92	96	100	104	108	130	155	183	213	247
FOOD & KINDRED PRODUCTS	92	95	97	100	103	105	119	134	150	167	184
TEXTILE MILL PRODUCTS	100	100	100	100	100	100	100	100	100	100	100
APPAREL & OTHER FABRIC PR	84	89	95	100	106	112	145	186	234	292	360
LUMBER PRODUCTS & FURNITU	86	91	95	100	105	110	138	170	208	251	301
PAPER & ALLIED PRODUCTS	100	100	100	100	100	100	100	100	100	100	100
PRINTING & PUBLISHING	88	92	96	100	104	109	132	159	189	222	260
CHEMICALS & ALLIED PRODUC	89	93	96	100	104	108	129	152	178	207	238
PETROLEUM REFINING	95	97	98	100	102	103	111	119	128	136	144
PRIMARY METALS	94	96	98	100	102	104	113	123	133	143	153
FABRICATED METALS & ORDNA	89	92	96	100	104	108	130	155	183	215	249
MACHINERY, EXCLUDING ELEC	91	94	97	100	103	107	124	143	164	186	210
ELECTRICAL MACHINERY & SU	82	87	94	100	107	114	156	208	275	357	437
MOTOR VEHICLES & EQUIPMEN	100	100	100	100	100	100	100	100	100	100	100
TRANS. EQUIP., EXCL. MTR.	95	97	98	100	102	103	112	120	132	138	147
OTHER MANUFACTURING	85	90	95	100	105	111	143	181	227	280	343
POPULATION (SERIES E-0)	98	99	100	100	100	102	106	110	114	117	119

TABLE B.3.7
LOS ANGELES COUNTY - Los Angeles-Long Beach SMSA

SERIES 'C' GROWTH INDICES

(NORMALIZED TO 1973)

	1970	1971	1972	1973	1974	1975	1980	1985	1990	1995	2000
AGRICULTURE	102	101	101	100	99	99	100	105	110	120	130
FORESTRY & FISHERIES	94	96	98	100	102	104	122	134	149	166	185
MINING											
METAL	100	100	100	100	100	100	100	100	100	100	100
CRUDE PETROLEUM & NATURAL	90	93	96	100	104	107	119	130	142	155	169
NONMETALLIC, EXCEPT FUELS	91	94	97	100	103	106	127	144	163	187	215
CONTRACT CONSTRUCTION	86	90	95	100	105	111	139	172	212	266	333
MANUFACTURING	81	87	93	100	107	115	140	169	203	249	305
FOOD & KINDRED PRODUCTS	85	90	95	100	106	111	132	152	176	204	236
TEXTILE MILL PRODUCTS	82	88	94	100	107	114	137	161	188	223	263
APPAREL & OTHER FABRIC PR	83	88	94	100	107	114	139	164	193	230	274
LUMBER PRODUCTS & FURNITU	76	84	91	100	109	120	141	162	186	215	248
PAPER & ALLIED PRODUCTS	85	89	95	100	106	112	135	161	192	232	281
PRINTING & PUBLISHING	85	89	95	100	106	112	139	170	208	256	315
CHEMICALS & ALLIED PRODUC	79	86	93	100	108	117	150	190	240	306	389
PETROLEUM REFINING	94	96	98	100	102	104	121	139	160	185	214
PRIMARY METALS	81	87	93	100	107	115	130	146	164	185	209
FABRICATED METALS & ORDNA	77	84	92	100	109	119	150	186	230	287	359
MACHINERY, EXCLUDING ELEC	85	90	95	100	105	111	134	159	190	231	282
ELECTRICAL MACHINERY & SU	81	87	93	100	107	115	145	184	232	297	381
MOTOR VEHICLES & EQUIPMEN	84	89	94	100	106	112	116	136	159	189	225
TRANS. EQUIP., EXCL. MTR.	73	81	90	100	111	124	152	176	202	238	279
OTHER MANUFACTURING	86	91	95	100	105	110	137	167	204	252	311
POPULATION (SERIES C-150)	101	102	100	100	100	100	101	105	109	114	120

SERIES 'E' GROWTH INDICES

(NORMALIZED TO 1973)

	1970	1971	1972	1973	1974	1975	1980	1985	1990	1995	2000
AGRICULTURE	95	97	98	100	102	103	112	121	130	140	149
FORESTRY & FISHERIES	94	96	98	100	102	104	115	126	137	149	161
MINING											
METAL	100	100	100	100	100	100	100	100	100	100	100
CRUDE PETROLEUM & NATURAL	97	98	99	100	101	102	106	111	115	120	124
NONMETALLIC, EXCEPT FUELS	95	97	98	100	102	103	111	119	127	135	144
CONTRACT CONSTRUCTION	89	92	96	100	104	108	129	154	180	210	243
MANUFACTURING	90	94	97	100	103	107	125	144	165	188	213
FOOD & KINDRED PRODUCTS	93	96	98	100	102	104	116	128	141	153	167
TEXTILE MILL PRODUCTS	88	92	96	100	104	109	134	162	194	230	270
APPAREL & OTHER FABRIC PR	89	92	96	100	104	108	129	153	180	209	242
LUMBER PRODUCTS & FURNITU	92	94	97	100	103	106	121	138	155	174	194
PAPER & ALLIED PRODUCTS	89	93	96	100	104	108	128	151	176	203	234
PRINTING & PUBLISHING	89	93	96	100	104	108	129	153	179	208	239
CHEMICALS & ALLIED PRODUC	87	91	95	100	105	110	136	168	204	245	291
PETROLEUM REFINING	92	94	97	100	103	106	121	138	155	174	193
PRIMARY METALS	96	97	99	100	101	103	109	116	122	129	135
FABRICATED METALS & ORDNA	91	94	97	100	103	106	122	138	156	175	196
MACHINERY, EXCLUDING ELEC	91	94	97	100	103	107	124	143	164	186	210
ELECTRICAL MACHINERY & SU	88	92	96	100	104	109	133	161	192	227	266
MOTOR VEHICLES & EQUIPMEN	90	93	97	100	104	107	127	148	171	197	225
TRANS. EQUIP., EXCL. MTR.	96	97	99	100	101	103	109	116	120	130	136
OTHER MANUFACTURING	88	92	96	100	104	108	131	158	187	220	256
POPULATION (SERIES E-0)	101	102	100	100	100	100	96	94	94	94	94

TABLE B.3.8
MONTEREY COUNTY - Salinas, Monterey SMSA

SERIES 'C' GROWTH INDICES

(NORMALIZED TO 1973)

	1970	1971	1972	1973	1974	1975	1980	1985	1990	1995	2000
AGRICULTURE	92	95	97	100	103	105	110	111	112	121	132
FORESTRY & FISHERIES	83	88	94	100	106	113	156	170	190	225	255
MINING											
METAL	100	100	100	100	100	100	100	100	100	100	100
CRUDE PETROLEUM & NATURAL	92	95	97	100	103	106	137	143	160	186	209
NONMETALLIC, EXCEPT FUELS	102	101	101	100	99	99	102	116	132	153	178
CONTRACT CONSTRUCTION	74	82	90	100	111	123	163	205	258	326	413
MANUFACTURING	81	87	93	100	107	115	152	191	241	304	385
FOOD & KINDRED PRODUCTS	89	92	96	100	104	108	130	153	180	212	250
TEXTILE MILL PRODUCTS	100	100	100	100	100	100	100	100	100	100	100
APPAREL & OTHER FABRIC PR	66	76	87	100	115	132	178	220	263	318	386
LUMBER PRODUCTS & FURNITU	73	81	90	100	111	130	144	160	194	227	265
PAPER & ALLIED PRODUCTS	75	83	91	100	110	121	162	201	247	307	382
PRINTING & PUBLISHING	85	90	95	100	106	111	153	201	262	343	442
CHEMICALS & ALLIED PRODUC	80	86	93	100	108	116	151	189	239	302	382
PETROLEUM REFINING	100	100	100	100	100	100	100	100	100	100	100
PRIMARY METALS	100	100	100	100	100	100	100	100	100	100	100
FABRICATED METALS & ORDNA	100	100	100	100	100	100	100	100	100	100	100
MACHINERY, EXCLUDING ELEC	105	104	102	100	98	97	127	168	224	296	390
ELECTRICAL MACHINERY & SU	50	63	79	100	126	159	262	339	438	560	715
MOTOR VEHICLES & EQUIPMEN	100	100	100	100	100	100	100	100	100	100	100
TRANS. EQUIP., EXCL. MTR.	100	100	100	100	100	100	100	100	100	100	100
OTHER MANUFACTURING	74	82	90	100	111	122	178	236	314	413	545
POPULATION (SERIES C-150)	97	100	99	100	102	104	119	134	151	169	187

SERIES 'E' GROWTH INDICES

(NORMALIZED TO 1973)

	1970	1971	1972	1973	1974	1975	1980	1985	1990	1995	2000
AGRICULTURE	95	97	98	100	102	103	111	119	127	135	143
FORESTRY & FISHERIES	93	95	97	100	103	105	118	132	147	163	179
MINING											
METAL	100	100	100	100	100	100	100	100	100	100	100
CRUDE PETROLEUM & NATURAL	91	94	97	100	103	106	123	141	161	182	204
NONMETALLIC, EXCEPT FUELS	95	96	98	100	102	104	113	122	131	140	150
CONTRACT CONSTRUCTION	87	91	95	100	105	110	136	168	203	244	291
MANUFACTURING	86	91	95	100	105	110	137	169	207	249	298
FOOD & KINDRED PRODUCTS	91	94	97	100	103	106	123	141	160	180	202
TEXTILE MILL PRODUCTS	100	100	100	100	100	100	100	100	100	100	100
APPAREL & OTHER FABRIC PR	89	93	96	100	104	108	129	153	179	208	239
LUMBER PRODUCTS & FURNITU	92	94	97	100	103	106	121	138	156	175	195
PAPER & ALLIED PRODUCTS	88	92	96	100	104	109	132	159	190	224	262
PRINTING & PUBLISHING	84	89	94	100	106	112	147	189	241	307	375
CHEMICALS & ALLIED PRODUC	86	91	95	100	105	110	138	172	211	255	306
PETROLEUM REFINING	100	100	100	100	100	100	100	100	100	100	100
PRIMARY METALS	91	94	97	100	103	106	122	140	159	179	200
FABRICATED METALS & ORDNA	100	100	100	100	100	100	100	100	100	100	100
MACHINERY, EXCLUDING ELEC	86	90	95	100	105	111	140	176	217	265	321
ELECTRICAL MACHINERY & SU	88	92	96	100	104	109	134	162	194	231	272
MOTOR VEHICLES & EQUIPMEN	100	100	100	100	100	100	100	100	100	100	100
TRANS. EQUIP., EXCL. MTR.	94	96	98	100	102	104	114	125	136	147	159
OTHER MANUFACTURING	84	89	94	100	106	112	147	189	241	303	375
POPULATION (SERIES E-0)	97	100	99	100	102	104	114	121	129	136	142

TABLE B.3.9
ORANGE COUNTY - Anaheim-Santa Ana-Garden Grove SMSA

SERIES 'C' GROWTH INDICES

(NORMALIZED TO 1973)

	1970	1971	1972	1973	1974	1975	1980	1985	1990	1995	2000
AGRICULTURE	96	97	99	100	102	103	107	113	118	128	139
FORESTRY & FISHERIES	99	100	100	100	100	100	120	130	141	155	171
MINING											
METAL	100	100	100	100	100	100	100	100	100	100	100
CRUDE PETROLEUM & NATURAL	90	93	97	100	104	107	118	128	140	153	167
NONMETALLIC, EXCEPT FUELS	111	107	104	100	97	93	119	140	164	196	233
CONTRACT CONSTRUCTION	86	90	95	100	105	111	137	171	213	268	337
MANUFACTURING	79	85	92	100	108	117	157	199	254	324	412
FOOD & KINDRED PRODUCTS	86	91	95	100	105	110	139	167	200	240	288
TEXTILE MILL PRODUCTS	90	93	96	100	104	108	136	170	211	262	324
APPAREL & OTHER FABRIC PR	85	89	95	100	106	112	141	174	216	269	334
LUMBER PRODUCTS & FURNITU	73	81	90	100	111	123	158	192	235	286	348
PAPER & ALLIED PRODUCTS	83	88	94	100	106	113	145	181	226	283	356
PRINTING & PUBLISHING	85	90	95	100	106	112	146	182	227	285	356
CHEMICALS & ALLIED PRODUC	82	87	93	100	107	114	168	226	304	405	541
PETROLEUM REFINING	84	89	94	100	106	113	140	169	203	244	294
PRIMARY METALS	82	88	94	100	107	114	125	146	170	198	231
FABRICATED METALS & ORDNA	80	87	93	100	108	116	156	202	261	336	434
MACHINERY, EXCLUDING ELEC	82	87	93	100	107	114	146	185	233	295	373
ELECTRICAL MACHINERY & SU	73	81	90	100	111	123	168	216	279	359	460
MOTOR VEHICLES & EQUIPMEN	97	98	99	100	101	102	101	118	137	163	194
TRANS. EQUIP., EXCL. MTR.	80	86	93	100	108	116	147	180	220	270	332
OTHER MANUFACTURING	87	91	95	100	105	110	143	181	228	290	368
POPULATION (SERIES C-150)	90	92	96	100	104	106	125	146	165	180	193

SERIES 'E' GROWTH INDICES

(NORMALIZED TO 1973)

	1970	1971	1972	1973	1974	1975	1980	1985	1990	1995	2000
AGRICULTURE	95	97	98	100	102	103	112	121	130	140	149
FORESTRY & FISHERIES	95	97	98	100	102	103	111	118	126	134	142
MINING											
METAL	100	100	100	100	100	100	100	100	100	100	100
CRUDE PETROLEUM & NATURAL	97	98	99	100	101	102	106	111	115	120	124
NONMETALLIC, EXCEPT FUELS	93	95	98	100	102	105	118	131	145	159	174
CONTRACT CONSTRUCTION	89	92	96	100	104	108	130	155	183	215	249
MANUFACTURING	88	92	96	100	104	109	132	158	188	222	259
FOOD & KINDRED PRODUCTS	91	94	97	100	103	106	122	140	159	179	200
TEXTILE MILL PRODUCTS	85	89	95	100	106	111	144	184	232	288	353
APPAREL & OTHER FABRIC PR	86	90	95	100	105	110	139	173	213	258	311
LUMBER PRODUCTS & FURNITU	88	92	96	100	104	108	132	158	188	221	258
PAPER & ALLIED PRODUCTS	87	91	95	100	105	109	136	166	201	241	286
PRINTING & PUBLISHING	88	92	96	100	104	109	133	160	190	225	263
CHEMICALS & ALLIED PRODUC	84	89	94	100	106	112	147	191	243	305	379
PETROLEUM REFINING	89	93	96	100	104	108	129	152	178	207	238
PRIMARY METALS	94	96	98	100	102	104	115	126	137	149	161
FABRICATED METALS & ORDNA	89	93	96	100	104	108	128	151	176	204	234
MACHINERY, EXCLUDING ELEC	88	92	96	100	104	109	132	159	190	224	262
ELECTRICAL MACHINERY & SU	88	92	96	100	104	109	134	162	194	230	271
MOTOR VEHICLES & EQUIPMEN	90	93	96	100	104	107	127	148	172	198	226
TRANS. EQUIP., EXCL. MTR.	93	95	98	100	102	105	118	132	146	161	177
OTHER MANUFACTURING	87	91	95	100	105	110	137	169	206	248	296
POPULATION (SERIES E-0)	90	92	96	100	104	106	119	130	138	144	149

TABLE B.3.10

RIVERSIDE & SAN BERNARDINO COUNTIES - Riverside-San Bernardino-Ontario SMSA

SERIES 'C' GROWTH INDICES

(NORMALIZED TO 1973)

	1970	1971	1972	1973	1974	1975	1980	1985	1990	1995	2000
AGRICULTURE	94	96	98	100	102	104	107	112	118	128	138
FORESTRY & FISHERIES	100	100	100	100	100	100	100	100	100	100	100
MINING											
METAL	93	96	98	100	102	105	118	138	163	191	225
CRUDE PETROLEUM & NATURAL	100	100	100	100	100	100	100	100	100	100	100
NONMETALLIC, EXCEPT FUELS	91	94	97	100	103	107	129	152	179	213	253
CONTRACT CONSTRUCTION	85	89	95	100	106	112	149	192	248	321	414
MANUFACTURING	84	89	94	100	106	113	138	167	203	249	305
FOOD & KINDRED PRODUCTS	91	94	97	100	103	106	126	148	174	205	242
TEXTILE MILL PRODUCTS	111	107	104	100	97	93	102	125	155	192	236
APPAREL & OTHER FABRIC PR	72	80	90	100	112	125	178	224	283	356	447
LUMBER PRODUCTS & FURNITU	74	82	90	100	111	122	159	197	242	295	359
PAPER & ALLIED PRODUCTS	81	87	93	100	107	115	147	186	234	296	375
PRINTING & PUBLISHING	82	88	94	100	107	114	152	190	238	299	376
CHEMICALS & ALLIED PRODUC	85	90	95	100	106	111	137	163	206	254	315
PETROLEUM REFINING	100	100	100	100	100	100	100	100	100	100	100
PRIMARY METALS	82	88	94	100	107	114	130	147	167	192	220
FABRICATED METALS & ORDNA	85	89	95	100	106	112	155	204	269	353	462
MACHINERY, EXCLUDING ELEC	89	92	96	100	104	108	130	158	192	236	291
ELECTRICAL MACHINERY & SU	76	83	91	100	110	120	172	231	310	411	545
MOTOR VEHICLES & EQUIPMEN	112	108	104	100	96	93	63	73	86	103	124
TRANS. EQUIP., EXCL. MTR.	74	82	90	100	111	122	159	192	232	282	343
OTHER MANUFACTURING	97	98	99	100	101	102	115	138	166	203	248
POPULATION (SERIES C-150)	96	98	99	100	101	103	116	131	147	163	178

SERIES 'E' GROWTH INDICES

(NORMALIZED TO 1973)

	1970	1971	1972	1973	1974	1975	1980	1985	1990	1995	2000
AGRICULTURE	95	97	98	100	102	103	112	121	130	140	149
FORESTRY & FISHERIES	100	100	100	100	100	100	100	100	100	100	100
MINING											
METAL	94	96	98	100	102	104	114	124	134	145	156
CRUDE PETROLEUM & NATURAL	100	100	100	100	100	100	100	100	100	100	100
NONMETALLIC, EXCEPT FUELS	93	95	98	100	102	105	117	130	144	159	173
CONTRACT CONSTRUCTION	87	91	95	100	105	110	136	167	203	243	289
MANUFACTURING	90	93	97	100	103	107	125	146	168	192	218
FOOD & KINDRED PRODUCTS	92	95	97	100	103	105	119	134	150	166	183
TEXTILE MILL PRODUCTS	85	90	95	100	106	111	143	182	228	283	346
APPAREL & OTHER FABRIC PR	86	90	95	100	105	111	141	176	218	267	324
LUMBER PRODUCTS & FURNITU	88	92	96	100	104	109	133	160	191	225	264
PAPER & ALLIED PRODUCTS	86	91	95	100	105	110	138	171	208	252	302
PRINTING & PUBLISHING	88	92	96	100	104	109	133	161	193	229	269
CHEMICALS & ALLIED PRODUC	89	92	96	100	104	108	130	155	182	213	247
PETROLEUM REFINING	100	100	100	100	100	100	100	100	100	100	100
PRIMARY METALS	95	97	98	100	102	103	111	120	128	137	145
FABRICATED METALS & ORDNA	88	92	96	100	104	108	131	157	187	219	256
MACHINERY, EXCLUDING ELEC	90	93	97	100	104	107	126	148	171	196	224
ELECTRICAL MACHINERY & SU	86	90	95	100	105	111	141	176	218	266	322
MOTOR VEHICLES & EQUIPMEN	90	93	96	100	104	107	127	149	173	199	227
TRANS. EQUIP., EXCL. MTR.	93	96	98	100	102	104	116	128	140	153	166
OTHER MANUFACTURING	89	93	96	100	104	108	129	152	178	206	238
POPULATION (SERIES E-0)	96	98	99	100	101	102	111	119	126	133	139

TABLE B.3.11
NAPA & SOLANO COUNTIES - Vallejo-Fairfield-Napa SMSA

SERIES 'C' GROWTH INDICES

(NORMALIZED TO 1973)

	1970	1971	1972	1973	1974	1975	1980	1985	1990	1995	2000
AGRICULTURE	91	94	97	100	103	106	109	114	118	129	140
FORESTRY & FISHERIES	100	100	100	100	100	100	100	100	100	100	100
MINING											
METAL	100	100	100	100	100	100	100	100	100	100	100
CRUDE PETROLEUM & NATURAL	89	93	96	100	104	108	132	149	168	188	211
NONMETALLIC, EXCEPT FUELS	100	100	100	100	100	100	100	100	100	100	100
CONTRACT CONSTRUCTION	77	84	91	100	109	120	161	209	272	353	457
MANUFACTURING	88	92	96	100	104	109	134	159	190	229	276
FOOD & KINDRED PRODUCTS	87	91	95	100	105	110	131	152	177	206	241
TEXTILE MILL PRODUCTS	100	100	100	100	100	100	100	100	100	100	100
APPAREL & OTHER FABRIC PR	87	91	95	100	105	110	127	148	171	202	237
LUMBER PRODUCTS & FURNITU	74	82	90	100	111	123	177	220	277	331	395
PAPER & ALLIED PRODUCTS	100	100	100	100	100	100	100	100	100	100	100
PRINTING & PUBLISHING	77	84	92	100	109	119	166	220	291	385	509
CHEMICALS & ALLIED PRODUC	100	100	100	100	100	100	100	100	100	100	100
PETROLEUM REFINING	116	110	105	100	95	91	97	123	157	196	245
PRIMARY METALS	67	76	87	100	115	131	160	182	206	235	269
FABRICATED METALS & ORDNA	88	92	96	100	104	109	137	170	210	263	329
MACHINERY, EXCLUDING ELEC	68	77	88	100	114	129	176	222	280	355	452
ELECTRICAL MACHINERY & SU	100	100	100	100	100	100	100	100	100	100	100
MOTOR VEHICLES & EQUIPMEN	100	100	100	100	100	100	100	100	100	100	100
TRANS. EQUIP., EXCL. MTR.	100	100	100	100	100	100	100	100	100	100	100
OTHER MANUFACTURING	92	95	97	100	103	106	129	156	188	230	281
POPULATION (SERIES C-150)	95	98	100	100	102	103	116	133	155	179	207

SERIES 'E' GROWTH INDICES

(NORMALIZED TO 1973)

	1970	1971	1972	1973	1974	1975	1980	1985	1990	1995	2000
AGRICULTURE	95	97	98	100	102	103	112	121	130	139	149
FORESTRY & FISHERIES	100	100	100	100	100	100	100	100	100	100	100
MINING											
METAL	100	100	100	100	100	100	100	100	100	100	100
CRUDE PETROLEUM & NATURAL	91	94	97	100	103	106	124	142	162	184	207
NONMETALLIC, EXCEPT FUELS	100	100	100	100	100	100	100	100	100	100	100
CONTRACT CONSTRUCTION	85	90	95	100	105	111	141	178	221	271	329
MANUFACTURING	89	93	96	100	104	107	128	150	175	202	232
FOOD & KINDRED PRODUCTS	92	94	97	100	103	106	121	137	154	172	191
TEXTILE MILL PRODUCTS	100	100	100	100	100	100	100	100	100	100	100
APPAREL & OTHER FABRIC PR	91	94	97	100	103	106	122	138	156	176	196
LUMBER PRODUCTS & FURNITU	89	93	96	100	104	108	129	153	179	209	241
PAPER & ALLIED PRODUCTS	100	100	100	100	100	100	100	100	100	100	100
PRINTING & PUBLISHING	83	88	94	100	106	113	150	196	252	319	400
CHEMICALS & ALLIED PRODUC	91	94	97	100	103	106	122	139	157	177	198
PETROLEUM REFINING	86	91	95	100	105	110	138	171	209	253	303
PRIMARY METALS	95	97	98	100	102	103	112	121	130	139	148
FABRICATED METALS & ORDNA	90	93	97	100	103	107	125	145	167	191	217
MACHINERY, EXCLUDING ELEC	88	92	96	100	104	109	132	159	190	224	262
ELECTRICAL MACHINERY & SU	85	90	95	100	106	111	144	183	230	285	349
MOTOR VEHICLES & EQUIPMEN	100	100	100	100	100	100	100	100	100	100	100
TRANS. EQUIP., EXCL. MTR.	100	100	100	100	100	100	100	100	100	100	100
OTHER MANUFACTURING	89	92	96	100	104	108	130	155	182	213	247
POPULATION (SERIES E-0)	95	98	100	100	102	103	110	117	124	130	135

TABLE B.3.12

SACRAMENTO - YOLO-PLACER COUNTIES - Sacramento SMSA

SERIES 'C' GROWTH INDICES

(NORMALIZED TO 1973)

	1970	1971	1972	1973	1974	1975	1980	1985	1990	1995	2000
AGRICULTURE	94	96	98	100	102	104	104	106	109	117	127
FORESTRY & FISHERIES	100	100	100	100	100	100	100	100	100	100	100
MINING											
METAL	100	100	100	100	100	100	100	100	100	100	100
CRUDE PETROLEUM & NATURAL	100	100	100	100	100	100	100	100	100	100	100
NONMETALLIC, EXCEPT FUELS	31	46	68	100	147	216	353	409	464	520	601
CONTRACT CONSTRUCTION	89	92	96	100	104	108	131	161	193	347	307
MANUFACTURING	80	86	93	100	108	116	141	170	204	248	301
FOOD & KINDRED PRODUCTS	88	92	96	100	104	109	128	147	168	193	223
TEXTILE MILL PRODUCTS	100	100	100	100	100	100	100	100	100	100	100
APPAREL & OTHER FABRIC PR	88	92	96	100	104	109	144	168	215	259	312
LUMBER PRODUCTS & FURNITU	77	84	92	100	109	119	143	167	194	227	265
PAPER & ALLIED PRODUCTS	91	94	97	100	103	107	139	178	220	294	378
PRINTING & PUBLISHING	82	88	94	100	107	114	146	182	227	286	360
CHEMICALS & ALLIED PRODUC	71	80	89	100	112	125	174	234	314	421	564
PETROLEUM REFINING	95	97	98	100	102	103	121	138	162	188	220
PRIMARY METALS	95	97	98	100	102	104	110	120	130	144	159
FABRICATED METALS & ORDNA	68	78	88	100	114	129	166	208	261	329	415
MACHINERY, EXCLUDING ELEC	84	89	94	100	106	112	143	180	225	283	356
ELECTRICAL MACHINERY & SU	85	89	95	100	106	112	150	190	241	291	352
MOTOR VEHICLES & EQUIPMEN	115	110	105	100	95	91	59	74	94	122	158
TRANS. EQUIP., EXCL. MTR.	72	80	90	100	112	125	157	183	211	248	293
OTHER MANUFACTURING	84	89	94	100	106	113	142	175	217	270	337
POPULATION (SERIES C-150)	95	96	98	100	102	103	117	131	144	156	169

SERIES 'E' GROWTH INDICES

(NORMALIZED TO 1973)

	1970	1971	1972	1973	1974	1975	1980	1985	1990	1995	2000
AGRICULTURE	96	97	99	100	101	103	109	116	123	130	136
FORESTRY & FISHERIES	100	100	100	100	100	100	100	100	100	100	100
MINING											
METAL	100	100	100	100	100	100	100	100	100	100	100
CRUDE PETROLEUM & NATURAL	100	100	100	100	100	100	100	100	100	100	100
NONMETALLIC, EXCEPT FUELS	100	100	100	100	100	100	100	100	100	100	100
CONTRACT CONSTRUCTION	88	92	96	100	104	108	131	156	184	215	250
MANUFACTURING	91	94	97	100	103	106	124	142	163	184	208
FOOD & KINDRED PRODUCTS	93	95	98	100	102	105	117	129	142	156	170
TEXTILE MILL PRODUCTS	100	100	100	100	100	100	100	100	100	100	100
APPAREL & OTHER FABRIC PR	87	91	95	100	105	110	137	168	205	246	294
LUMBER PRODUCTS & FURNITU	89	93	96	100	104	108	129	153	180	209	242
PAPER & ALLIED PRODUCTS	87	92	96	100	104	109	134	163	195	232	278
PRINTING & PUBLISHING	87	91	95	100	105	110	136	168	204	245	291
CHEMICALS & ALLIED PRODUC	88	92	96	100	104	108	131	156	184	216	251
PETROLEUM REFINING	90	93	97	100	103	107	125	145	167	191	216
PRIMARY METALS	94	96	98	100	102	104	113	123	133	143	153
FABRICATED METALS & ORDNA	92	95	97	100	103	105	119	134	150	166	183
MACHINERY, EXCLUDING ELEC	90	93	97	100	104	107	126	147	171	196	223
ELECTRICAL MACHINERY & SU	83	88	94	100	106	113	151	190	250	329	415
MOTOR VEHICLES & EQUIPMEN	88	92	96	100	104	109	132	160	190	225	263
TRANS. EQUIP., EXCL. MTR.	95	97	98	100	102	103	111	120	128	136	115
OTHER MANUFACTURING	87	91	95	100	105	110	136	168	203	244	291
POPULATION (SERIES E-0)	95	96	98	100	102	103	112	118	124	129	133

TABLE B.3.13

SAN DIEGO COUNTY - San Diego SMSA

SERIES 'C' GROWTH INDICES

(NORMALIZED TO 1973)

	1970	1971	1972	1973	1974	1975	1980	1985	1990	1995	2000
AGRICULTURE	97	98	99	100	101	102	102	105	108	117	127
FORESTRY & FISHERIES	95	97	98	100	102	104	121	132	144	160	178
MINING											
METAL	100	100	100	100	100	100	100	100	100	100	100
CRUDE PETROLEUM & NATURAL	100	100	100	100	100	100	100	100	100	100	100
NONMETALLIC, EXCEPT FUELS	92	95	97	100	103	106	130	152	177	211	250
CONTRACT CONSTRUCTION	88	92	96	100	104	109	131	160	196	242	299
MANUFACTURING	82	88	94	100	107	114	144	178	221	276	344
FOOD & KINDRED PRODUCTS	88	92	96	100	104	109	128	150	175	206	242
TEXTILE MILL PRODUCTS	100	100	100	100	100	100	100	100	100	100	100
APPAREL & OTHER FABRIC PR	80	86	93	100	108	116	146	177	214	262	320
LUMBER PRODUCTS & FURNITU	77	84	92	100	109	119	148	177	210	251	300
PAPER & ALLIED PRODUCTS	84	89	94	100	106	113	145	186	238	301	381
PRINTING & PUBLISHING	89	93	96	100	104	108	133	163	199	247	305
CHEMICALS & ALLIED PRODUC	91	94	97	100	103	106	125	144	166	196	232
PETROLEUM REFINING	92	95	97	100	103	105	127	150	177	211	253
PRIMARY METALS	77	84	92	100	109	119	129	135	140	151	164
FABRICATED METALS & ORDNA	82	88	94	100	107	114	138	168	205	252	309
MACHINERY, EXCLUDING ELEC	95	97	98	100	102	103	132	166	209	266	338
ELECTRICAL MACHINERY & SU	73	81	90	100	111	123	174	237	322	433	582
MOTOR VEHICLES & EQUIPMEN	183	149	122	100	82	67	26	33	42	54	69
TRANS. EQUIP., EXCL. MTR.	76	83	91	100	110	120	155	183	217	260	313
OTHER MANUFACTURING	92	95	97	100	103	105	129	156	189	231	283
POPULATION (SERIES C-150)	93	94	96	100	104	107	125	145	167	187	207

SERIES 'E' GROWTH INDICES

(NORMALIZED TO 1973)

	1970	1971	1972	1973	1974	1975	1980	1985	1990	1995	2000
AGRICULTURE	96	97	99	100	101	103	110	118	125	133	140
FORESTRY & FISHERIES	94	96	98	100	102	104	114	124	135	146	157
MINING											
METAL	100	100	100	100	100	100	100	100	100	100	100
CRUDE PETROLEUM & NATURAL	100	100	100	100	100	100	100	100	100	100	100
NONMETALLIC, EXCEPT FUELS	91	94	97	100	103	106	123	141	161	182	205
CONTRACT CONSTRUCTION	88	92	96	100	104	109	133	161	192	227	267
MANUFACTURING	88	92	96	100	104	108	132	158	188	221	258
FOOD & KINDRED PRODUCTS	90	93	97	100	103	107	126	146	169	193	220
TEXTILE MILL PRODUCTS	100	100	100	100	100	100	100	100	100	100	100
APPAREL & OTHER FABRIC PR	85	90	95	100	106	111	144	183	230	285	349
LUMBER PRODUCTS & FURNITU	90	93	97	100	104	107	126	148	171	197	224
PAPER & ALLIED PRODUCTS	85	90	95	100	105	111	141	177	220	269	327
PRINTING & PUBLISHING	87	91	95	100	105	110	137	168	204	245	292
CHEMICALS & ALLIED PRODUC	86	91	95	100	105	110	138	171	210	254	304
PETROLEUM REFINING	88	92	96	100	104	108	131	156	185	217	252
PRIMARY METALS	94	96	98	100	102	104	113	123	133	143	153
FABRICATED METALS & ORDNA	91	94	97	100	103	106	123	141	161	182	204
MACHINERY, EXCLUDING ELEC	87	91	96	100	104	109	134	163	196	233	275
ELECTRICAL MACHINERY & SU	83	88	94	100	106	113	150	196	253	321	403
MOTOR VEHICLES & EQUIPMEN	88	92	96	100	104	109	134	162	194	231	272
TRANS. EQUIP., EXCL. MTR.	92	95	97	100	103	105	119	134	150	167	184
OTHER MANUFACTURING	86	90	95	100	105	111	141	176	218	266	322
POPULATION (SERIES E-0)	93	94	96	100	104	107	119	129	139	147	154

TABLE B.3.14

SAN JOAQUIN COUNTY - Stockton SMSA

SERIES 'C' GROWTH INDICES

(NORMALIZED TO 1973)

	1970	1971	1972	1973	1974	1975	1980	1985	1990	1995	2000
AGRICULTURE	94	96	98	100	102	104	106	108	107	118	129
FORESTRY & FISHERIES	100	100	100	100	100	100	100	100	100	100	100
MINING											
METAL	100	100	100	100	100	100	100	100	100	100	100
CRUDE PETROLEUM & NATURAL	100	100	100	100	100	100	100	100	100	100	100
NONMETALLIC, EXCEPT FUELS	100	100	100	100	100	100	100	100	100	100	100
CONTRACT CONSTRUCTION	92	95	97	100	103	105	126	149	175	211	254
MANUFACTURING	85	90	95	100	105	111	135	163	197	240	293
FOOD & KINDRED PRODUCTS	90	93	96	100	104	108	128	151	178	212	252
TEXTILE MILL PRODUCTS	100	100	100	100	100	100	100	100	100	100	100
APPAREL & OTHER FABRIC PR	62	72	85	100	110	138	178	208	242	285	337
LUMBER PRODUCTS & FURNITU	79	85	92	100	108	117	145	170	200	236	279
PAPER & ALLIED PRODUCTS	85	90	95	100	105	111	135	160	188	225	270
PRINTING & PUBLISHING	87	91	96	100	105	110	132	157	185	224	272
CHEMICALS & ALLIED PRODUC	74	82	91	100	110	122	172	231	308	410	546
PETROLEUM REFINING	100	100	100	100	100	100	100	100	100	100	100
PRIMARY METALS	79	85	92	100	108	117	139	161	191	224	264
FABRICATED METALS & ORDNA	87	91	96	100	105	109	129	160	199	242	312
MACHINERY, EXCLUDING ELEC	87	91	95	100	105	110	125	142	161	187	217
ELECTRICAL MACHINERY & SU	73	81	90	100	111	124	178	243	328	433	573
MOTOR VEHICLES & EQUIPMEN	100	100	100	100	100	100	100	100	100	100	100
TRANS. EQUIP., EXCL. MTR.	74	82	90	100	111	122	161	195	238	294	363
OTHER MANUFACTURING	88	92	96	100	105	109	134	164	202	248	305
POPULATION (SERIES C-150)	98	99	100	100	101	102	113	123	133	143	153

SERIES 'E' GROWTH INDICES

(NORMALIZED TO 1973)

	1970	1971	1972	1973	1974	1975	1980	1985	1990	1995	2000
AGRICULTURE	96	97	99	100	101	103	109	116	123	130	136
FORESTRY & FISHERIES	100	100	100	100	100	100	100	100	100	100	100
MINING											
METAL	100	100	100	100	100	100	100	100	100	100	100
CRUDE PETROLEUM & NATURAL	100	100	100	100	100	100	100	100	100	100	100
NONMETALLIC, EXCEPT FUELS	100	100	100	100	100	100	100	100	100	100	100
CONTRACT CONSTRUCTION	91	94	97	100	103	106	123	142	162	183	206
MANUFACTURING	89	93	96	100	104	108	128	150	175	203	233
FOOD & KINDRED PRODUCTS	90	93	96	100	104	107	127	148	172	198	226
TEXTILE MILL PRODUCTS	100	100	100	100	100	100	100	100	100	100	100
APPAREL & OTHER FABRIC PR	89	92	96	100	104	108	130	154	181	211	244
LUMBER PRODUCTS & FURNITU	91	94	97	100	103	107	124	143	163	186	209
PAPER & ALLIED PRODUCTS	90	93	96	100	104	107	127	149	173	200	229
PRINTING & PUBLISHING	89	93	96	100	104	108	128	150	175	202	232
CHEMICALS & ALLIED PRODUC	84	89	94	100	106	112	146	188	239	299	370
PETROLEUM REFINING	100	100	100	100	100	100	100	100	100	100	100
PRIMARY METALS	93	95	98	100	102	105	118	131	145	159	174
FABRICATED METALS & ORDNA	94	96	98	100	102	104	114	124	134	145	156
MACHINERY, EXCLUDING ELEC	93	95	98	100	102	105	118	131	145	160	175
ELECTRICAL MACHINERY & SU	84	89	95	100	106	112	145	185	234	291	359
MOTOR VEHICLES & EQUIPMEN	100	100	100	100	100	100	100	100	100	100	100
TRANS. EQUIP., EXCL. MTR.	91	94	97	100	103	106	123	140	160	180	202
OTHER MANUFACTURING	87	92	96	100	104	109	134	162	195	231	272
POPULATION (SERIES E-150)	98	99	100	100	101	102	108	113	117	121	124

TABLE B.3.15

SAN MATEO-ALAMEDA-CONTRA COSTA-MARIN-SAN FRANCISCO COUNTIES - San Francisco-Oakland SMSA

SERIES 'C' GROWTH INDICES

(NORMALIZED TO 1973)

	1970	1971	1972	1973	1974	1975	1980	1985	1990	1995	2000
AGRICULTURE	96	97	98	100	102	103	110	115	119	129	140
FORESTRY & FISHERIES	95	96	98	100	102	104	117	136	154	177	202
MINING											
METAL	85	90	95	100	105	111	142	164	198	235	278
CRUDE PETROLEUM & NATURAL	103	102	101	100	99	98	109	123	138	155	175
NONMETALLIC, EXCEPT FUELS	91	94	97	100	103	107	128	145	166	192	222
CONTRACT CONSTRUCTION	85	90	95	100	105	111	135	162	196	239	292
MANUFACTURING	84	89	94	100	106	112	137	163	197	240	292
FOOD & KINDRED PRODUCTS	90	93	96	100	104	108	122	135	151	170	192
TEXTILE MILL PRODUCTS	102	102	101	100	99	98	113	125	139	157	176
APPAREL & OTHER FABRIC PR	83	88	94	100	106	113	139	166	198	238	296
LUMBER PRODUCTS & FURNITU	72	81	90	100	111	124	149	170	194	224	257
PAPER & ALLIED PRODUCTS	87	91	95	100	105	110	129	151	176	208	248
PRINTING & PUBLISHING	85	90	95	100	106	112	135	161	191	231	278
CHEMICALS & ALLIED PRODUC	83	89	94	100	106	113	139	169	206	253	311
PETROLEUM REFINING	95	97	98	100	102	103	121	141	163	190	222
PRIMARY METALS	86	91	95	100	105	110	123	137	153	172	194
FABRICATED METALS & ORDNA	87	91	96	100	105	109	133	163	199	246	304
MACHINERY, EXCLUDING ELEC	84	89	94	100	106	112	140	173	214	266	332
ELECTRICAL MACHINERY & SU	76	83	91	100	110	121	171	228	302	398	524
MOTOR VEHICLES & EQUIPMEN	63	73	86	100	117	136	185	225	275	339	418
TRANS. EQUIP., EXCL. MTR.	82	87	93	100	107	115	114	130	148	171	199
OTHER MANUFACTURING	88	92	96	100	104	109	134	161	194	237	289
POPULATION (SERIES C-150)	99	100	100	100	100	100	106	112	119	126	133

SERIES 'E' GROWTH INDICES

(NORMALIZED TO 1973)

	1970	1971	1972	1973	1974	1975	1980	1985	1990	1995	2000
AGRICULTURE	95	97	98	100	102	103	112	121	130	139	149
FORESTRY & FISHERIES	92	95	97	100	103	106	120	136	152	169	187
MINING											
METAL	99	99	100	100	100	101	102	104	106	107	109
CRUDE PETROLEUM & NATURAL	91	94	97	100	103	106	123	141	161	182	204
NONMETALLIC, EXCEPT FUELS	95	96	98	100	102	104	113	122	132	141	151
CONTRACT CONSTRUCTION	89	93	96	100	104	108	128	151	177	205	235
MANUFACTURING	90	93	97	100	103	107	125	145	166	189	214
FOOD & KINDRED PRODUCTS	94	96	98	100	102	104	114	125	135	146	158
TEXTILE MILL PRODUCTS	98	99	99	100	101	101	104	107	109	112	114
APPAREL & OTHER FABRIC PR	90	93	97	100	104	107	127	148	172	197	225
LUMBER PRODUCTS & FURNITU	93	95	97	100	103	105	118	133	147	163	179
PAPER & ALLIED PRODUCTS	91	94	97	100	103	106	123	141	160	181	203
PRINTING & PUBLISHING	90	93	96	100	104	107	127	149	173	200	229
CHEMICALS & ALLIED PRODUC	88	92	96	100	104	109	132	160	190	225	263
PETROLEUM REFINING	91	94	97	100	103	107	124	143	163	185	208
PRIMARY METALS	96	97	99	100	101	103	110	116	123	130	137
FABRICATED METALS & ORDNA	91	94	97	100	103	106	123	141	160	180	202
MACHINERY, EXCLUDING ELEC	89	93	96	100	104	107	128	150	175	202	232
ELECTRICAL MACHINERY & SU	86	90	95	100	105	110	139	174	214	260	313
MOTOR VEHICLES & EQUIPMEN	90	94	97	100	103	107	124	144	165	187	212
TRANS. EQUIP., EXCL. MTR.	94	96	98	100	102	104	113	123	133	143	154
OTHER MANUFACTURING	89	93	96	100	104	108	129	152	179	207	239
POPULATION (SERIES E-0)	99	100	100	100	100	100	103	105	108	109	110

TABLE B.3.16

SANTA BARBARA COUNTY - Santa Barbara-Lompoc-Santa Maria SMSA

SERIES 'C' GROWTH INDICES

(NORMALIZED TO 1973)

	1970	1971	1972	1973	1974	1975	1980	1985	1990	1995	2000
AGRICULTURE	102	101	101	100	99	99	89	82	77	83	90
FORESTRY & FISHERIES	100	100	100	100	100	100	100	100	100	100	100
MINING											
METAL	85	90	95	100	105	111	170	232	297	383	493
CRUDE PETROLEUM & NATURAL	98	99	99	100	101	101	98	107	117	127	139
NONMETALLIC, EXCEPT FUELS	88	92	96	100	104	109	127	146	156	177	201
CONTRACT CONSTRUCTION	76	83	91	100	110	120	154	195	248	316	403
MANUFACTURING	87	91	95	100	105	110	131	158	191	232	283
FOOD & KINDRED PRODUCTS	96	97	99	100	101	103	114	119	125	133	141
TEXTILE MILL PRODUCTS	100	100	100	100	100	100	100	100	100	100	100
APPAREL & OTHER FABRIC PR	100	100	100	100	100	100	100	100	100	100	100
LUMBER PRODUCTS & FURNITU	100	100	100	100	100	100	100	100	100	100	100
PAPER & ALLIED PRODUCTS	100	100	100	100	100	100	100	100	100	100	100
PRINTING & PUBLISHING	94	96	98	100	102	104	122	146	171	205	247
CHEMICALS & ALLIED PRODUC	100	100	100	100	100	100	100	100	100	100	100
PETROLEUM REFINING	100	100	100	100	100	100	109	119	129	138	148
PRIMARY METALS	95	97	98	100	102	104	85	91	99	109	120
FABRICATED METALS & ORDNA	79	85	92	100	108	117	148	185	231	290	364
MACHINERY, EXCLUDING ELEC	88	94	97	100	103	106	121	139	159	186	217
ELECTRICAL MACHINERY & SU	97	98	99	100	101	102	119	143	170	204	244
MOTOR VEHICLES & EQUIPMEN	100	100	100	100	100	100	100	100	100	100	100
TRANS. EQUIP., EXCL. MTR.	62	73	85	100	117	137	129	163	205	257	322
OTHER MANUFACTURING	85	90	95	100	105	111	133	175	215	266	330
POPULATION (SERIES C-150)	97	98	99	100	102	102	113	124	137	149	161

SERIES 'E' GROWTH INDICES

(NORMALIZED TO 1973)

	1970	1971	1972	1973	1974	1975	1980	1985	1990	1995	2000
AGRICULTURE	97	98	99	100	101	102	107	112	117	122	127
FORESTRY & FISHERIES	100	100	100	100	100	100	100	100	100	100	100
MINING											
METAL	100	100	100	100	100	100	100	100	100	100	100
CRUDE PETROLEUM & NATURAL	97	98	99	100	101	102	106	110	115	119	123
NONMETALLIC, EXCEPT FUELS	96	97	99	100	101	103	109	116	122	129	135
CONTRACT CONSTRUCTION	88	92	96	100	104	109	134	162	194	230	270
MANUFACTURING	91	94	97	100	103	106	122	139	157	177	197
FOOD & KINDRED PRODUCTS	100	100	100	100	100	100	100	100	99	99	99
TEXTILE MILL PRODUCTS	100	100	100	100	100	100	100	100	100	100	100
APPAREL & OTHER FABRIC PR	100	100	100	100	100	100	100	100	100	100	100
LUMBER PRODUCTS & FURNITU	95	97	98	100	102	103	111	119	128	136	144
PAPER & ALLIED PRODUCTS	86	90	95	100	105	111	140	176	217	265	321
PRINTING & PUBLISHING	91	94	97	100	103	106	123	140	160	180	202
CHEMICALS & ALLIED PRODUC	100	100	100	100	100	100	100	100	100	100	100
PETROLEUM REFINING	95	97	98	100	102	103	111	118	126	134	141
PRIMARY METALS	97	98	99	100	101	102	106	110	114	118	122
FABRICATED METALS & ORDNA	91	94	97	100	103	106	123	141	160	180	202
MACHINERY, EXCLUDING ELEC	93	96	98	100	102	104	116	128	140	153	166
ELECTRICAL MACHINERY & SU	93	95	98	100	102	105	118	132	146	161	177
MOTOR VEHICLES & EQUIPMEN	100	100	100	100	100	100	100	100	100	100	100
TRANS. EQUIP., EXCL. MTR.	91	94	97	100	103	106	123	141	160	181	203
OTHER MANUFACTURING	88	92	96	100	104	109	132	159	189	222	259
POPULATION (SERIES E-0)	97	98	99	100	102	102	109	114	119	123	126

TABLE B.3.17

SANTA CLARA COUNTY - San Jose SMSA

SERIES 'C' GROWTH INDICES

(NORMALIZED TO 1973)

	1970	1971	1972	1973	1974	1975	1980	1985	1990	1995	2000
AGRICULTURE	91	94	97	100	103	106	111	116	121	131	142
FORESTRY & FISHERIES	100	100	100	100	100	100	100	100	100	100	100
MINING											
METAL	100	100	100	100	100	100	100	100	100	100	100
CRUDE PETROLEUM & NATURAL	100	100	100	100	100	100	100	100	100	100	100
NONMETALLIC, EXCEPT FUELS	82	88	94	100	107	114	150	168	195	224	257
CONTRACT CONSTRUCTION	80	86	93	100	108	116	148	188	238	303	386
MANUFACTURING	80	86	93	100	108	116	153	198	257	333	432
FOOD & KINDRED PRODUCTS	82	88	94	100	107	114	135	157	183	213	249
TEXTILE MILL PRODUCTS	100	100	100	100	100	100	100	100	100	100	100
APPAREL & OTHER FABRIC PR	81	87	93	100	107	115	154	191	236	291	359
LUMBER PRODUCTS & FURNITU	76	83	91	100	110	120	142	161	183	208	238
PAPER & ALLIED PRODUCTS	85	90	95	100	106	112	141	173	213	263	325
PRINTING & PUBLISHING	88	92	96	100	104	109	142	180	226	285	360
CHEMICALS & ALLIED PRODUC	77	84	92	100	109	119	157	205	268	348	453
PETROLEUM REFINING	91	94	97	100	103	107	143	171	209	260	323
PRIMARY METALS	76	83	91	100	110	120	136	155	175	200	228
FABRICATED METALS & ORDNA	77	84	92	100	109	119	153	191	239	300	377
MACHINERY, EXCLUDING ELEC	87	91	95	100	105	110	144	186	239	309	400
ELECTRICAL MACHINERY & SU	80	86	93	100	108	116	162	220	299	402	540
MOTOR VEHICLES & EQUIPMEN	62	72	85	100	118	138	188	229	279	344	425
TRANS. EQUIP., EXCL. MTR.	109	106	103	100	97	94	77	93	113	137	166
OTHER MANUFACTURING	87	91	96	100	105	110	138	169	208	258	320
POPULATION (SERIES C-150)	94	95	98	100	102	104	118	132	146	158	169

SERIES 'E' GROWTH INDICES

(NORMALIZED TO 1973)

	1970	1971	1972	1973	1974	1975	1980	1985	1990	1995	2000
AGRICULTURE	95	97	98	100	102	103	112	121	130	139	149
FORESTRY & FISHERIES	100	100	100	100	100	100	100	100	100	100	100
MINING											
METAL	100	100	100	100	100	100	100	100	100	100	100
CRUDE PETROLEUM & NATURAL	100	100	100	100	100	100	100	100	100	100	100
NONMETALLIC, EXCEPT FUELS	100	100	100	100	100	100	100	100	100	100	100
CONTRACT CONSTRUCTION	86	91	95	100	105	110	137	170	207	249	298
MANUFACTURING	87	91	96	100	105	109	136	166	201	240	285
FOOD & KINDRED PRODUCTS	92	94	97	100	103	106	121	137	155	173	193
TEXTILE MILL PRODUCTS	100	100	100	100	100	100	100	100	100	100	100
APPAREL & OTHER FABRIC PR	88	92	96	100	104	109	132	159	189	223	261
LUMBER PRODUCTS & FURNITU	93	95	98	100	102	105	117	129	142	156	170
PAPER & ALLIED PRODUCTS	88	92	96	100	104	108	131	157	186	219	255
PRINTING & PUBLISHING	87	91	95	100	105	110	137	169	206	248	295
CHEMICALS & ALLIED PRODUC	84	89	95	100	106	112	145	186	234	292	359
PETROLEUM REFINING	87	91	96	100	105	109	135	166	200	239	284
PRIMARY METALS	95	97	98	100	102	103	112	121	129	138	147
FABRICATED METALS & ORDNA	90	93	97	100	104	107	126	147	170	195	223
MACHINERY, EXCLUDING ELEC	87	91	96	100	105	109	136	165	201	241	286
ELECTRICAL MACHINERY & SU	85	90	95	100	106	111	144	183	230	286	351
MOTOR VEHICLES & EQUIPMEN	90	94	97	100	103	107	124	144	165	188	212
TRANS. EQUIP., EXCL. MTR.	91	94	97	100	103	106	122	140	158	178	199
OTHER MANUFACTURING	88	92	96	100	104	109	133	161	193	229	269
POPULATION (SERIES E-0)	94	95	98	100	102	104	114	122	129	135	139

TABLE B.3.18
SANTA CRUZ COUNTY - Santa Cruz SMSA

SERIES '[illegible]' GROWTH INDICES

(NORMALIZED TO 1973)

	1970	1971	1972	1973	1974	1975	1980	1985	1990	1995	2000
AGRICULTURE	97	98	99	100	101	102	100	102	103	112	123
FORESTRY & FISHERIES	100	100	100	100	100	100	100	100	100	100	100
MINING											
METAL	100	100	100	100	100	100	100	100	100	100	100
CRUDE PETROLEUM & NATURAL	100	100	100	100	100	100	100	100	100	100	100
NONMETALLIC, EXCEPT FUELS	92	95	97	100	103	106	126	145	165	[illegible]	[illegible]
CONTRACT CONSTRUCTION	100	100	100	100	100	100	100	100	100	100	100
MANUFACTURING	81	87	93	100	107	115	152	187	[illegible]	284	[illegible]
FOOD & KINDRED PRODUCTS	90	93	97	100	104	107	133	155	179	205	[illegible]
TEXTILE MILL PRODUCTS	100	100	100	100	100	100	100	100	100	100	100
APPAREL & OTHER FABRIC PR	100	100	100	100	100	100	100	100	100	100	100
LUMBER PRODUCTS & FURNITU	71	79	89	100	112	126	157	189	229	[illegible]	[illegible]
PAPER & ALLIED PRODUCTS	100	100	100	100	100	100	100	100	100	100	100
PRINTING & PUBLISHING	81	87	93	100	107	115	161	209	280	371	493
CHEMICALS & ALLIED PRODUC	100	100	100	100	100	100	100	100	100	100	100
PETROLEUM REFINING	100	100	100	100	100	100	100	100	100	100	100
PRIMARY METALS	78	85	92	100	109	118	149	180	219	264	317
FABRICATED METALS & ORDNA	101	100	100	100	100	100	134	142	162	[illegible]	217
MACHINERY, EXCLUDING ELEC	71	79	89	100	112	126	200	274	378	510	689
ELECTRICAL MACHINERY & SU	58	70	83	100	120	144	226	301	400	520	693
MOTOR VEHICLES & EQUIPMEN	100	100	100	100	100	100	100	100	100	100	100
TRANS. EQUIP., EXCL. MTR.	100	100	100	100	100	100	100	100	100	100	100
OTHER MANUFACTURING	92	95	97	100	102	105	136	173	219	277	351
POPULATION (SERIES C-150)	88	91	97	100	103	105	127	149	171	192	214

SERIES '[illegible]' GROWTH INDICES

(NORMALIZED TO 1973)

	1970	1971	1972	1973	1974	1975	1980	1985	1990	1995	2000
AGRICULTURE	95	97	98	100	102	103	112	121	130	139	148
FORESTRY & FISHERIES	100	100	100	100	100	.100	100	100	100	100	100
MINING											
METAL	100	100	100	100	100	100	100	100	100	100	100
CRUDE PETROLEUM & NATURAL	100	100	100	100	100	100	100	100	100	100	100
NONMETALLIC, EXCEPT FUELS	95	96	98	.100	102	104	113	122	131	141	151
CONTRACT CONSTRUCTION	88	92	96	100	104	109	132	159	189	223	260
MANUFACTURING	89	92	96	100	104	108	130	156	184	215	249
FOOD & KINDRED PRODUCTS	92	94	97	100	103	106	121	136	153	171	190
TEXTILE MILL PRODUCTS	100	100	100	100	100	100	100	100	100	100	100
APPAREL & OTHER FABRIC PR	100	100	100	100	100	100	100	100	100	100	100
LUMBER PRODUCTS & FURNITU	89	93	96	100	104	108	128	151	176	204	234
PAPER & ALLIED PRODUCTS	100	100	100	100	100	100	100	100	100	100	100
PRINTING & PUBLISHING	83	88	94	100	107	113	150	196	252	320	401
CHEMICALS & ALLIED PRODUC	100	100	100	100	100	100	100	100	100	100	100
PETROLEUM REFINING	100	100	100	100	100	100	100	100	100	100	100
PRIMARY METALS	91	94	97	100	103	106	122	140	159	[illegible]	200
FABRICATED METALS & ORDNA	96	97	99	100	101	103	110	117	124	132	139
MACHINERY, EXCLUDING ELEC	84	89	94	100	106	112	147	189	239	300	372
ELECTRICAL MACHINERY & SU	82	90	95	100	105	110	140	175	215	263	[illegible]
MOTOR VEHICLES & EQUIPMEN	100	100	100	100	100	100	100	100	100	100	100
TRANS. EQUIP., EXCL. MTR.	100	100	100	100	100	100	100	100	100	100	100
OTHER MANUFACTURING	86	91	95	100	105	.110	137	169	206	249	297
POPULATION (SERIES E-[illegible])	88	91	97	100	103	105	121	123	[illegible]	[illegible]	140

TABLE B.3.19

SONOMA COUNTY - Santa Rosa SMSA

SERIES 'C' GROWTH INDICES

(NORMALIZED TO 1973)

	1970	1971	1972	1973	1974	1975	1980	1985	1990	1995	2000
AGRICULTURE	107	104	102	100	98	96	83	87	90	98	107
FORESTRY & FISHERIES	88	92	96	100	104	108	139	170	201	230	263
MINING											
METAL	84	89	94	100	106	112	118	139	163	191	225
CRUDE PETROLEUM & NATURAL	100	100	100	100	100	100	100	100	100	100	100
NONMETALLIC, EXCEPT FUELS	85	90	95	100	105	111	137	155	177	205	237
CONTRACT CONSTRUCTION	85	89	95	100	106	112	136	168	207	258	321
MANUFACTURING	84	89	94	100	106	112	137	163	196	240	292
FOOD & KINDRED PRODUCTS	94	96	98	100	102	104	114	123	133	147	161
TEXTILE MILL PRODUCTS	100	100	100	100	100	100	100	100	100	100	100
APPAREL & OTHER FABRIC PR	100	100	100	100	100	100	100	100	100	100	100
LUMBER PRODUCTS & FURNITU	73	81	90	100	111	124	145	175	206	243	286
PAPER & ALLIED PRODUCTS	100	100	100	100	100	100	100	100	100	100	100
PRINTING & PUBLISHING	86	90	95	100	105	111	136	164	200	245	300
CHEMICALS & ALLIED PRODUC	100	100	100	100	100	100	100	100	100	100	100
PETROLEUM REFINING	100	100	100	100	100	100	100	100	100	100	100
PRIMARY METALS	65	75	87	100	115	133	163	190	223	260	304
FABRICATED METALS & ORDNA	81	87	93	100	107	115	146	180	223	279	348
MACHINERY, EXCLUDING ELEC	89	92	96	100	104	108	121	154	193	246	314
ELECTRICAL MACHINERY & SU	102	101	101	100	99	99	143	210	309	439	624
MOTOR VEHICLES & EQUIPMEN	78	85	92	100	109	118	154	190	237	290	355
TRANS. EQUIP., EXCL. MTR.	100	100	100	100	100	100	100	100	100	100	100
OTHER MANUFACTURING	83	88	94	100	107	114	152	192	241	305	386
POPULATION (SERIES C-150)	89	91	96	100	103	105	131	159	186	214	244

SERIES 'E' GROWTH INDICES

(NORMALIZED TO 1973)

	1970	1971	1972	1973	1974	1975	1980	1985	1990	1995	2000
AGRICULTURE	95	97	98	100	102	103	112	121	130	140	149
FORESTRY & FISHERIES	91	94	97	100	103	106	123	142	161	182	205
MINING											
METAL	100	100	100	100	100	100	100	100	100	100	100
CRUDE PETROLEUM & NATURAL	100	100	100	100	100	100	100	100	100	100	100
NONMETALLIC, EXCEPT FUELS	95	96	98	100	102	104	113	122	132	142	152
CONTRACT CONSTRUCTION	88	92	96	100	104	109	132	160	190	224	263
MANUFACTURING	90	93	96	100	104	107	127	149	173	199	228
FOOD & KINDRED PRODUCTS	96	97	99	100	101	103	109	116	122	128	135
TEXTILE MILL PRODUCTS	100	100	100	100	100	100	100	100	100	100	100
APPAREL & OTHER FABRIC PR	100	100	100	100	100	100	100	100	100	100	100
LUMBER PRODUCTS & FURNITU	91	94	97	100	103	106	123	142	162	183	206
PAPER & ALLIED PRODUCTS	100	100	100	100	100	100	100	100	100	100	100
PRINTING & PUBLISHING	89	92	96	100	104	108	130	155	183	214	248
CHEMICALS & ALLIED PRODUC	100	100	100	100	100	100	100	100	100	100	100
PETROLEUM REFINING	100	100	100	100	100	100	100	100	100	100	100
PRIMARY METALS	100	100	100	100	100	100	100	100	100	100	100
FABRICATED METALS & ORDNA	90	93	97	100	103	107	126	146	169	193	220
MACHINERY, EXCLUDING ELEC	88	92	96	100	104	109	132	159	190	224	261
ELECTRICAL MACHINERY & SU	81	87	93	100	107	114	157	212	282	365	474
MOTOR VEHICLES & EQUIPMEN	90	93	97	100	103	107	126	146	169	194	220
TRANS. EQUIP., EXCL. MTR.	100	100	100	100	100	100	100	100	100	100	100
OTHER MANUFACTURING	86	91	95	100	105	110	137	170	207	250	299
POPULATION (SERIES E-0)	89	91	96	100	103	105	124	136	145	154	162

TABLE B.3.20

STANISLAUS COUNTY - Modesto SMSA

SERIES 'C' GROWTH INDICES

(NORMALIZED TO 1973)

	1970	1971	1972	1973	1974	1975	1980	1985	1990	1995	2000
AGRICULTURE	94	96	98	100	102	104	102	107	111	121	131
FORESTRY & FISHERIES	100	100	100	100	100	100	100	100	100	100	100
MINING											
METAL	100	100	100	100	100	100	100	100	100	100	100
CRUDE PETROLEUM & NATURAL	100	100	100	100	100	100	100	100	100	100	100
NONMETALLIC, EXCEPT FUELS	100	100	100	100	100	100	100	100	100	100	100
CONTRACT CONSTRUCTION	86	90	95	100	105	111	134	164	201	250	310
MANUFACTURING	88	92	96	100	104	109	134	164	200	250	310
FOOD & KINDRED PRODUCTS	94	96	98	100	102	104	122	144	169	201	238
TEXTILE MILL PRODUCTS	100	100	100	100	100	100	100	100	100	100	100
APPAREL & OTHER FABRIC PR	100	100	100	100	100	100	100	100	100	100	100
LUMBER PRODUCTS & FURNITU	99	99	100	100	100	101	113	132	156	185	219
PAPER & ALLIED PRODUCTS	88	92	96	100	104	109	136	166	203	251	303
PRINTING & PUBLISHING	89	92	96	100	104	108	135	168	209	263	332
CHEMICALS & ALLIED PRODUC	87	91	95	100	105	110	140	180	230	296	379
PETROLEUM REFINING	100	100	100	100	100	100	100	100	100	100	100
PRIMARY METALS	100	100	100	100	100	100	100	100	100	100	100
FABRICATED METALS & ORDNA	61	72	85	100	118	138	190	261	343	464	619
MACHINERY, EXCLUDING ELEC	90	93	97	100	104	107	115	132	145	163	184
ELECTRICAL MACHINERY & SU	85	89	95	100	106	112	152	206	279	366	481
MOTOR VEHICLES & EQUIPMEN	78	85	92	100	109	118	163	192	237	290	355
TRANS. EQUIP., EXCL. MTR.	100	100	100	100	100	100	100	100	100	100	100
OTHER MANUFACTURING	90	93	97	100	104	107	150	197	259	343	453
POPULATION (SERIES C-150)	96	97	98	100	102	104	117	131	144	156	168

SERIES 'E' GROWTH INDICES

(NORMALIZED TO 1973)

	1970	1971	1972	1973	1974	1975	1980	1985	1990	1995	2000
AGRICULTURE	96	97	99	100	101	103	110	118	126	133	141
FORESTRY & FISHERIES	100	100	100	100	100	100	100	100	100	100	100
MINING											
METAL	100	100	100	100	100	100	100	100	100	100	100
CRUDE PETROLEUM & NATURAL	100	100	100	100	100	100	100	100	100	100	100
NONMETALLIC, EXCEPT FUELS	100	100	100	100	100	100	100	100	100	100	100
CONTRACT CONSTRUCTION	88	92	96	100	104	108	131	156	184	215	250
MANUFACTURING	88	92	96	100	104	108	131	156	185	217	252
FOOD & KINDRED PRODUCTS	90	93	97	100	104	107	126	147	170	195	222
TEXTILE MILL PRODUCTS	100	100	100	100	100	100	100	100	100	100	100
APPAREL & OTHER FABRIC PR	100	100	100	100	100	100	100	100	100	100	100
LUMBER PRODUCTS & FURNITU	90	93	97	100	103	107	125	145	166	190	215
PAPER & ALLIED PRODUCTS	88	92	96	100	104	109	133	161	193	229	269
PRINTING & PUBLISHING	87	91	95	100	105	110	137	168	204	245	292
CHEMICALS & ALLIED PRODUC	86	91	95	100	105	110	137	169	207	249	298
PETROLEUM REFINING	100	100	100	100	100	100	100	100	100	100	100
PRIMARY METALS	100	100	100	100	100	100	100	100	100	100	100
FABRICATED METALS & ORDNA	90	93	97	100	103	107	126	147	169	191	221
MACHINERY, EXCLUDING ELEC	95	97	98	100	102	103	112	121	130	139	149
ELECTRICAL MACHINERY & SU	84	89	94	100	106	113	146	187	237	296	365
MOTOR VEHICLES & EQUIPMEN	91	94	97	100	103	107	124	143	164	186	210
TRANS. EQUIP., EXCL. MTR.	100	100	100	100	100	100	100	100	100	100	100
OTHER MANUFACTURING	82	88	94	100	107	111	153	204	266	347	435
POPULATION (SERIES E 0)	96	97	98	100	102	104	111	116	121	126	129

TABLE B.3.21

VENTURA COUNTY - Oxnard - Simi Valley-Ventura SMSA

SERIES 'C' GROWTH INDICES

(NORMALIZED TO 1973)

	1970	1971	1972	1973	1974	1975	1980	1985	1990	1995	2000
AGRICULTURE	87	91	96	100	105	109	118	124	130	141	153
FORESTRY & FISHERIES	100	100	100	100	100	100	100	100	100	100	100
MINING											
METAL	100	100	100	100	100	100	100	100	100	100	100
CRUDE PETROLEUM & NATURAL	95	97	98	100	102	103	115	125	137	149	163
NONMETALLIC, EXCEPT FUELS	85	90	95	100	106	111	130	152	181	215	254
CONTRACT CONSTRUCTION	89	92	96	100	104	108	126	163	212	274	355
MANUFACTURING	77	84	92	100	109	119	165	211	270	344	438
FOOD & KINDRED PRODUCTS	83	88	94	100	106	113	157	193	238	290	355
TEXTILE MILL PRODUCTS	100	100	100	100	100	100	100	100	100	100	100
APPAREL & OTHER FABRIC PR	73	81	90	100	111	123	192	254	336	435	564
LUMBER PRODUCTS & FURNITU	72	81	90	100	111	124	178	223	280	351	440
PAPER & ALLIED PRODUCTS	155	134	116	100	86	75	92	124	166	219	287
PRINTING & PUBLISHING	83	89	94	100	106	113	154	197	255	328	421
CHEMICALS & ALLIED PRODUC	77	84	92	100	109	119	177	242	328	441	592
PETROLEUM REFINING	85	90	95	100	105	111	132	157	189	226	271
PRIMARY METALS	79	86	93	100	108	117	135	161	193	229	272
FABRICATED METALS & ORDNA	76	83	91	100	110	120	158	201	258	331	424
MACHINERY, EXCLUDING ELEC	79	85	92	100	108	117	179	247	339	452	602
ELECTRICAL MACHINERY & SU	72	80	90	100	112	125	177	232	304	395	514
MOTOR VEHICLES & EQUIPMEN	100	100	100	100	100	100	100	100	100	100	100
TRANS. EQUIP., EXCL. MTR.	63	73	86	100	117	136	192	235	287	352	432
OTHER MANUFACTURING	93	96	98	100	102	105	146	191	250	327	426
POPULATION (SERIES C-150)	92	94	97	100	103	106	128	154	181	209	237

SERIES 'E' GROWTH INDICES

(NORMALIZED TO 1973)

	1970	1971	1972	1973	1974	1975	1980	1985	1990	1995	2000
AGRICULTURE	95	97	98	100	102	103	112	121	130	140	149
FORESTRY & FISHERIES	100	100	100	100	100	100	100	100	100	100	100
MINING											
METAL	100	100	100	100	100	100	100	100	100	100	100
CRUDE PETROLEUM & NATURAL	97	98	99	100	101	102	106	111	115	120	124
NONMETALLIC, EXCEPT FUELS	93	95	98	100	102	105	117	130	144	158	173
CONTRACT CONSTRUCTION	87	91	95	100	105	110	137	168	204	246	293
MANUFACTURING	87	91	96	100	105	109	135	164	198	236	279
FOOD & KINDRED PRODUCTS	90	93	97	100	104	107	126	147	170	195	222
TEXTILE MILL PRODUCTS	100	100	100	100	100	100	100	100	100	100	100
APPAREL & OTHER FABRIC PR	84	89	94	100	106	112	148	191	244	307	383
LUMBER PRODUCTS & FURNITU	86	91	95	100	105	110	138	171	209	254	304
PAPER & ALLIED PRODUCTS	84	89	94	100	106	112	147	190	242	304	377
PRINTING & PUBLISHING	86	91	95	100	105	110	138	171	209	252	302
CHEMICALS & ALLIED PRODUC	83	89	94	100	106	112	149	194	248	314	392
PETROLEUM REFINING	100	100	100	100	100	100	100	100	100	100	100
PRIMARY METALS	93	95	98	100	103	105	118	132	146	162	177
FABRICATED METALS & ORDNA	90	93	96	100	104	107	127	148	172	198	226
MACHINERY, EXCLUDING ELEC	85	89	95	100	106	111	144	184	231	287	352
ELECTRICAL MACHINERY & SU	87	91	95	100	105	110	136	167	203	244	290
MOTOR VEHICLES & EQUIPMEN	100	100	100	100	100	100	100	100	100	100	100
TRANS. EQUIP., EXCL. MTR.	93	95	98	100	102	105	118	131	145	160	175
OTHER MANUFACTURING	85	90	95	100	105	111	143	182	227	281	344
POPULATION (SERIES E-0)	92	94	97	100	103	106	120	133	145	155	163

TABLE B.3.22

EXPLANATORY NOTES FOR TABLES B.3.5 THROUGH B.3.21

Tables B.3.5 through B.3.21 are used to project stationary source emissions. The Series C and E projections are described in Section 3.1.7 of the text. The indices presented in Tables B.3.5 - B.3.21 were developed through computer programs utilizing data from references [37] and [49]. Table B.3.23 depicts an example of using the indices from Table B.3.9 to generate growth factors for Orange County. The Emission Source Categories in Table B.3.23 correspond to emission inventory categories used by the ARB. The Growth Indicator Category Indices correspond to the relationships described by Table 3.11 in the text. For example, it is assumed the Mineral Emissions Category will grow at the rate indicated by the "Mining Non-metallic, except fuels" growth index. From Table B.3.9, the "Mining Non-metallic, except fuels" growth indices for Series C and Series E are:

Orange County Growth Indices

Mining Non-metallic, except fuels	Year							
	1973	1974	1975	1980	1985	1990	1995	2000
Series C	100	97	93	119	140	164	196	233
Series E	100	102	105	118	131	145	159	174

These indices and the other appropriate indices are presented in Table B.3.23. Some time should be spent understanding the relationships between Table 3.11 of the text, Table B.3.9 of Appendix B and Table B.3.23

Study of Tables 3.11, B.3.9 and B.3.23, will reveal that only about one-third of the indices in Table B.3.9 are used in Table B.3.23. The explanation is that Table 3.11 relates only the present form of ARB emission inventory to the industry growth indices in Table B.3.5 through

B.3.21. If an available emissions inventory has greater disaggregation of emission sources, then it may be appropriate to use growth indices different to those described in Table 3.11. Table 3.12 in the text relates the industrial groupings used by OBERS to Standard Industrial Classification (SIC) codes. SIC code descriptions are presented in the Standard Industrial Classification Manual - 1972, prepared by the Office of Management and Budget and available through the U. S. Government Printing Office, Washington, D. C. (Stock number 4101-0066).

The population indices in Tables B.3.5 through B.3.21 are based on either C-150 or E-0 population projections from Department of Finance Report 74 P-2, June 1974. If a range of emission values is desired, then the use of the Series C and Series E indices for population and industry is appropriate to establish the upper and lower limits. However, if only one projection is desired, the D-100 population projection used with the Series E projection for industry is recommended. Discussion with Department of Finance staff indicates that present population trends are best described by the D-100 series.[1] The Series E industry projections are recommended because present economic trends indicate slow growth.

The remainder of this explanatory note lists specific growth indices development by computer program methods.

Methods Used to Develop Growth Indices

Growth indices of population for both C-150 and E-0 series were obtained from mid-year (July 1) population estimates by county in 1970, 1971, 1972, 1973, 1974, and 1975, and mid-year (July 1) population projections (of the C-150 and E-0 series) for 1980, 1985, 1990, 1995, and 2000. County populations for each year were totaled to produce SMSA population values for the eleven years. All SMSA populations values were then divided by the 1973 SMSA population and multiplied by 100 to produce population growth indices expressed as percentages of the 1973 population (1973 = 100%).

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[1]Staff discussion with Nels Rasmussen of the Dept. of Finance, March 1976.

Industrial growth indices for the 'C' series were obtained from OBERS industrial earnings data for 1970, 1975, 1980, 1985, 1990, and 2000 [37]. These earnings (expressed in 1967 dollars) were converted to constant dollar gross production using multiples supplied by OBERS. Production for 1971, 1972, 1973, and 1974 was determined from logarithmic interpolation between the 1970 and 1975 production values. Production for 1995 was determined from logarithmic interpolation between 1990 and 2000 production. Production figures for all eleven years were then divided by the 1973 production figure and multiplied by 100 to produce growth indices expressed as percentages of the 1973 activity (1973 = 100%). If the earning data were deleted for reasons of confidentiality, the OBERS indices were used to estimate our growth indices. If a category's earnings were zero or too small to project, all indices were set to 100 to indicate no change in activity.

Industrial growth indices for the 'E' series were obtained from OBERS industrial earnings for 1980, 1985, 1990, 2000, and 2020 [49]. These earnings (expressed in 1967 dollars) were converted to constant dollar gross production using multiples supplied by OBERS. Power curve ($Y=aX^b$) regression was applied to the five production values and the resultant coefficients used to estimate production for all eleven years, based on the growth trend for that category. Production figures for all years were then divided by the 1973 production value and multiplied by 100 to produce growth indices expressed as percentages of the 1973 activity (1973 = 100%). If a category's earnings were too small to project, all indices were set to 100 to indicate no change in activity.

TABLE B.3.23

GROWTH FACTORS FOR STATIONARY SOURCE EMISSIONS

ORANGE COUNTY - Anaheim - Santa Ana - Garden Grove SMSA

EMISSION SOURCES (Growth Indices Category)	GROWTH FACTORS[1]															
	1973		1974		1975		1980		1985		1990		1995		2000	
	'C'	'E'	'C'	'E'	'C'	'E'	'C'	'E'	'C'	'E'	'C'	'E'	'C'	'E'	'C'	'E'
PETROLEUM																
Production-(Mining-crude petroleum & natural gas)	100	100	104	101	107	102	118	106	128	111	140	115	153	120	167	124
Refining-(Manufacturing-petroleum refining)	100	100	106	104	113	108	140	129	169	152	203	178	244	207	294	238
Marketing-(Population)	100	100	104	104	106	106	125	119	146	130	165	138	180	144	193	149
ORGANIC SOLVENT USERS																
Surface Coating-(Manufacturing-composite index)	100	100	108	104	117	109	157	132	199	158	254	188	324	222	412	259
Dry Cleaning-(Population)	100	100	104	104	106	106	125	119	146	130	165	138	180	144	193	149
Degreasing-(Manufacturing-composite index)	100	100	108	104	117	109	157	132	199	158	254	188	324	222	412	259
Other-(Population)	100	100	104	104	106	106	125	119	146	130	165	138	180	144	193	149
CHEMICAL-(Manufacturing-chemical and allied products)	100	100	107	106	114	112	168	147	226	191	304	243	405	305	541	379
METALLURGICAL-(Manufacturing-primary metals)	100	100	107	102	114	104	125	115	146	126	170	137	198	149	231	161
MINERAL-(Mining or non-metallic, except fuels)	100	100	97	102	93	105	119	118	140	131	164	145	196	159	233	174
FOOD & AGRICULTURAL PROCESSING - (Manufacturing food & kindred products)	100	100	105	103	110	106	139	122	167	140	200	159	240	179	288	200
PESTICIDES-(Agriculture)	100	100	102	102	103	103	107	112	113	121	118	130	128	140	139	149
WOOD PROCESSING-(Manufacturing-lumber products & furniture)	100	100	111	104	123	108	158	132	192	158	235	188	286	221	348	258
COMBUSTION OF FUELS																
Power Plants[2]	100	100	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Other Industrial-(Manufacturing-composite index)	100	100	108	104	117	109	157	132	199	158	254	188	324	222	412	259
Domestic & Commerical-(Population)	100	100	104	104	106	106	125	119	146	130	165	138	180	144	193	149
Orchard Heaters-(Agriculture)	100	100	102	102	103	103	107	112	113	121	118	130	128	140	139	149
WASTE BURNING																
Agriculture Debris-(Agriculture)	100	100	102	102	103	103	107	112	113	121	118	130	128	140	139	149
Forest Management-(Forest & Fisheries)	100	100	100	102	100	103	120	111	130	118	141	126	155	134	171	142
Range Improvement-(Agriculture)	100	100	102	102	103	103	107	112	113	121	118	130	128	140	139	149
Dumps[3]	100	100	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Conical Burners-(Manufacturing-lumber products & furniture)	100	100	111	104	123	108	158	132	192	158	235	188	286	221	348	258
Incinerators-(Population)	100	100	104	104	106	106	125	119	146	130	165	138	180	144	193	149
Other-(Population)	100	100	104	104	106	106	125	119	146	130	165	138	180	144	193	149
MISCELLANEOUS AREA SOURCES																
Wild Fires-(Constant)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Structural Fires-(Population)	100	100	104	104	106	106	125	119	146	130	165	138	180	144	193	149
Farming Operations-(Agriculture)	100	100	102	102	103	103	107	112	113	121	118	130	128	140	139	149
Construction & Demolition-(Contract Construction)	100	100	105	104	111	108	137	130	171	155	213	183	268	215	337	249
Unpaved Roads-(Population)	100	100	104	104	106	106	125	119	146	130	165	138	180	144	193	149
Other-(Population)	100	100	104	104	106	106	125	119	146	130	165	138	180	144	193	149

[1] From Table B.3.9

[2] Special Study - Please refer to section on Fossil Fuel Electric Generating Plants.

[3] Future emissions are assumed negligible.

ACKNOWLEDGMENTS

The discussion of air quality models presented in this section utilizes significant portions of a report [28] prepared by Dr. Ronald Y. Wada. This report titled A Critical Assessment of the Role of Computer Models In Air Quality Planning and Decision-Making, discusses the technical approaches utilized in air quality modeling and the use of air quality models in planning and decision-making processes.

We wish to express our appreciation to Dr. Wada for allowing the use of his work.

SECTION 4. - AIR QUALITY MONITORING AND AIR QUALITY MODELING

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4. AIR QUALITY MONITORING AND AIR QUALITY MODELING

4.1 AIR QUALITY MONITORING SYSTEMS AND DATA BASES

The air quality monitoring program operating in California provides data necessary to meet a number of objectives [1]:

- To assess air quality in each air basin.

- To determine compliance with air quality standards and with rules pertaining to significant deterioration of air quality.

- To determine the long-term trends of air pollutant concentrations and the effectiveness of State and local control programs.

- To establish control strategies, appropriate air pollution control rules and regulations, and land use plans.

- To determine the relationship between pollutant concentrations and their effects on man, animals, vegetation, property and visibility.

- To implement air pollution episode emergency action systems and agricultural burning decisions.

These objectives, together with practical considerations, are the basic determinants of the existing monitoring network in the State of California. The practical considerations include the selection of pollutants to be monitored, the determination of the number and location of sampling sites, the selection of appropriate instrumentation, analytical techniques, sampling frequencies, and the development of applicable data handling and analysis procedures [3]. Practical considerations should also include assuring traceable calibration between different instrumental methods and station locations. The amount of funding available is in most cases the major consideration in the design, operation and expansion of monitoring networks.

4.1.1 Existing Networks

The air pollutants measured and recorded at stations in the California network include photochemical oxidants, ozone, carbon monoxide, nitrogen dioxide, nitric oxide, total oxides of nitrogen, sulfur dioxide, total hydrocarbons, methane, lead and particulate matter [4]. The types of pollutants monitored and the sampling period and frequency for these pollutants are a function of the respective ambient air quality standard, instrumentation, and agency practices. Hourly concentrations are recorded for all pollutants except suspended particulate matter, and the highest hourly value each day is recorded as the maximum-hour (or max-hour) concentration. Hourly concentrations are averaged for those pollutants with standards requiring a longer averaging period, e.g., the 8-hour standard for carbon monoxide. For suspended particulate matter, a 24-hour sampling period is used to collect data. The frequency of particulate sampling is a function of the agency. The Air Resources Board recommends a sample every sixth day; the districts vary from every sixth day to every other day [4]. The highest 24-hour concentration measured during the year and the annual geometric mean of all samples are compared with the standards to determine compliance. Samples for particulate lead analyses are collected in the same manner as suspended particulate matter samples except different filter materials are used. The ARB recommends a 3-day sampling frequency. The analyses of the samples collected during a month's period are averaged to determine compliance with the 30-day average lead standard.

Ambient concentrations of one or more gaseous pollutants are measured continuously at 131 air monitoring stations in California. Oxidants are measured at 120 stations. Samples for suspended particulate matter are collected at 189 stations [2]. The Air Resources Board operates 20 of these air monitoring stations. These stations are capable of monitoring continuously six to eight pollutants and wind direction and speed. Additionally, 18 of these stations are operated by local air pollution control districts under contract to the Air Resources Board. The locations of the stations in the State-supported network are shown in Figure 4.1. The remainder of the stations are operated as part of the local air pollution districts' control programs.

Data from all State and air pollution control district air monitoring stations are received, processed and published by the Air Resources Board. The data are published on a regular basis in quarterly reports [5] and also in special publications [6,7]. These data are also forwarded to the Environmental Protection Agency for inclusion in the Storage and Retrieval of Aerometric Data (SAROAD) System. The SAROAD System is an ambient air quality data bank maintained by the Environmental Protection Agency. SAROAD also contains information on the scope of the monitoring activities throughout the nation. Summaries of monitoring and air quality data are published annually by EPA [8].

4.1.2 Mobile Monitoring Stations and Special Studies

The Air Resources Board, the California Department of Transportation and some local air pollution control districts have mobile monitoring vans and trailers. The majority of these stations have the capability of continuously monitoring all the gaseous pollutants monitored at fixed stations. The ARB mobile stations also measure wind speed and direction.

The use of these mobile stations is a function of the operating agency. The Bay Area Air Pollution Control District uses vans for calibration of SO_2 and H_2S monitoring instruments operated by refinery companies, for surveillance of SO_2 and H_2S in complaint areas, and for areawide air monitoring purposes. These activities are listed in decreasing priority [9].

FIGURE 4.1

STATE OF CALIFORNIA
AIR RESOURCES BOARD

AIR RESOURCES BOARD SUPPORTED AIR QUALITY MONITORING NETWORK

The Air Resources Board uses vans for special studies to [10]:

-- Fulfill obligations to monitor air quality in all air basins in the state.

-- Determine optimal location of fixed stations by identifying peak concentration points.

-- Complement existing fixed station monitoring systems (emergency episodes).

-- Crosscheck existing monitoring station data.

-- Audit local air pollution control district monitoring stations.

-- Participate in enforcement and complaint investigation activites.

The residence time of the Air Resources Board mobile stations at any site ranges from 2 to 6 weeks depending on the objectives of the study. The air quality data obtained from these special ARB studies are published in the quarterly air quality data reports of the Air Resources Board [11].

4.1.3 Criteria for the Number of Monitoring Stations

The U.S. Environmental Protection Agency has promulgated regulations concerning air monitoring in all Air Quality Control Regions (AQCRs). These regulations specify what pollutants are to be monitored and the minimum number of monitoring stations [12].

The minimum number of stations and the pollutants to be monitored for the AQCRs in California are given in Table 4.1. Table 4.1 also gives the number of monitoring sites in existence in 1973 and 1975. The number of monitors required depends on the Priority Classification, i.e.,

TABLE 4.1

SUMMARY TABLE OF AIR QUALITY MONITORING SYSTEMS BY AIR BASIN(a)

Air Basin	Pollutant	Priority Classification Using 1974 Air Quality Data(b)	Monitors Required	Monitors in Use 1973	Monitors in Use 1975	Additional Monitors Required
North Coast	Particulate	I	5 Hi-Vol 1 Tape sampler	21 Hi-Vol 5 Tape	14 Hi-Vol 2 Tape	-- --
	SO_2	III	1 Bubbler	0	1 Bubbler	--
	CO	III	0	0	1	--
	NO_2	III	0	1	0	--
	O_x	III	0	1	0	--
San Francisco Bay Area	Particulate	II	3 Hi-Vol 1 Tape	19 Hi-Vol 23 Tape	21 Hi-Vol 23 Tape	-- --
	SO_2	III	1 Bubbler	11 Cont. 3 Bubbler	11 Cont. 24 Bubbler	--
	CO	I	8	15	17	--
	NO_2	III	0	3 Bubbler 13 Cont.	4 Bubbler 17 Cont.	-- --
	O_x	I	8	22	27	--
North Central Coast	Particulate	I	7 Hi-Vol 2 Tape	9 Hi-Vol 7 Tape	5 Hi-Vol 5 Tape	2 Hi-Vol --
	SO_2	III	1 Bubbler	0	1 Bubbler	--
	CO	III	0	4	3	--
	NO_2	III	0	5	4	--
	O_x	I	2	7	0	--

TABLE 4.1 (continued)

Air Basin	Pollutant	Priority Classification Using 1974 Air Quality Data(b)	Monitors Required	Monitors in Use 1973	Monitors in Use 1975	Additional Monitors Required
South Central Coast	Particulate	II	3 Hi-Vol 1 Tape	2 Hi-Vol 1 Tape	3 Hi-Vol 2 Tape	-- --
	SO_2	III	1 Bubbler	0	0	1 Bubbler
	CO	III	0	1	1	--
	NO_2	III	0	1	2	--
	O_x	I	1	2	2	--
South Coast	Particulate	I	28 Hi-Vol 8 Tape	38 Hi-Vol 11 Tape	41 Hi-Vol 21 Tape	-- --
	SO_2	II	1 Continuous 3 Bubbler	20 Cont. 4 Bubbler	24 Cont. 7 Bubbler	-- --
	CO	I	11	30	35	--
	NO_2	I	10	33 Cont. 4 Bubbler	35 Cont. 7 Bubbler	--
	O_x	I	11	31	48	--
San Diego	Particulate	I	11 Hi-Vol 6 Tape	3 Hi-Vol 3 Tape	8 Hi-Vol 6 Tape	3 Hi-Vol --
	SO_2	III	1 Bubbler	3 Cont. 1 Bubbler	5 Cont. 1 Bubbler	-- --
	CO	I	3	3	7	--
	NO_2	III	0	1 Bubbler 3 Cont.	1 Bubbler 7 Cont.	-- --
	O_x	I	3	6	8	--

TABLE 4.1 (continued)

Air Basin	Pollutant	Priority Classification Using 1974 Air Quality Data(b)	Monitors Required	Monitors in Use 1973	Monitors in Use 1975	Additional Monitors Required
Northeast Plateau	Particulate	I	4 Hi-Vol 0 Tape	5 Hi-Vol 1 Tape	10 Hi-Vol 1 Tape	-- --
	SO_2	III	1 Bubbler	0	1 Bubbler	--
	CO	III	0	0	0	--
	NO_2	III	0	0	0	--
	O_x	III	0	0	0	--
Sacramento Valley	Particulate	II	3 Hi-Vol 1 Tape	16 Hi-Vol 6 Tape	27 Hi-Vol 7 Tape	-- --
	SO_2	III	1 Bubbler	1 Bubbler	2 Bubbler	--
	CO	I	3	4	4	--
	NO_2	III	0	4 Cont. 1 Bubbler	5 Cont. 1 Bubbler	-- --
	O_x	I	3	5	7	-- --
San Joaquin Valley	Particulate	I	12 Hi-Vol 7 Tape	18 Hi-Vol 11 Tape	29 Hi-Vol 12 Tape	-- --
	SO_2	III	1 Bubbler	0 Cont. 1 Bubbler	2 Cont. 1 Bubbler	-- --
	CO	I	4	7	9	--
	NO_2	III	0	5 1 Bubbler	7 Cont 1 Bubbler	-- --
	O_x	I	4	9	12	--
Great Basin Valleys	Particulate	I	4 Hi-Vol 0 Tape	3 Hi-Vol 0 Tape	1 Hi-Vol 0 Tape	3 Hi-Vol --
	SO_2	III	1 Bubbler	0	1 Bubbler	--
	CO	III	0	0	0	--
	NO_2	III	0	0	0	--
	O_x	III	0	0	0	--

TABLE 4.1 (continued)

Air Basin	Pollutant	Priority Classification Using 1974 Air Quality Data(b)	Monitors Required	Monitors in Use 1973	Monitors in Use 1975	Additional Monitors Required
Southeast Desert	Particulate	I	7 Hi-Vol 2 Tape	8 Hi-Vol 3 Tape	14 Hi-Vol 8 Tape	-- --
	SO_2	III	1 Bubbler	2 Cont.	2 Cont.	--
	CO	III	0	6	6	--
	NO_2	III	0	4 Cont.	4 Cont.	--
	O_x	I	2	4	9	--
Mountain Counties	Particulate	III	1 Hi-Vol 0 Tape	8 Hi-Vol 0 Tape	15 Hi-Vol 1 Tape	-- --
	SO_2	III	1 Bubbler	0	0	1 Bubbler
	CO	III	0	0	1	--
	NO_2	III	0	0	0	--
	O_x	III	0	0	1	--
Lake County	Particulate	III	1 Hi-Vol 0 Tape	1 Hi-Vol 0 Tape	2 Hi-Vol 0 Tape	
	SO_2	III	1 Bubbler	0	1 Cont.	--
	CO	III	0	0	0	--
	NO_2	III	0	0	0	--
	O_x	III	0	0	0	--

(a) From Air Quality Engineering Unit, Division of Technical Services, Air Resources Board. July 9, 1975, November 3, 1975.

(b) Reference: Federal Register, Vol. 36, No. 158 - Saturday, August 14, 1971.

I, II, or III. These classification criteria consider the maximum pollutant concentrations recorded in the AQCR with a classification of Priority I indicating higher levels of pollution.

It should be noted that the existing monitoring system in most areas of California greatly exceeds the minimum requirements of the Environmental Protection Agency [13].

4.1.4 Criteria for Locating Monitoring Stations

The placement or location of sampling stations in a network must be such that the data obtained by the stations will be of value in meeting the stated objectives of the monitoring program. With this in mind, the following criteria have been identified [3]. The different criteria reflect the different objectives of monitoring activities and a proposed monitoring site will not meet all criteria.

Criteria 1. Monitoring stations must be pollution oriented

> It is most important that areas most heavily polluted be identified and monitored. It is in these areas that progress toward meeting ambient air quality standards is most critical.

Criteria 2. Monitoring stations must be population oriented

> A portion of the network must be located according to the population distribution. This is particularly important during times of air pollution alerts and episodes.

Criteria 3. Sampling stations must be located to provide areawide representation of ambient air quality

> Data must be representative of the entire Air Quality Control Region. Areawide data is needed to show conformity to the ambient air quality standards. This includes both developed and undeveloped areas within the region. In the nonurban areas, increased consideration should be given to those areas where future land development is anticipated.

Criteria 4. Ambient monitoring stations must not be source or source category oriented

In ambient monitoring, every effort is made to avoid a source oriented exposure unless the source influences a significant section of the public. However, a control regulation limiting the emissions from certain industrial activities would require that stations be located where compliance with the regulation can best be evaluated. This type of monitoring is set up at stack level or ground level as required under the applicable rules and regulations. Data collected from source testing by the Air Resources Board is not regularly published.

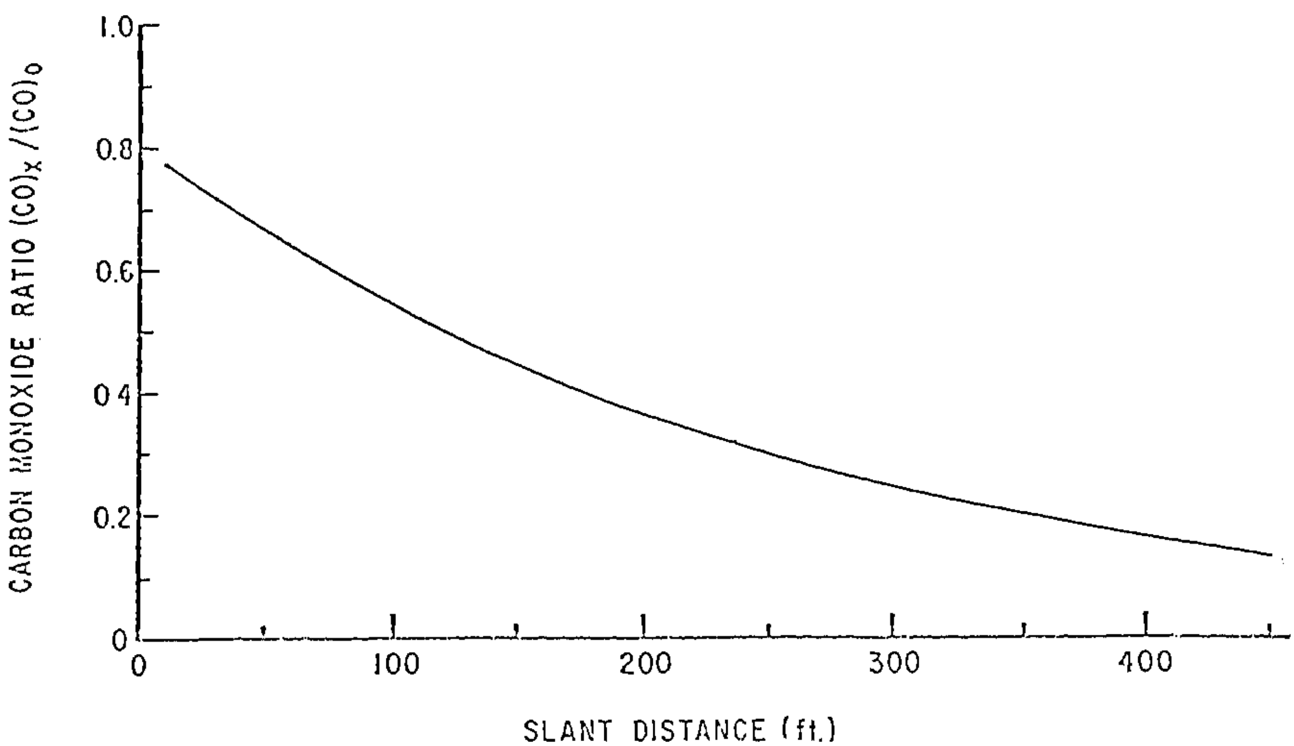
The air quality monitoring network should then comprise stations reflecting one or more of the above criteria. It should contain stations that are situated primarily to monitor the highest levels in the region, to measure population exposure, to measure pollution generated by specific classes of sources and to record the nonurban levels of pollution. In many cases a given station location will be capable of meeting more than one of the listed criteria, i.e., a station located in a densely populated area, besides measuring population exposure, will also monitor the effectiveness of controls on emissions from certain industrial activities if such emissions controls are part of the overall control strategy.

The preceding discussion would imply that monitoring systems are designed and established after a comprehensive, regionwide analysis of needs, objectives, and resources. This is not the case. The existing air quality monitoring network in the state has been developed in an incremental fashion. Different agencies throughout the state establish stations based on different site selection and monitoring criteria. The main reasons that have governed the location of a station were convenience and availability of a site rather than the selection of a location which had a definite purpose of determining the air quality of a particular area or layer of the atmosphere. The height above ground level of a station seemed to be unimportant. Many agencies still report air monitoring data as if all of the stations have the same physical characteristics with respect to height, area, sample collection methods, and calibration procedures [14].

4.1.5 Influence of Monitoring Site Location

The impact that site location can have on air quality data is shown by the plot of carbon monoxide concentration vs. slant height in Figure 4.2 [15]. (Slant height is the "line of sight" distance from the sampling probe inlet to the nearest motor vehicle traffic.)

FIGURE 4.2



RATIO OF CO CONCENTRATIONS VS DISTANCE FROM FREEWAY

" DEPRESSED SECTION " ALL STABILITY CLASSES

SOURCE: (15)

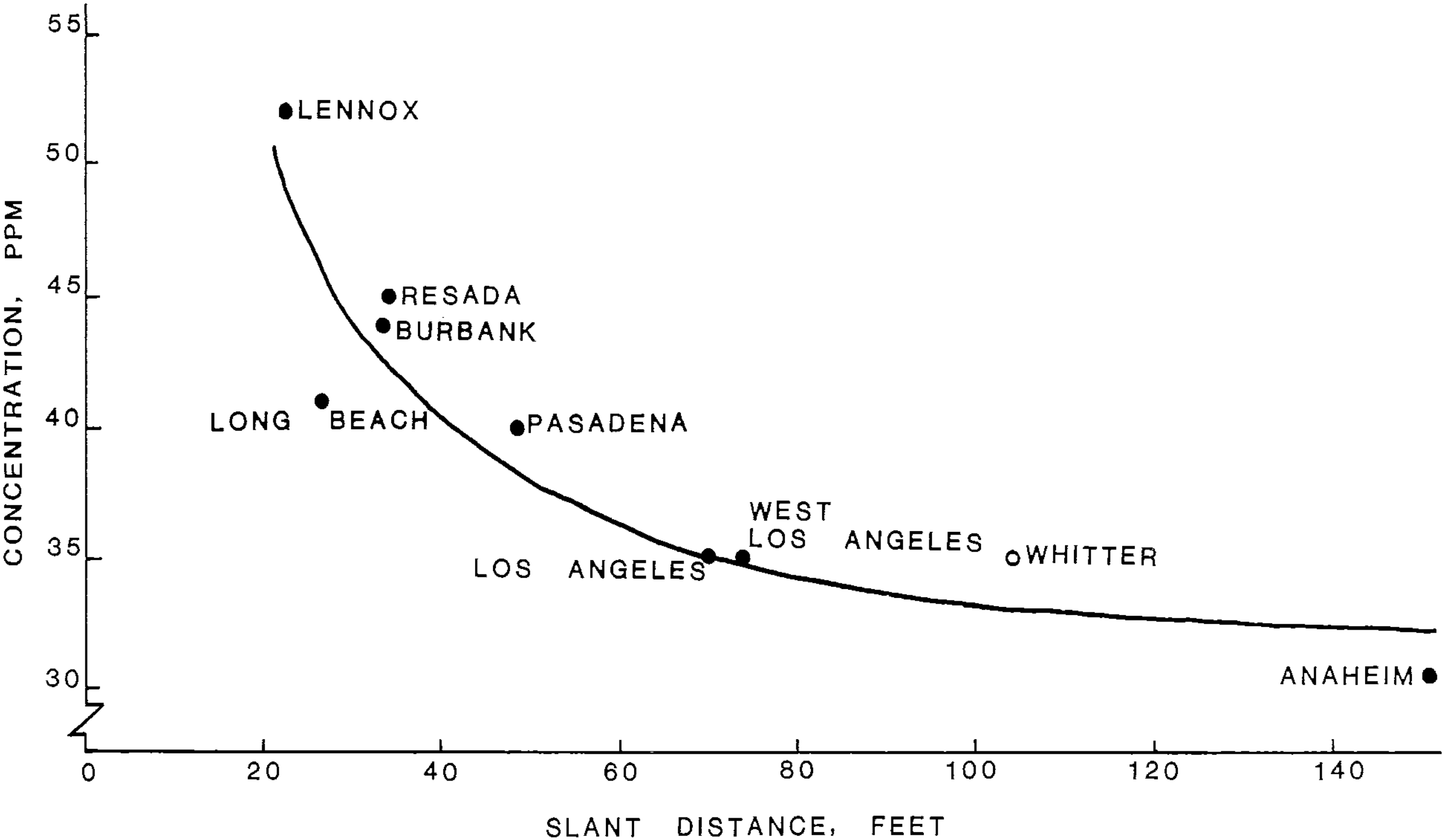
In Figure 4.2, $(CO)_o$ represents concentrations of carbon monoxide measured four feet above the highway median. $(CO)_x$ represents carbon monoxide concentrations measured at select distances from the median. The ratios $(CO)_x/(CO)_o$ are plotted to indicate the dependence of carbon monoxide concentrations on slant height. Figure 4.2 indicates a decreasing carbon monoxide concentration with increasing distance from the roadway.

This is an intuitively obvious relationship known for many years that has not been considered in reporting carbon monoxide data. This relationship between CO concentration and slant height is normally considered when establishing a monitoring site. The sampling probe must be set back a minimum distance from vehicular activity to avoid undue influence. However, the degree to which the slant height factor has been considered in the location of existing stations is uncertain. Also, the influence that slant height has on air quality data presently being recorded at these existing stations is also uncertain.

Figure 4.3, which presents a plot of 3-year maximum hourly averages of CO concentrations versus slant height [16], indicates an inverse relationship between average CO concentrations and slant height, i.e., increasing slant heights resulting in decreasing average concentrations. There are other factors that are unique to each monitoring site and that influence the CO concentrations recorded, e.g., motor vehicle activity and meteorological processes. However, the influence of slant height on existing air quality CO data is clearly demonstrated in Figures 4.2 and 4.3.

Research studies have been completed identifying a technique for quantifying the influence of slant height on CO concentrations and for adjusting CO air quality data to reflect this influence [15]. However, it is unlikely that an adjustment factor for CO data will be incorporated into air quality data banks. Since the needs of various users differ,

FIGURE 4.3



AVERAGES OF THE 1969-1970 ANNUAL MAXIMUM HOURLY CO CONCENTRATIONS AND SLANT DISTANCES AT AIR MONITORING STATIONS

SOURCE: (16)

it is considered more valuable to report unadjusted data and allow the individual users to make the adjustments for their particular needs [4]. Unfortunately, this approach requires a degree of expertise and familiarity with air monitoring practices and data that is seldom found in planning agencies.

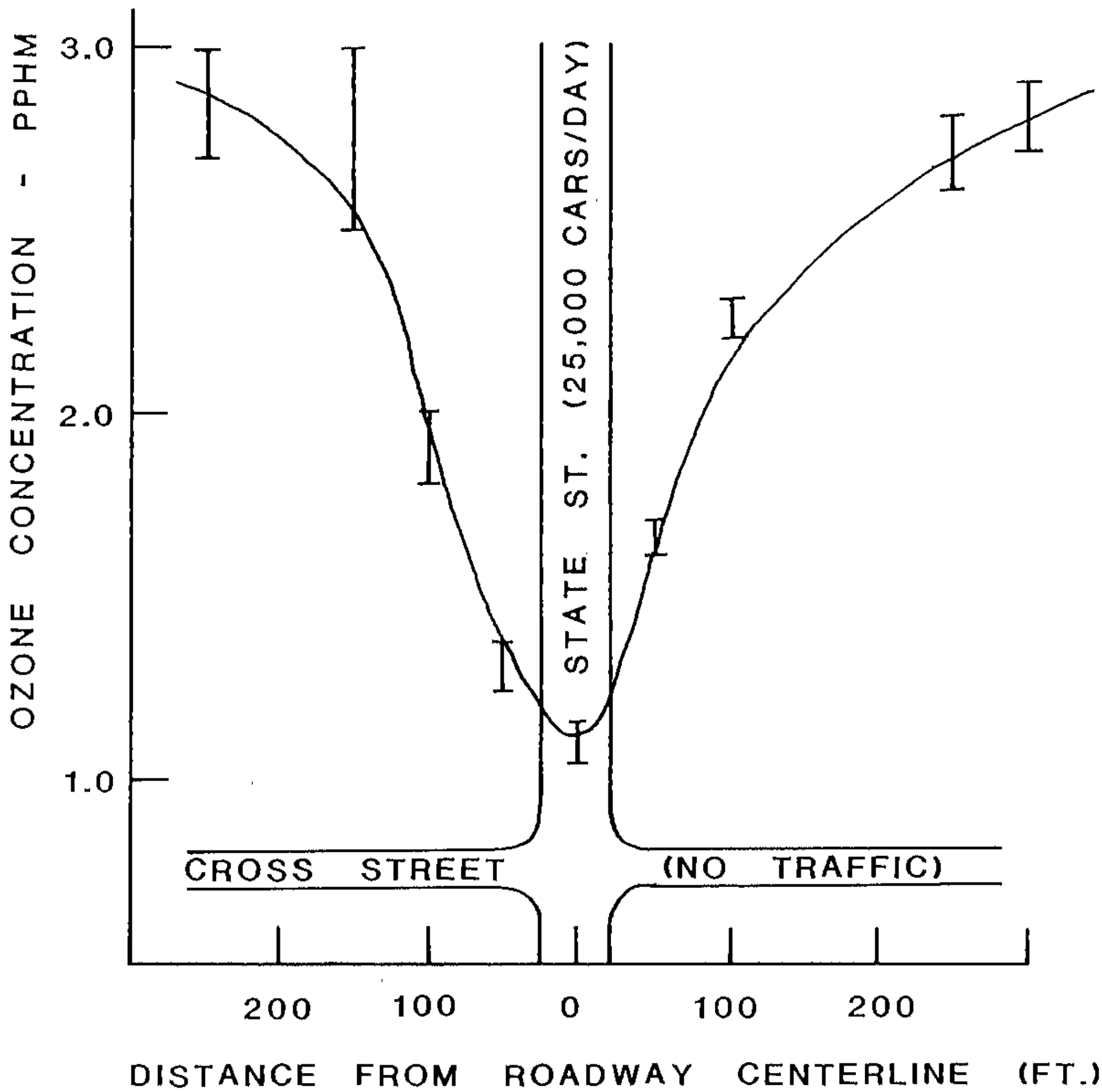
Another phenomenon which demonstrates the influence of monitoring site location on air quality data is the ozone depression experienced near heavily traveled roadways [17].

Unburned organic gases and nitrogen oxides combine under the action of sunlight to produce ozone in smog. The production of ozone by the photochemical reactions is a relatively slow process. Studies in smog chambers have shown that the ozone level does not rise until most of the available nitric oxide has disappeared by reaction. The reaction $NO + O_3 = NO_2 + O_2$ is responsible for this behavior. That reaction is so fast that ozone and nitric oxide cannot co-exist in any appreciable concentrations. This process is known as scavenging of ozone (O_3) by nitric oxide (NO).

Fresh vehicle exhaust, which contains high concentrations of nitric oxide, reduces ozone concentrations. Near roads, in areas of high traffic density or where exhaust fumes are trapped, the ozone level drops to very low values. This effect is demonstrated in Figure 4.4 which shows ozone concentrations as a function of perpendicular distance from a roadway [17]. The results shown in Figure 4.4 should be considered qualitative since the concentrations shown approach the level of sensitivity of the instrument used to measure oxidant [18].

This scavenging effect must be considered in locating fixed air monitoring stations. To obtain valid measurements of ozone (or oxidants since ozone is the principal constituent of oxidants), monitoring sites should be located well away from sources of nitric oxide such as power plants and heavily traveled roadways.

FIGURE 4.4



MEASURED OZONE CONCENTRATIONS AS A FUNCTION OF PERPENDICULAR DISTANCE FROM A BUSY STREET. DATA FROM STATE STREET AND CALLE LAURELES, SANTA BARBARA, CALIFORNIA. SOURCE: (17)

In summary, air quality monitoring stations are pollutant oriented resulting in a bias in the concentrations measured [11]. Monitoring stations are characterized as being oriented for primary pollutants or oriented for secondary pollutants. Since air quality data from different stations are influenced by a combination of variables unique to each station, care should be exercised when making comparisons of air quality data from different monitoring stations.

4. AIR QUALITY MONITORING AND AIR QUALITY MODELING

4.2 AIR QUALITY MODELING

4.2.1 Introduction

Air quality modeling is a systematic method for quantitatively relating pollutant emissions from sources to pollutant concentrations at receptors. This involves either analytical approaches based on the theoretical treatment of atmospheric dispersion and transport or empirical approaches based on relationships deduced from observed emissions and air quality data. The analytical models are commonly termed dispersion models and the empirical models are called statistical models.

In its simplest form, a model relates ambient pollutant concentrations (x) to pollutant source emission rates (Q) and a background concentration (b),

$$x = KQ + b$$

The variable K is a function of atmospheric conditions and the spatial relationships between a source and a receptor. Depending on the sophistication of the model, K can be highly complex or very simple.

The development and application of air quality models requires careful evaluation of the situation and the models available to insure selection of the best approach. Air quality models are at a stage of development such that no model is capable of completely simulating the many possible interactions of pollutant emissions and meteorological processes. Many models are well suited for particular applications and a variety of techniques can be used to satisfy a particular application.

It is unlikely that any one model will be acceptable or appropriate for all applications in a given region. Optimally, a variety of techniques should be available. The choice of any one of the alternatives depends primarily on the quality of the input data, the budgetary resources of the user, and the nature of the problem to be investigated. The components of an air quality model are shown in Figure 4.5. As illustrated, a model comprises four major inputs that include the following areas:

1. Emissions assessment;
2. meteorological processes;
3. topography; and
4. applicable chemical reactions.

A geocoded emissions inventory provides the pollutant data base for an air quality model. These data must identify emission quantities along with spatial and temporal distributions. Meteorological processes constitute the basic dynamic framework for predicting pollutant concentrations in the atmosphere. In general, climatic summaries provide a data base for operating the model and specifying expected conditions for a certain time or place. Specific meteorological data are used to simulate particular situations such as pollutant episodes. The fluid flow of atmospheric processes is sensitive to topographic features. Hills obstruct the flow, while valleys channel wind movement. Buildings and similar structures obstruct winds and complicate the prediction of pollutant movement. Many of the chemical reactions between pollutants and atmospheric constituents are a complex function of particular pollutants and meteorological processes.

The current field of air quality models covers a wide spectrum from the very simple proportional model to very complex and costly regional photochemical air quality models. The following sections cover the basic theory and approaches of air quality modeling, specific modeling techniques, and examples of the very simple proportional model. The following discussions are at times very technical. If interest is waning, go to Section 4.2.6 on Statistical Models. This is the suggested minimum reading on air quality modeling. It should be pointed out that the proportional model, the simplest of all models, has been the technique for almost all air quality control strategy evaluation completed to date. Consequently, familiarity with this model is essential.

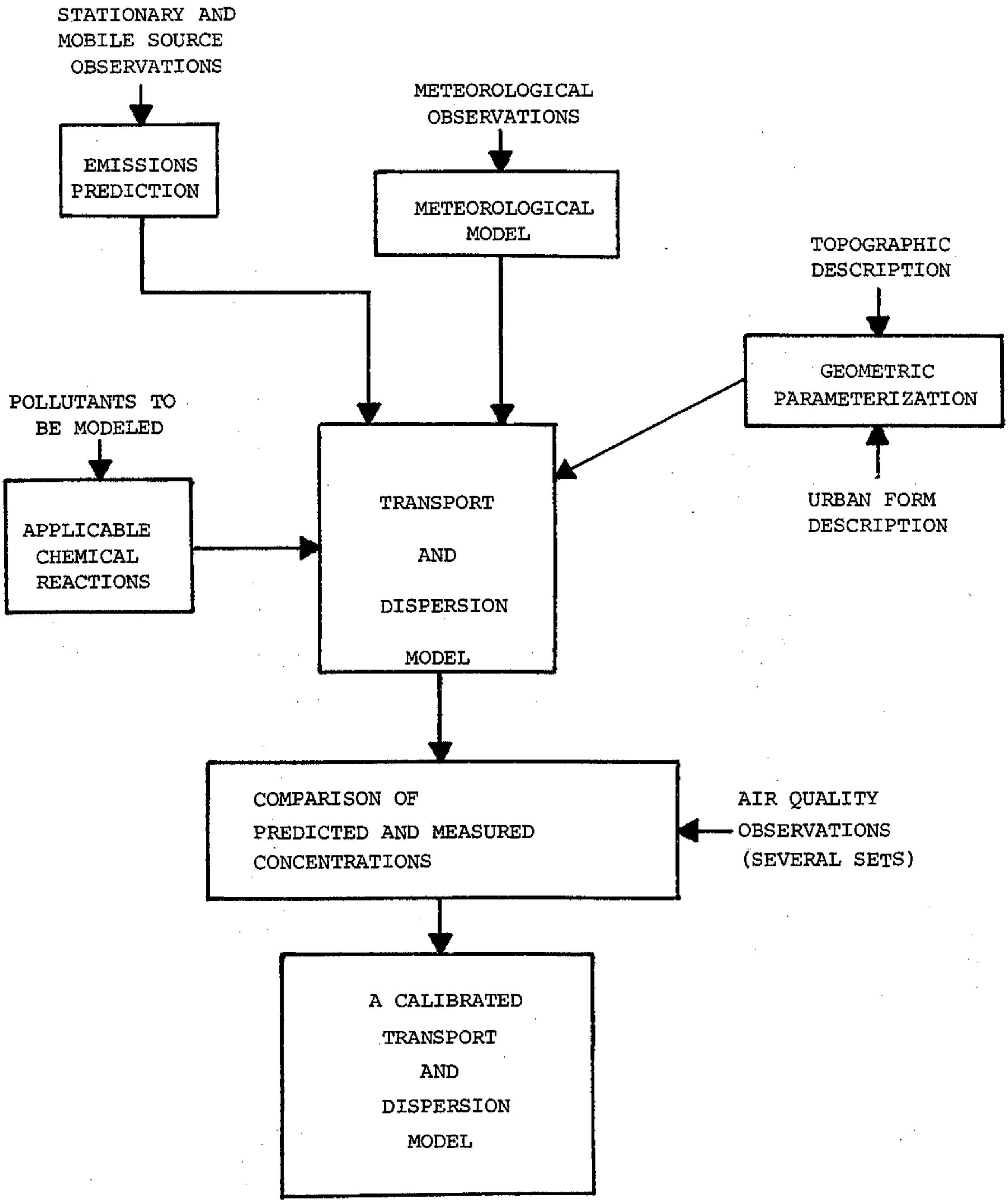


FIGURE 4.5
Components of an Air Quality Model

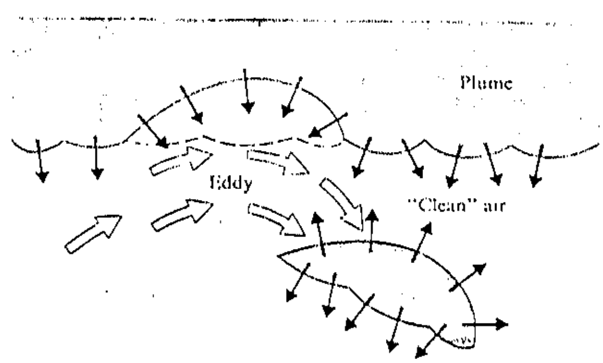
4.4.2 General Theory

Air quality models are designed to simulate the action of the atmosphere in mixing, modifying, and transporting pollutants. Pollutants are mixed by the physical process of turbulent dispersion.

When a stream of exhaust gases (a plume) is released into the atmosphere, small eddies of air act on the edge of the plume to mix the pollutants with the surrounding air (Figure 4.6). The edge of a plume has a large gradient (difference) in concentration between it and the ambient air.

FIGURE 4.6

TURBULENT DISPERSION



Grossly simplified view of how a turbulent eddy breaks up a plume and causes rapid mixing of pollutants with ambient "clean" air.

SOURCE: (20)

Pollutants will mix with the ambient air across this gradient by two processes. Mixing by molecular diffusion occurs by the interaction of pollutant molecules with air molecules. This is indicated by the thin arrows in Figure 4.6. Another more important mechanism for mixing and transporting pollutants is turbulent motion. The eddies associated with this turbulent motion affect sizeable volumes of the plume. A parcel of the plume moved by a turbulent eddy is shown in Figure 4.6. Turbulent eddies will produce a much more rapid mixing of the plume than molecular diffusion. For this reason, molecular diffusion is usually ignored in any analysis of pollutant dispersion.

In the process of turbulent motion, pollutants are modified by chemical as well as physical processes. These can be simulated by kinetic mechanisms comprising sets of chemical equations. The transport of pollutants is a function of regional winds, temperature inversions, and topographic features. Transport phenomena are usually accounted for in models by the specification of regional wind patterns based on wind observation data.

The set of equations governing the behavior of a fluid system such as the atmosphere consists of the conservation equations for mass, momentum (Navier-Stokes equations), and energy. In the most general case these equations are coupled as well as nonlinear, thus posing a formidable computational problem. In the case of air pollution, if it is assumed that the presence of the pollutants does not alter the behavior of the atmosphere on the scales of interest, then the conservation of mass equation becomes decoupled from the others. This assumption is quite valid in most cases. Only very high concentrations of NO_2 or particulate matter (~several ppm for NO_2, ~several hundred ug/m^3 for particulates) result in a significant perturbation of the flow field due to their influence on the radiative exchange processes of the ambient atmosphere. Further, if the atmospheric flow field is described by a combination of empirical observations such as wind and stability data, and reasonable assumptions are made to fill data gaps, the momentum and energy equations may be eliminated from consideration.

After appropriate assumptions and manipulations, the conservation of mass equation may be written to represent the basic transport-dispersion processes of the atmosphere as follows:

$$\frac{\partial C_i}{\partial t} + u\frac{\partial C_i}{\partial x} + v\frac{\partial C_i}{\partial y} + w\frac{\partial C_i}{\partial z} = \frac{\partial}{\partial x}\left(Kx\frac{\partial C_i}{\partial x}\right) + \frac{\partial}{\partial y}\left(Ky\frac{\partial C_i}{\partial y}\right) \quad (1)$$

$$+ \frac{\partial}{\partial z}\left(Kz\frac{\partial C_i}{\partial z}\right) + [\pm R_i\,(C_i,\ldots, Cn)] + (\pm S_i)$$

Where,

t = time

x,y,z = Cartesian coordinates

u,v,w = components of the mean wind velocity in each of the coordinate directions respectively

K_x, K_y, K_z = eddy diffusivity coefficients in each direction that are related to temperature stability, wind shear, surface roughness and convective heat flux

R_i = rate of generation of the i-th pollutant by chemical reactions and may be a function of the concentrations of other pollutants

S_i = net source term which considers both emissions and losses by deposition

$\frac{\partial C_i}{\partial t}$ = change in concentration of pollutant C with respect to time

$\frac{\partial C_i}{\partial x}$ = change in concentration of pollutant C_i with respect to distance in the x direction. The other partial derivatives ($\partial C_i/\partial y$ and $\partial C_i/\partial z$) indicate similar relationships

The concentration C_i of each of the $i = 1,\ldots, n$ pollutants considered may be written as an equation of this form.

The change of concentration with time is expressed in the first term of the dispersion equation. Steady-state solutions are obtained by models which assume this term ($\partial C_i/\partial t$) to be zero, i.e., no change in concentration with time. The next three terms represent the advection or transport of pollutants by the mean winds. The first three terms on the right hand side of the equation allow for pollutant dispersion by turbulence. The last two terms account for the generation of the pollutant, the emission into the atmosphere and the losses by chemical reaction, deposition, etc. This equation and its associated boundary conditions form the basis for all the dispersion models discussed in this report. Figure 4.7 presents a schematic representation of this basic equation.

In the case of air pollution, since it is assumed that the presence of the pollutants does not alter the behavior of the atmosphere, the dispersion equation is decoupled from the equations governing atmospheric motions. Once u, v, w, K_x, K_y, and K_z are specified, the dispersion relation may be solved.

The derivation of the parameters mentioned above and effects of the atmosphere on other aspects of pollutant dispersal are discussed in the section on meteorology submodels. The following sections discuss the solution techniques utilized to solve the dispersion and transport relationships once the atmospheric parameters are specified.

4.2.3 Dispersion Models

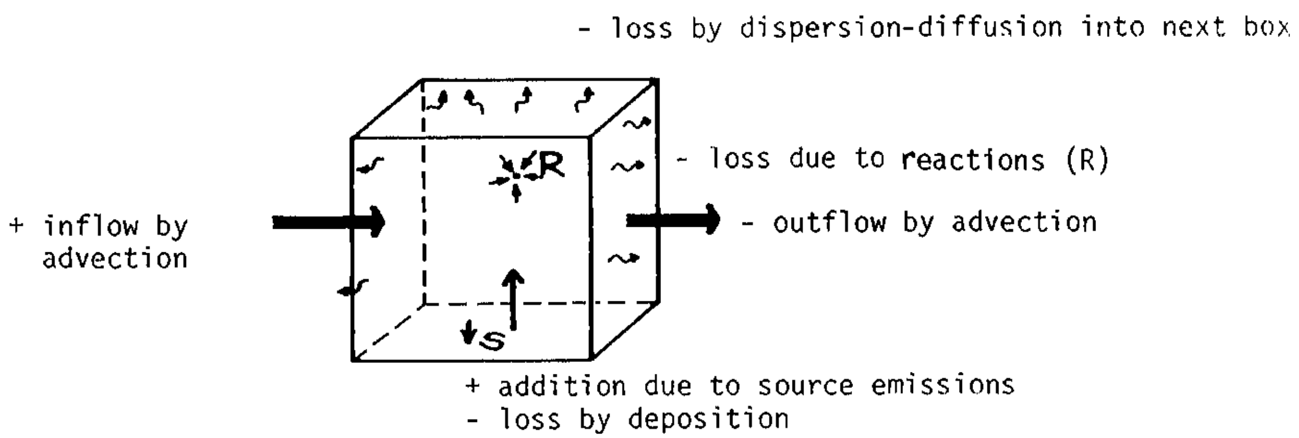
Dispersion models are generally differentiated by the approach utilized for solution of the dispersion and transport relationships shown in Equation 1. Assumptions inherent in deriving the solutions limit the range of cases that can be handled. Before any individual model is used, the assumptions involved in the derivations and the limitations of each model type must be understood. The basic types of dispersion models and their assumptions, formulations, and input requirements are presented after a brief discussion of sources, scales of analysis, and coordinate systems.

There are three general configurations of emission sources: point sources, line sources, and area sources. Point sources, as the name implies, emit pollutants from one specific point in space. Power plants, sulfuric acid plants, and incinerators are examples of point sources. Line sources are an idealized situation in which pollutants are emitted

FIGURE 4.7

REPRESENTATION OF THE BASIC TRANSPORT - DISPERSION EQUATION

The change in concentration in a given time equals the sum of:



at a constant and uniform rate along a line. Freeways and heavily-traveled streets are treated as line sources for dispersion modeling. The area source approximation is used when numerous small point and line sources result in uniform emissions from an area. Urban areas and large parking lots have been idealized as area sources for dispersion modeling. Typical units for the emission rates from these source configurations are given below:

Point sources	grams/second
Line sources	grams/meter-second
Area sources	grams/meter^2-second

The scales of analysis for air quality modeling of interest in land use planning are the microscale and the mesoscale. Microscale analysis deals with the localized impact of a single source or a group of sources. The methodology for microscale air quality estimates is based on the Gaussian dispersion model and is usually applied only to point and line sources. The study area for a microscale analysis ranges from 1 to 10 kilometers across in the direction of the average wind. A mesoscale or airshed analysis is regional in scope and is normally used when the area source approximation is being made. A coordinate system is used to delineate grid squares for a study area (e.g., a checker board pattern) and area source emission rates for each grid square are identified. This allows the use of a simple model for estimating the dispersion of pollutants. When emissions are not assigned to grids, they are assumed to be uniformly distributed throughout the study area.

One of the basic differences between individual mesoscale models is the choice of the coordinate system to be employed. Airshed models may be classified according to the type of coordinate system used. The first type of model employs a coordinate system which is fixed with respect to the ground. It is known as an Eulerian coordinate system. The second type attaches its coordinate system to a fictitious vertical air column which moves horizontally in the direction of the large scale winds. This form is often called the Lagrangian Model.

The more common coordinate system is the Eulerian frame in which sources are located, winds are described, and concentrations are computed or measured at specific points in a fixed grid. However, the dispersion part of the pollution problem is more naturally formulated in terms of a moving air parcel or Lagrangian reference frame. Some models attempt to use this method. Since sources are more easily described in a fixed frame, and conservation of mass is more difficult to express in Lagrangian coordinates, moving cell models incorporate a quasi-Lagrangian coordinate set.

The meteorological factors in many situations are the most important variables in air quality estimates. Consider the fact that for a given year, the total daily emissions into the atmosphere from a region are essentially the same and that the day to day differences in air quality for that region depend entirely on the differences in meteorology. Wind behavior is almost invariably separated into two parts for modeling. Relatively large scale motions are described as transporting the pollution from sources to receptor. Relatively small scale motions are described as dispersing and mixing the pollutant as it is transported. Additional meteorological considerations include mixing layer, atmospheric stability, and solar radiation.

To be meaningful, estimates of air quality must be given in terms of pollutant concentration and averaging time. When estimates are given with averaging times identical to those of the ambient air quality standards, direct comparisons with the standards are possible. However, several methodologies for estimating air quality result in estimates with averaging times different than the standards. To compare these estimates with the standards, they must be converted to the same averaging time. The mathematical technique for this conversion, known as Larsen's model, is discussed later in this section.

4.2.3-1 The Gaussian Formulation

Historically, efforts to further simplify the basic dispersion equation (Equation 1) so that it could be solved analytically have resulted in the familiar Guassian plume formulation. The assumptions utilized by Turner [19] in the development of solutions for the Guassian dispersion model for point, line, and area sources are given below:

1) The average wind direction determines the x-axis and the average wind speed used is representative of the mixing layer.

2) There is continuous and constant emission from the source, or the period of emission is equal to or greater than the travel time to the downwind position of interest, so that dispersion in the direction of transport may be neglected, i.e.,

$$\frac{\partial C_i}{\partial x} > K_x \frac{\partial^2 C_i}{\partial x^2} \qquad \text{and } S_i \text{ is constant.}$$

3) The pollutant being diffused is a stable gas or particulate matter less than 20 microns diameter which remains suspended in the air over long periods of time, i.e., $R_i = 0$.

4) Except where specifically mentioned, the plume constituents are normally distributed in both the cross wind and vertical directions.

5) The equation of continuity is fulfilled, i.e., none of the pollutant emitted is removed from the plume as it moves downwind and there is complete reflection at the ground.

6) The standard deviations (σ's) used by Turner represent time periods of about 10 minutes and are empirically derived parameters of the atmosphere's ability to disperse the plume constituents.

Based on the above assumptions, Equation 1 is simplified to the following form:

$$u \frac{\partial C_i}{\partial x} = K_y \frac{\partial^2 C_i}{\partial y^2} + K_z \frac{\partial^2 C_i}{\partial z^2} + S_i \qquad (2)$$

The substitution of $\sigma_y(x)^2 = 2K_y\frac{x}{\bar{u}}$ and $\sigma_z(x)^2 = 2K_z\frac{x}{\bar{u}}$ yields a solution for a point source at ground level with the following form:

$$C_i = \frac{S_i}{\pi \bar{u} \sigma_y \sigma_z} \exp - 1/2 \left[\frac{Y^2}{\sigma_y^2} + \frac{Z^2}{\sigma_z^2}\right] \qquad (3)$$

Where,

C_i = concentration of pollutant at receptor

S_i = emission rate of pollutant i

X,Y,Z = coordinate values for receptor (Figure 4.8)

$\bar{u}$ = mean wind speed

σ_y, σ_z = empirically derived measures of the eddy diffusivity (K_y,K_z) of the atmosphere, i.e., how well the atmosphere can disperse the pollutants.

The important features [19] of Equation 3 which apply to a point source at ground level, are:

1. The downwind concentration at any location is directly proportional to the emission rate of the sources.

2. The more turbulent the atmosphere, the more rapid the spread of the plume in the transverse direction. Turbulence increases the eddy diffusivities K_y and K_z.

3. The maximum concentration at ground level is found directly downwind, on the plume line, and is inversely proportional to the downwind distance from the source.

4. The maximum concentration decreases with higher wind speeds, $\bar{u}$. Even on the plume line, where at ground level there is no explicit dependence on $\bar{u}$ (because σ_y and σ_z are inversely proportional to $\bar{u}$), concentrations will actually decrease with increasing wind. This is because the eddy diffusivity K in the equation above increases with wind speed due to increased mechanical turbulence.

These are the four key features of most Guassian models used to describe the dispersion of emissions from a point source.

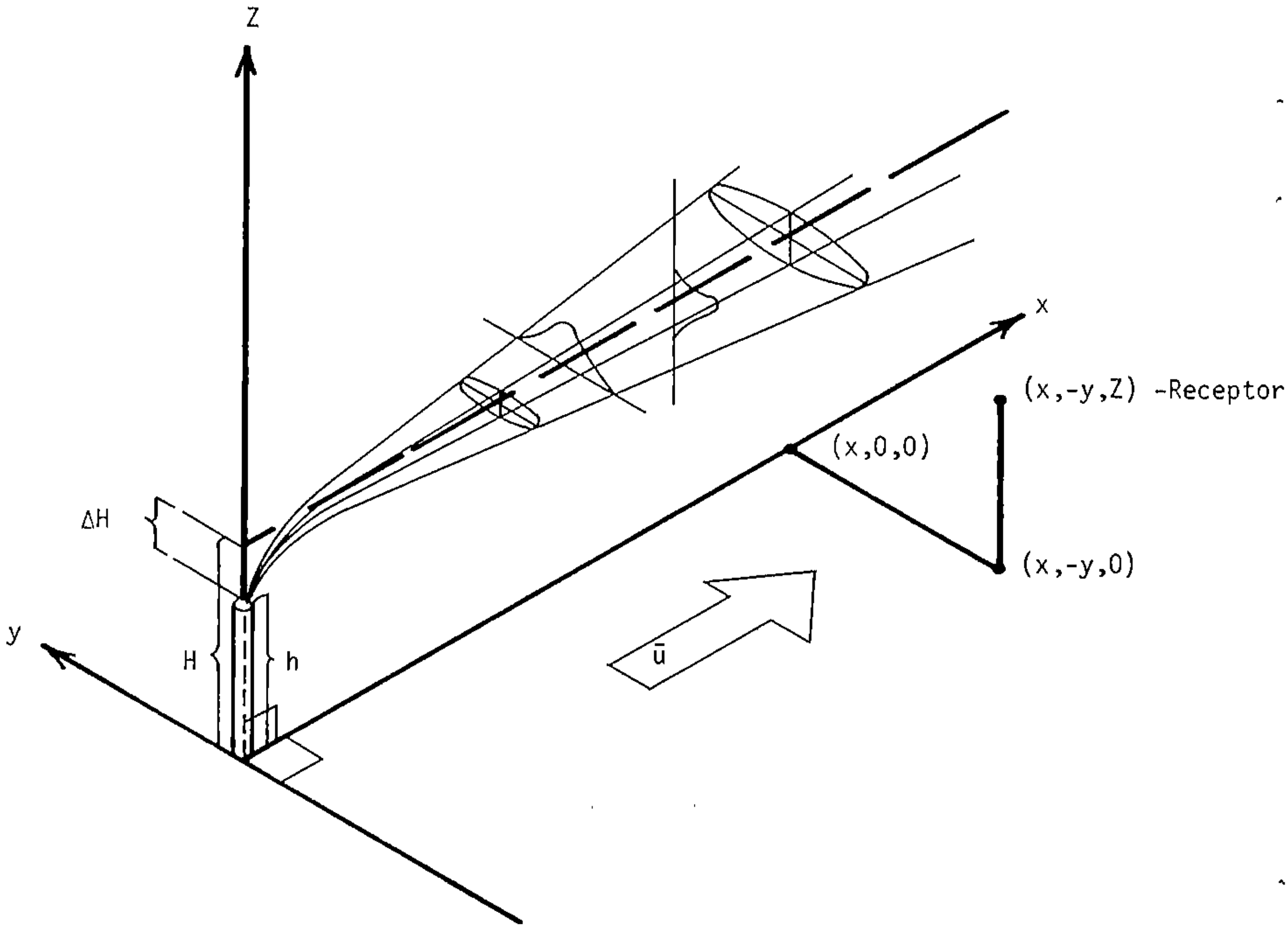
The spatial relationship between the emissions source and receptor must be established through a coordinate system. A commonly accepted coordinate system used by Turner [19] for point sources is shown in Figure 4.8. In the system considered here, the origin is at ground level at or beneath the point of emission, with the x-axis extending horizontally in the direction of the mean wind. The y-axis is in the horizontal plane and perpendicular to the x-axis, and the z-axis extends vertically. The plume travels along or parallel to the x-axis.

For line and area sources, the pollutant concentration along the y-axis (a horizontal line perpendicular to the wind direction) is assumed uniform. Therefore, the y coordinate is not used in estimating pollutant concentrations for these sources.

The plume formulas have been used extensively in the past and have formed the basis of many of the air quality models currently available. However, the simplicity of the classical Gaussian models has been achieved through assumptions which restrict their application. The requirement for a uniform and constant wind over the entire three-dimensional area of concern is contrary to the known behavior of winds. Wind speed generally increases with height in the lower several hundred

FIGURE 4.8

COORDINATE SYSTEM SHOWING GAUSSIAN DISTRIBUTIONS IN THE HORIZONTAL AND VERTICAL



h = Actual Stack Height
H = Effective Stack Height
ΔH = Initial Plume Rise Due to the Buoyancy and momentum of Stack Gases
ū = Mean Wind Velocity and Direction

SOURCE: (19)

meters of the atmosphere. Consequently, the assumption of a single wind speed will tend to underestimate concentrations at lower heights and overestimate at higher heights. Also, these equations breakdown in the case of very light or calm winds since the wind speed is in the denominator, i.e., division by zero. The existence of a temperature inversion or stable layer prevents the upward spread of pollutants. The region below such an inversion is called the mixing layer and the thickness of this layer is called the mixing depth. When certain meteorological conditions exist, the equations are modified so that the vertical plume material distribution becomes uniform at a certain downwind distance from the point where the plume encounters the mixing level. The distribution in the horizontal remains Gaussian.

Since meteorological variables in the model are assumed to be uniform in time and space, the use of the model is restricted to regions of relative flat terrain without bodies of water or tall buildings in the immediate vicinity. Coastal regions with land/sea breeze circulation patterns and generally hilly or mountainous surrounding terrain are poor locations for application of this model. Second, the plume formulation cannot account for chemical reactions that are more complex than a simple decay mechanism due to the steady-state assumption. Plume model applications are then restricted to primary pollutants such as sulfur dioxide, particulates, and carbon monoxide.

The plume formulation is the only technique developed so far to describe individual point and line source emissions, such as from power plant stacks and highway segments. In situations where sources are isolated and analyzed individually, the Gaussian plume model may be "fine-tuned" to yield results which are much improved over a multiple source analysis.

Gaussian Puff Formulation

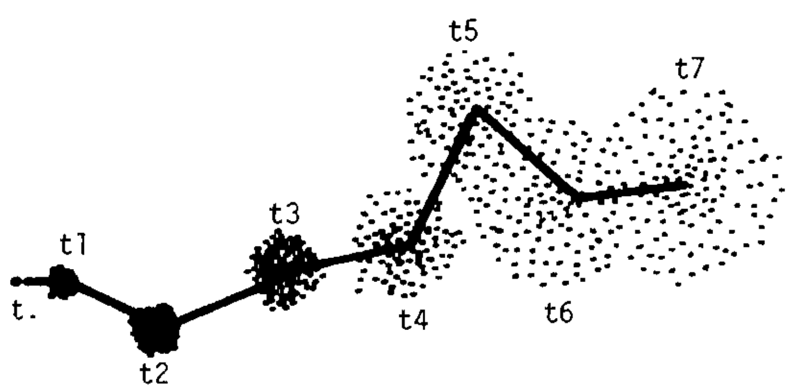
In an attempt to improve on some of the disadvantages of the plume models, the Gaussian puff models have been developed. The transformation of Equation 3 to the Lagrangian (moving) coordinate system is one which moves with the puff and retains time dependence, but the computations become extremely lengthy for multiple-source situation. The solution remains valid for light wind conditions unlike the plume models.

Refinements for elevated sources and receptors are also possible as in the case of the plume models. A similar decay term may also be incorporated. Line source formulas have been developed for the general case of highways at any angle to the mean wind. When the angles are small, the same formula applies but the line must be broken into shorter segments and contributions from each segment must be added.

These models follow the history of a polluted puff as it travels downwind and disperses in a Gaussian distribution (Figure 4.9). The trajectories of the air flow must be known and a puff moving along a trajectory must

FIGURE 4.9

GAUSSIAN PUFF IN A VARIABLE WIND FIELD



pass over the receptor in order to predict concentrations at a downwind receptor. Both the determination of the trajectory pattern and the number of puffs that must be followed requires the use of computers to obtain a fair representation of the concentrations over the study area.

As in the Gaussian plume formulation, topography is difficult to incorporate. Background contributions to the pollutant are allowed to vary in time and can thus be better incorporated. The primary disadvantages to this approach are the computational requirements of time and storage.

Available Manual Methodologies for Gaussian Dispersion Modeling

The modification and application of the basic Gaussian model for manual solution in a variety of situations is presented in [19,20,21]. For applications to any specific situations, it is suggested that the reader refer to these or other references on Gaussian dispersion modeling. Williamson [20] is recommended as an introduction to the analytical considerations of the Gaussian model. For point sources, the work by Turner [19] is recommended.

For line sources, a recent survey report [22] of highway models recommends among others the Highway Air Quality Impact Assessment Model of the California Department of Transportation.

The User Manuals [23] for the Highway Model covers six topics as follows:

1. Meteorology and its Influence on the Dispersion of Pollutants from Highway Line Sources

2. Motor Vehicle Emission Factors for Estimates of Highway Impact on Air Quality

3. Traffic Information Requirements for Estimates of Highway Impact on Air Quality

4. Mathematical Approach to Estimating Highway Impact on Air Quality

5. Analysis of Ambient Air Quality for Highway Environmental Projects

6. A Method for Analyzing and Reporting Highway Impact on Air Quality

The User Manuals are oriented for use by highway engineers in preparing the air quality elements of environmental impact statements for highway projects. The manuals provide an excellent introduction to the modeling of air pollutant dispersion from line sources. Manual solutions for many highway configurations and meteorological conditions are possible through the use of graphical solutions for the basic Gaussian diffusion equations.

Solutions for area source models based on dispersion principles are possible but are often very time consuming. Most solutions involve the use of digital computers. A simple but physically realistic model has been developed by Hanna [24] for estimating pollutant concentrations due to area sources. In this model, the surface concentration is directly proportional to the wind speed. The area source emissions for individual grid squares should be uniformly distributed within each grid and the source strength of adjacent grid squares should not differ too greatly.

4.2.3-2 The Air Pollution Potential Model

Another simple urban dispersion model has been developed by Miller and Holzworth [25]. The model calculates the average normalized concentration ($\overline{X}/\overline{Q}$) i.e., the concentration (X) averaged over a city and normalized for a uniform average area emission rate (Q) as a function of mixing height (H), wind speed ($\overline{u}$), and along-wind distance (S) across the city. The main assumptions of the model are:

1. Steady-state conditions prevail
2. Emissions occur at ground level and are uniform over the city
3. Pollutants are nonreactive
4. Lateral dispersion can be neglected
5. Vertical dispersion from each elemental source conforms to unstable conditions, and concentrations follow a Gaussian distribution out for a defined travel time that is a function of mixing height. Thereafter, a uniform vertical distribution of pollutant occurs as a result of further dispersion within the mixing layer.

The model treats the city as a continuous series of infinitely long cross-wind line sources with pollutants confined to the mixing layer. As indicated in assumption 5, the model requires two equations according to whether *none* or *some* of the pollutants emitted at ground level achieve a uniform vertical distribution within the mixing layer before being transported beyond the downwind edge of the city.

When none of the pollutants achieve a uniform vertical distribution, the equation may be written as

$$\overline{X}/\overline{Q} = 3.993(S/\overline{u})^{0.115} \text{ for } (\overline{S}/\overline{u}) \leq 0.471\ H^{1.130}$$

When some of the pollutants achieve a uniform vertical distribution, the average normalized concentration is

$$\overline{X}/\overline{Q} = 3.613\ H^{0.130} + \frac{S}{2HU} - \frac{0.088\overline{u}H^{1.260}}{S} \text{ for } (\overline{S}/\overline{u}) \geq H^{1.130}$$

For most cases the coefficient 0.088 is very small, and can be neglected [25].

This model was utilized to assess the mesoscale primary pollution potential for California [26]. Air pollution potential is a measure of the inability of atmospheric processes to adequately dilute and disperse pollutants. The pollution potential concept is valuable in relating changes in emissions to changes in air quality. An area of high air pollution potential will experience a relatively large degradation in air quality with increased emissions. Conversely, an area with low air pollution potential will experience a relatively small change in air quality for an identical change in emissions.

Air pollution potential is treated with statistical tools, in which the frequency of occurrence of meteorological events is of primary importance. For example, the pollution potential of a stable primary pollutant would be considered high in an area where light winds and strong, surface-based inversions occurred simultaneously and with great frequency. In assessing the air pollution potential for a particular area, emission factors are normalized or assumed to be constant. The model determines the spatial and temporal distribution of air pollution potential as a function of meteorological parameters only.

The meteorological parameters used to quantify the air pollution potential model are average wind speed and mixing height. These are determined from data on the wind and temperature structure of the lower layers of the atmosphere. Both of these meteorological variables can change rapidly in space and time. The pollution potential is an inverse function of the average wind speed and mixing height in this model. There are several ways to use wind and stability data to calculate pollution potential. Estimates of vertical atmospheric stability are made by following a procedure whereby stability criteria are divided into six classifications depending on the surface wind speed and the intensity of incoming sunlight [19,27]. From these classifications, pollution potentials are calculated using wind speed, mixing height, and normalized emission rates.

In the equations for the model, the values for mixing height (H) and mixing layer average wind ($\overline{u}$) are in the denominator. If either of these terms becomes very small, the value of $\overline{X}/\overline{Q}$ becomes very large and must be used with caution as a measure of urban pollution potential. The minimum values of morning mixing height (H) from the data are 45-50 meters [26]. With low mixing heights and wind speeds near zero, the term $\overline{X}/\overline{Q}$ becomes very large. For example:

Mixing Height (meters)	Surface Wind (knots)	Boundary Layer Winds (meters/sec)	Urban Pollution Potential ($\overline{X}/\overline{Q}$)
50	0	0.175	584
50	1	0.687	153
50	2	0.199	90

High values of $\overline{X}/\overline{Q}$ should be used cautiously when related to pollution potential. For all cases, the ratio $\overline{X}/\overline{Q}$ is calculated for a source size (i.e., city size) of 10,000 meters in the direction of the wind [26].

4.2.3-3 The Moving Box Model Approach

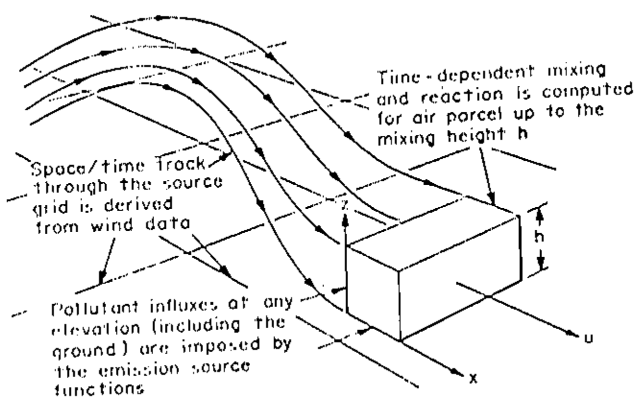
An alternative approach to air pollution modeling has been advanced by those investigators who have been concerned with the photochemistry of air pollution. In this case, the conservation of mass equation (Equation 1) is reduced to

$$\frac{\partial C_i}{\partial t} = R_i + S_i$$

A Lagrangian coordinate system is employed such that V = 0 while $K_x = K_y = 0$ and $K_z = \infty$. Or, in other words, a box is assumed to be carried by the winds with no lateral dispersion of pollutants allowed, while the pollutants emitted are presumed to mix instantaneously throughout the volume of the box. A later version of the moving cell model includes an analytical solution to accommodate horizontal dispersion [22]. The box may either extend from the ground up to the inversion base, or be represented by a column of boxes up to the inversion base (Figure 4.10). The simplifications made in this approach are clearly not representative of the actual atmospheric processes which affect the transport and dispersion of pollutants.

FIGURE 4.10

THE TRAJECTORY MODEL



SOURCE: (31)

In addition to its obvious misrepresentations, there are more subtle difficulties inherent in this moving-box approach. First, the technique by which the boxes are transported from one location to the next involves a wind trajectory analysis which is typically done by interpolation of wind measurements taken at ground level wind stations [29,30]. Generally, measurements of this type are not representative of the transport taking place throughout the vertical column. The proximity to buildings, the height of upwind buildings, and the stability of the atmosphere combine to modify the ground level measurements so that only estimates can be made of processes transpiring aloft. Thus, it must be anticipated that as the box is transported further and further downwind, the errors become larger and larger. This problem becomes acute with the complex wind patterns of California coastal air basins.

Second, the resulting computed concentrations are <u>instantaneous</u> values rather than hourly-averaged values. No attempt has been made thus far to justify the assumption that the instantaneous concentrations computed by a box model at a particular receptor point (i.e., at the site of a monitoring station) is representative of the hourly-averaged concentrations which are measured, and which also constitute the basis of the National Ambient Air Quality Standards. In particular, the technique employed by Eschenroeder and Martinez [29] for model validation purposes bears no relationship to the way air quality standards are defined. The time variation of pollutant concentrations in the box is computed at various points along its trajectory, and these computed values are compared not to actual monitoring data, but to values interpolated between monitoring stations nearest to the path of the box. In order for the box models to compute representative hourly-averaged concentrations at specified receptor points, trajectories would be needed for boxes arriving at each receptor point at, say, ten-minute intervals.

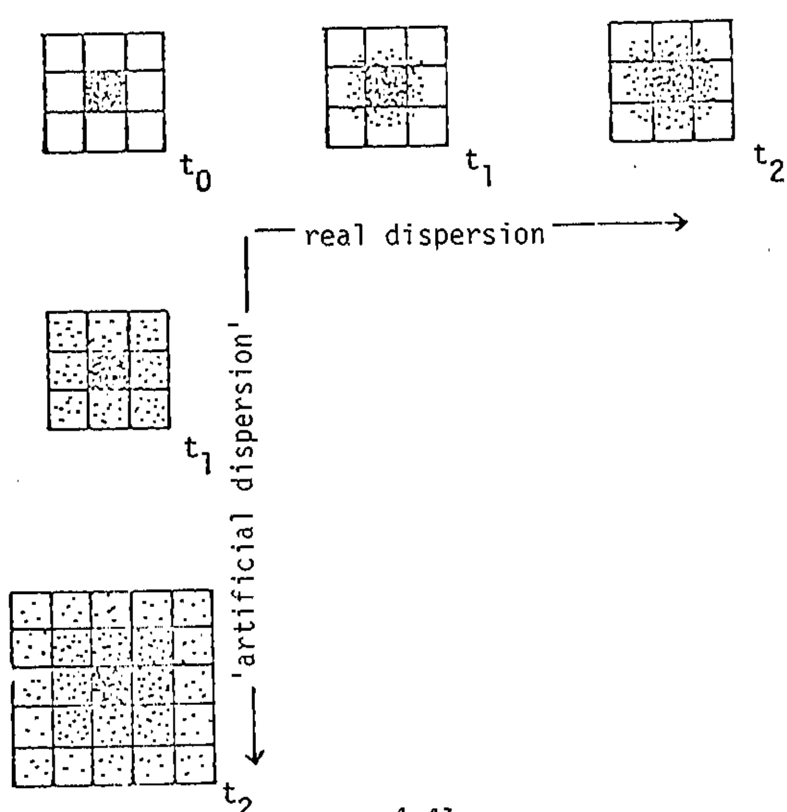
4.2.3-4 The Three Dimensional Grid Approach

The limitations of the Gaussian plume and moving box models, coupled with the need for more precise representations of air quality, have prompted a move toward the numerical solution of the conservation of mass equation on a fixed three-dimensional grid, including advection, dispersion and chemical reactions. Models which use this approach are quite complex and require much more data than are normally available for any given air quality control region. The level of <u>precision</u> (not necessarily accuracy) is correspondingly increased, however, such that more complex meteorological conditions may be accounted for and the model can in theory be applied to a greater variety of adverse situations occurring in the atmosphere over urban centers.

Unfortunately, many of the criticisms described for the box models may also apply to the grid models, particularly with respect to uncertainties in trajectories for air parcels. The disadvantage unique to the grid approach involves the phenomenon of numerical dispersion, also called artificial dispersion. In this case the finite difference solution of the conservation of mass equation introduces a machine-induced error into the analysis.

FIGURE 4.11

ARTIFICAL DISPERSION



Artificial dispersion is based on the assumption that pollutants are completely mixed and uniformly distributed in any given cell. For any time increment of a simulation, a certain amount of pollutant will be dispersed from each cell to adjacent cells. These pollutants are assumed to be spread evenly throughout the adjacent cells. In the next time increment, pollutants will be leaving these adjacent cells when in reality the pollutants have not traveled completely across the cells. Artificial and real dispersion are shown schematically in Figure 4.11.

4.2.4 Meteorological Sub-Models

4.2.4-1 Wind Fields

Wind behavior is almost invariably separated into two parts for modeling. Relatively large scale motions are described as transporting the pollution from source to receptor while relatively small scale motions are described as dispersing and mixing the pollutant as it is transported.

The simplest models assume that the mean winds (large scale motions) are constant in time and space and unchanging in either speed or direction. This is the assumption utilized in the Gaussian plume model. The values of wind speed and direction can be based on observations from a single location or a combination of observations from several locations.

In more complicated and realistic models, winds can be simulated from point to point with both vertical and horizontal variations. In the vertical, wind speeds almost always increase with height. Some approaches allow for vertical speed variation by using specified functions - such as a "power low function" in which wind speed is proportional to altitude raised to an exponent, i.e., $\overline{u} \propto Z^n$. Wind direction changes with height are more difficult to specify and to fit into models. Only if the wind is measured or carefully worked out from dynamic theory can realistic direction changes with height be incorporated into models.

Realistic horizontal wind variability is relatively difficult to incorporate into models. The dominating principle is the conservation of mass, for both the pollutant and the air. Models include schemes of varying complexity to meet this requirement. A relatively simple method is to calculate two-dimensional horizontal motion from a wind stream function and assume no vertical motion. This type of flow does not permit convergence or divergence of mass.

The mass-consistent wind formulation [32] is a more complicated technique for defining a wind field. With this approach, ground level wind observations at discrete points in space are interpolated and then adjusted to satisfy the continuity equation of fluid flow.

In the case of incompressible flow, the equation may be written as:

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0$$

where u and v are the lateral components of the wind vector and w is the vertical component of the wind vector. The resulting wind field gives the speed and direction at all points within the grid, and is theoretically consistent. Significant differences occur between an interpolated wind field and an interpolated wind field adjusted to be consistent with the continuity equation of wind flow. The interpolated observed wind field is obtained from wind monitoring stations which are subject to local influences and give little information concerning upper level winds. The mass-consistent wind field is produced depending on the nature of the wind shear and inversion height assumption. Until mixing depth and upper level winds are monitored as regularly as present ground level winds, the validity of either wind field will remain in question.

The role of small scale motions and turbulent eddies in dispersing pollution is handled by the models in several ways.

The most common method used in the Gaussian formulation is based on the relationship between the spread of a pollutant cloud, the distance from the source, and the meteorological conditions which control turbulent eddy mixing. These relationships are developed from experimental observations of plumes. This, together with the assumption of a Gaussian or "normal" distribution and the conservation of pollutant mass allows an estimate of concentration at any point downwind from the source.

The dispersion equation uses eddy diffusivity coefficients or "K" theory to account for the role of small wind eddies. This assumes that there will be a movement of pollutant from a region of higher concentration to regions of lower concentrations and this flow is proportional to the eddy diffusivity and to the change of concentration per unit distance across the area. This method parallels solution techniques for molecular diffusion problems.

Both theories mentioned above can be applied to the same problem. The advantage of "K" theory is a much greater versatility, but it is limited by greater computing time requirements and a greater chance of computational errors.

4.2.4-2 Mixing Depth

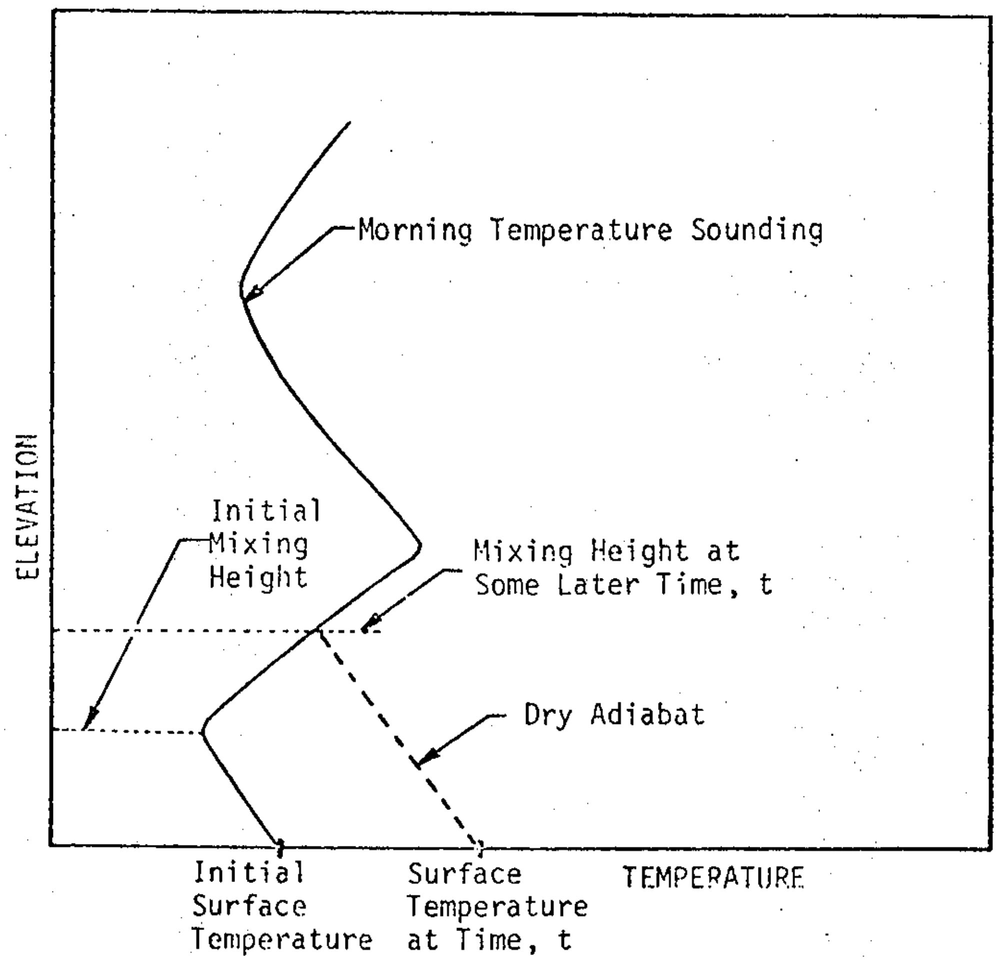
Two related techniques have been used to estimate the mixing depths (the height of the inversion base above the ground) over an urban area. The first technique was developed by Holzworth [33]. Here it is assumed that nighttime radiational cooling of the ground and heat loss from the air to the cool ground result in stable lapse rates at night; and that during the day, absorption of solar radiation by the ground and heating of the air results in unstable lapse rates and vertical motions (mixing) that ultimately produce a mixed dry adiabatic layer. Neglecting factors (e.g., advection, subsidence, etc.) that could change the vertical temperature profile after its time of observation, it is assumed that the mixing depth depends upon the vertical temperature structure and the surface temperature. This last assumption must be further conditioned by the fact that effects of vertical wind shear and mechanical turbulence in augmenting or diminishing vertical mixing have been neglected. In some cases, these factors may be important, but here only the effects of convection are considered. Since radiosonde observations are seldom made at the times of interest, the mixing depths are estimated by extending a dry adiabat from the maximum surface temperature to its intersection with the most recently observed temperature profile (Figure 4.12).

A second method [32] recognizes that the temperature profile observed at one location may not necessarily be assumed to apply in other locations, especially if the topography is complex. This method correlates the difference in mixing depths with the difference in surface temperatures recorded at a reference station with those at other locations in the study area. A set of curves is then prepared such that the mixing depth at the reference station may be used to predict the mixing depth at the other locations around the urban area on the basis of surface temperature measurements. Unfortunately, data were insufficient to properly define the correlation curves, and it remains to be seen whether such a technique can serve to adequately describe the substantial spatial and temporal variations characteristic of inversions, particularly those which occur over California coastal regions.

In addition to the effect which the mixing depth estimate has on the computed wind field, the significance of errors in mixing depth with regard to the impact on computed concentrations is also a function of the atmospheric stability within the mixing layer. If the mixed layer is highly unstable, then pollutants emitted at ground level will be mixed upward rapidly, and the mixing depth will be a direct determinant of computed ground level concentrations. If the mixing layer is relatively stable, the effect of the mixing depth at a given location will not be seen until the emitted pollutants are transported further downwind, since a longer time period would be required for the pollutants to mix upward and "sense" the presence of the inversion.

FIGURE 4.12

THE DETERMINATION OF MIXING HEIGHTS FROM SURFACE TEMPERATURE DATA



SOURCE: (33)

Perhaps the most critical aspect of estimating the mixing depth lies in the representation of an inversion base when it is at or near ground level. This particular condition is of utmost concern since it is often associated with severe air pollution episodes. Small fluctuations in the mixing depth under such conditions can lead to significant changes in ambient concentrations since the proportional change in the volume of air available for mixing may be quite large.

4.2.4-3 Diffusivities

To date, there has been a single, standard approach to the estimation of diffusivity coefficients and/or standard deviations of the wind field. This approach was originally advanced by Pasquill [27] on the basis of plume measurements taken in areas of flat topography with no nearby bodies of water. Subsequent attempts at estimation of diffusivity coefficients have been geared toward improving the data or modifying the results in order to account for more complex terrain conditions, such as that posed by a city [34].

There have been few measurements of these important parameters which may be used directly in the various models. Hence, more often than not, the diffusivities become "free" parameters which are adjusted to produce the best fit of model results to observations during the validation phase of model development.

4.2.4-4 Solar Radiation

The intensity of solar radiation is a critical factor in the photochemical processes leading to the formation of oxidant. Under uniform sky conditions the radiation intensity may be determined for an urban area. Problems occur when patchy or variable clouds are present, since the intensity may be drastically diminished in areas where direct sunlight is blocked. Reynolds, et al. [35] in their validation of the SAI Model noted that:

"In comparing the radiation profiles measured at the two measurement sites, Commerce and El Monte, for each of the six validation days, it is apparent that they are often not coincident. For example, on 29 September at noon the radiation intensity at El Monte was 30% lower than at Commerce. Consequently, the measures of photolysis rate, k1 and k7, differed by 30% between the sites. While we have adopted "averaged" curves based on measurements made at the two locations, it is clear that radiation intensity varies spatially as well as temporally, and that these variations can have a significant effect on the magnitudes of predicted concentrations. For example, if the steady-state approximation is valid, k1 is proportional to ozone concentration. A 30% error in k1, due to inaccuracies in estimation of the constant locally, will then result in approximately a 30% error in predicted ozone level."

4.2.5 Additional Considerations in Air Quality Modeling

4.2.5-1 Boundary and Initial Conditions

To simulate a particular day of high air pollution potential, it is necessary to make some assumptions about conditions on the boundaries of the modeling region. Normally, there is little or no data concerning pollutant concentrations at the boundaries since they are chosen such that the entire urbanized area is contained within the model. Likewise, there is no monitoring data available (except in special cases) concerning the initial vertical profiles of pollutant concentrations.

The procedure that is followed almost universally is to assume that there is no gradient in concentration across any boundary, and that the initial profiles are uniform with height above ground level. The errors which are introduced into the modeling process due to such assumptions are difficult to assess, since conditions will vary from day to day. Unfortunately, one of the more controversial aspects of control strategy development centers on the question of pollutant transport from one air basin to another. In regions where such controversies exist, the ability to properly set the boundary conditions is critical to the success of the modeling effort.

4.2.5-2 Sub-Grid Scale Methodologies

In the case of three-dimensional grid models, there are important processes occurring on scales smaller than the grid can resolve. Strong point and line source emissions such as from power plant stacks and street "canyons," respectively, require special treatment in order to be properly considered in these models.

To date, three of the models currently available have incorporated sub-models which address sub-grid scale considerations. These are the Stanford Research Institute (SRI) APRAC-1A model for carbon monoxide, and the Systems Applications Incorporated (SAI) Urban Airshed Model and S^3 EXPLOR model for photochemical pollutants. The SRI model has a street canyon sub-model which describes, in a relatively simple fashion, the circulation pattern expected to occur over a street that is bounded on both sides by tall buildings. The SAI model for photochemical pollutants incorporates a more sophisticated street canyon sub-model as well as a simple point source treatment which allocates portions of a plume to the grid cells which the plume is expected to occupy. EXPLOR was specifically designed to predict pollutant concentrations in a milewide corridor transversed by a roadway. By dividing the airspace over the roadway into cells, an attempt is made to track the particles of pollutants from one cell to the next in a numerical integration of the conservation of mass equation in two dimensions.

Although it is important that such effects be addressed, it is not realistic to expect model results to be vastly improved as a result. When dealing with such complex phenomena on such a small scale as an individual street canyon, the variability of building heights, the presence of parked cars, the speed of the traffic on the street and various other factors become critical in the determination of pollutant concentrations. It is presently beyond the scope of any of the models developed to consider such effects, and thus it must be expected that results would not be consistently good.

4.2.5-3 Chemical Reaction Sub-Models

In the case of photochemical oxidants, a special sub-model is required to describe the complex series of chemical reactions taking place in the atmosphere between the various pollutant species. Several reviews of atmospheric chemistry have appeared in recent years and a number of kinetic mechanisms for photochemical smog have been proposed [36,37,38]. Although the various mechanisms proposed produce reasonable agreement with smog chamber studies, it is clear that the nature of the multitude of reactions occurring in the atmosphere is not well understood. A polluted urban atmosphere typically contains upward of 100 hydrocarbon species, each of which may undergo any number of possible reactions with each other as well as with other atmospheric constituents. In addition, many of these species and their intermediate products are present in very low concentrations such that experimental studies are difficult if not impossible to conduct with available instrumentation. Thus, many of the rate constants used in chemical models have not been verified with actual experimental data.

For the purpose of an atmospheric simulation model, the kinetic mechanism must be as compact as possible to avoid excessive computing times in the numerical integration of the model. This requirement necessarily implies the use of a lumped-parameter approach, whereby a class of compounds or reactions are assumed to be described by a single compound or reaction with an "average" rate constant assigned. Additionally, the number of product molecules from a reaction may be assigned. The method by which such assignments are made involves the fitting of model results to smog chamber data.

Although this approach is reasonable under the circumstances, it is also fraught with uncertainty. Curves of pollutant concentrations vs. time may be produced with any desired shape if a sufficient number of free parameters are available for adjustment. Whether the kinetic mechanism thus developed is representative of what actually occurs is strictly a matter of conjecture, since the reactions that occur in a smog chamber are not necessarily similar to the reactions and other processes which occur in the ambient atmosphere (e.g., the formation of photochemical aerosol). These fundamental problems occur for any photochemical model, no matter how intricate its formulation.

Of the kinetic mechanisms published to date, the 15-step model of Hecht and Sienfeld [38] replicates smog chamber data rather well, in addition to being relatively compact. The fifteen steps are summarized in Table 4.2, where the symbol R denotes a generalized hydrocarbon radical; α, β, and γ, are adjustable coefficients; and PAN denotes peroxyacyl nitrates.

The first three steps involving nitric oxide, nitrogen dioxide, ozone and sunlight ($h\nu$) describe the formation and destruction of ozone in the absence of organic gases. These steps are common to all of the kinetic mechanisms which have been proposed. The mechanisms diverge when it comes to describing how the presence of organic gases disrupts this equilibrium situation.

4.2.6 Statistical Models

4.2.6-1 Appendix J Relationship

The Appendix J relationship for photochemical oxidants was developed by the U.S. Environmental Protection Agnecy for use in the development of state implementation plans for the achievement and maintenance of the National Ambient Air Quality Standards for oxidant.

The EPA relationship was derived by plotting the peak one hour oxidant measurements from four different cities vs. the 6-9 a.m. ambient non-methane hydrocarbon measurement for the same day. A curve was then

TABLE 4.2

The 15-Step Mechanism of Hecht and Seinfeld for Photochemical Oxidant

$NO_2 + h_\nu$	$\xrightarrow{1}$	$NO + O$
$O + O_2 + M$	$\xrightarrow{2}$	$O_3 + M$
$O_3 + NO$	$\xrightarrow{3}$	$NO_2 + O_2$
$O_3 + NO_2$	$\xrightarrow{4}$	$NO_3 + O_2$
$NO_3 + NO_2$	$\xrightarrow[H_2O]{5}$	$2HNO_3$
$NO + NO_2$	$\xrightarrow[H_2O]{6}$	$2HNO_2$
$HNO_2 + h_\nu$	$\xrightarrow{7}$	$OH + NO$
$CO + OH$	$\xrightarrow[O_2]{8}$	$CO_2 + HO_2$
$HO_2 + NO$	$\xrightarrow{9}$	$OH + NO_2$
$HO_2 + NO_2$	$\xrightarrow{10}$	$HNO_2 + O_2$
$HC + O$	$\xrightarrow{11}$	αRO_2
$HC + OH$	$\xrightarrow{12}$	βRO_2
$HC + O_3$	$\xrightarrow{13}$	γRO_2
$RO_2 + NO$	$\xrightarrow{14}$	$NO_2 + \varepsilon OH$
$RO_2 + NO_2$	$\xrightarrow{15}$	PAN

h_ν	represents energy from sunlight
M	a third body (like N_2) which acts as a catalyst
O_2	molecular oxygen
O	atomic oxygen
O_3	ozone
NO	nitric oxide
NO_2	nitrogen dioxide
CO	carbon monoxide
CO_2	carbon dioxide
OH	hydroxyl radical
H_2O	water vapor
HO_2	hydrogen dioxide
RO_2	a generalized free radical where R represents any HC chain
HC	a hydrocarbon usually averaged
PAN	peroxyacl nitrates
HNO_2	nitrous acid
HNO_3	nitric acid

α, β, γ and ε adjustable coefficients

Source [38]

drawn as shown in Figure 4.13 such that all points plotted are below it, thus representing an upper limit to possible oxidant concentrations for a given level of morning hydrocarbon concentration. This curve may then be used to construct a second curve which relates peak oxidant to percent emission reduction required to meet the standard (Figure 4.14). The second curve is known as EPA's "Appendix J" rollback curve.

The basic procedure for deriving the Appendix J curve is as follows:

1. Select the peak oxidant concentration and determine the corresponding non-methane hydrocarbon concentration as defined by the envelope curve shown in Figure 4.13.

2. The percentage rollback requirement to attain the 0.08 ppm oxidant standard is defined as follows:

$$\text{rollback} = \frac{H_1 - H_0}{H_1}$$

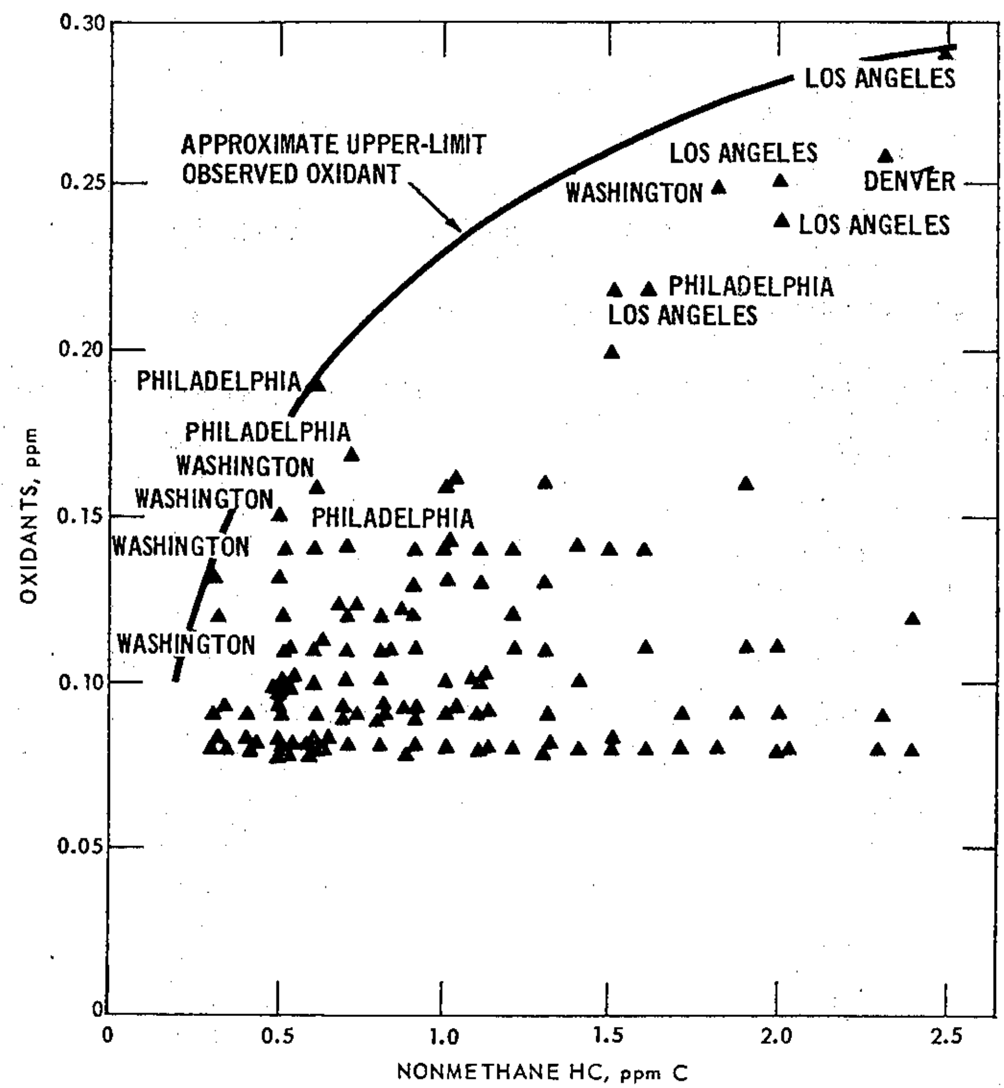
where H_1 = non-methane hydrocarbon concentration corresponding to the peak oxidant measurement

H_0 = 0.24 ppm non-methane hydrocarbon, as defined by the air qualtiy standard for hydrocarbons. This standard was selected as representing the hydrocarbon concentration corresponding to a peak oxidant level of 0.08 ppm. If the peak oxidant level is 0.23 ppm (corresponding to 1.0 ppm hydrocarbon), for example, then the percent emission reduction required is $\frac{1.0 - 0.24}{1.0} \times 100\% = 76\%$.

3. Repeat the computations for several values of peak oxidant to define the "rollback curve" shown in Figure 4.14.

FIGURE 4.13

MAXIMUM DAILY 1-HOUR- AVERAGE OXIDANTS AS A FUNCTION OF 6-TO-9-A.M. AVERAGES OF NON-METHANE HYDROCARBONS AT CAMP STATIONS

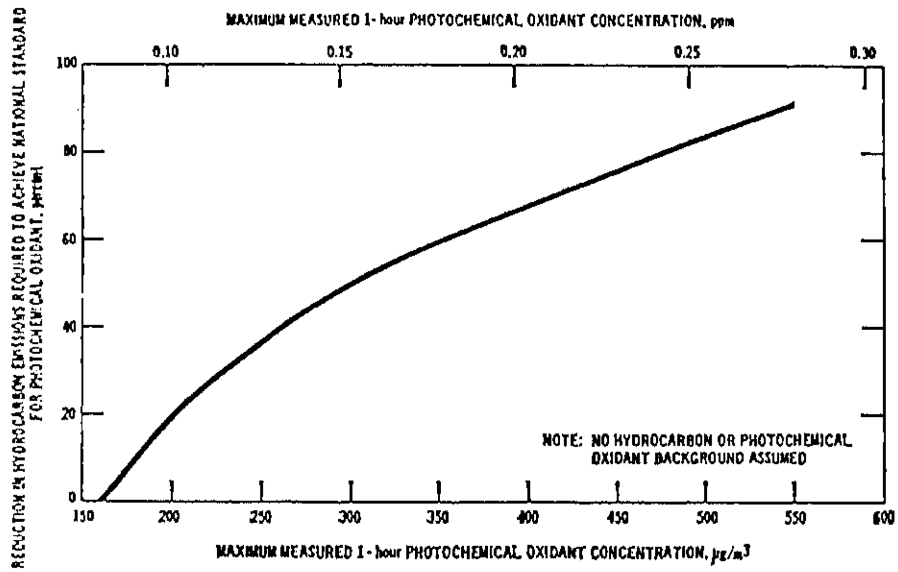


SOURCE: (39)

FIGURE 4.14

EPA'S APPENDIX J ROLLBACK MODEL FOR PHOTOCHEMICAL OXIDANTS

Appendix J



Required hydrocarbon emission control as a function of photochemical oxidant concentration. (Reference: Air Quality Criteria for Nitrogen Oxides, AP-84, Environmental Protection Agency, Washington, D.C., January 1971.)

SOURCE: (40)

There are several assumptions inherent in the development of this relationship, as summarized below:

1. The background concentration for oxidant is zero.

2. It is assumed that the 6-9 a.m. hydrocarbon measurement is directly proportional to total regional emissions.

3. It is assumed that the peak oxidant measured is representative of the peak oxidant which actually occurred in the region.

4. It is assumed that there is a consistent relationship between the peak oxidant measurement and the 6-9 a.m. hydrocarbon measurement (variable transport of pollutants is ignored).

5. It is assumed that the four cities for which data were used are representative of the nation as a whole.

In short, Appendix J ignores the space and time variable processes which are critical to determining the emissions/air quality relationship. Appendix J suffers from the problem that it must be assumed that the emission reductions will occur in the same proportion everywhere in the control region. Reliance on past data to define the relationship precludes a meaningful analysis of projected future emissions, which may be distributed quite differently from past emission patterns.

Finally, and perhaps most significant for control strategy development purposes, the Appendix J curve is undefined at peak oxidant concentrations above 0.28 ppm. For those air quality control regions with peak oxidant greater than 0.28 ppm, EPA has authorized the use of a linear rollback approach whereby oxidants are assumed to be directly proportional to hydrocarbon emissions (despite overwhelming evidence that the relationship is definitely non-linear). In this case, a 0.32 ppm peak oxidant measurement would imply that an emission reduction of

$\frac{(.32 - .08)}{.32} \times 100 = 75\%$ is necessary to achieve the oxidant standard. Note that this figure is less than the emission reduction required under Appendix J for a 0.23 ppm peak oxidant.

4.2.6-2 Proportional Model for Air Quality Estimates

The proportional model is a mesoscale approach to estimating air quality. This model assumes a linear relationship between the concentration of a pollutant in a study area and the emission rate of that pollutant in a study area. The proportional model as used in the State Implementation Plan [40] is applied to entire air basins. However, this model can be applied to a smaller study area when the transport of pollutants from other areas into the study area is not a significant consideration. The proportional relationship is represented by the following equation:

$$\text{Air Quality}_{\text{Future Year}} = B + (\text{Air Quality}_{\text{Base Year}} - B)\,\frac{\text{Emissions}_{\text{Future Year}}}{\text{Emissions}_{\text{Base Year}}}$$

Where B represents the background concentration due to natural phenomena. The air quality values used are the historical maximum concentrations of the pollutants in terms of the air quality standards.

This model requires representative air quality monitoring data for the study area and assumes that the meteorology for the study area will be similar for the base year and the future year.

The proportional model assumes that emissions are uniform throughout the study area and constant throughout the year of the emission inventory. In other words, temporal and spatial variations in emissions are not considered. Also, since there are many uncertainties concerning the relationship between the emissions of precursors of secondary pollutants and the resulting air quality, several simplifying conventions have been established to facilitate estimates of air quality. These assumptions are discussed below [41].

Convention 1. Air quality estimates for nitrogen dioxide (NO_2) are based on the emissions for all oxides of nitrogen.

This convention was established since there are few sources of NO_2, which is an unstable secondary pollutant. Nitric oxide (NO), which is generated mostly by high temperature combustion of fuels (automobiles and power plants), is the principal precursor of NO_2.

Convention 2. Air quality estimates for photochemical oxidants are based on the emissions of highly reactive organic gases.

The photochemical process that produces oxidants is a complex, multistep reaction that is not completely understood at this time. Air quality estimates based solely on the emission of highly reactive organic gases have a basic weakness in that the well-recognized role of oxides of nitrogen in the photochemical reaction is not considered.

The Appendix J relationship between non-methane hydrocarbons and photochemical oxidants [40] was developed for use in the preparation of control strategies for photochemical oxidant. Because of the scarcity of air quality monitoring data for non-methane hydrocarbons and questions as to the applicability of this relationship to the photochemical problem in California, the Air Resources Board staff did not use the Appendix J methodology. Instead, the ARB staff defined certain organic gas emissions as reactive and used a linear relationship between reactive organic gas emissions and oxidant concentrations.

Convention 3. Air quality estimates for particulate matter are adjusted to reflect the effect of natural or accidental phenomena.

The application of the proportional model to particulate matter is complicated by two additional factors. In some air basins, a significant portion of the atmospheric particulate matter is not directly emitted. Some is due to aerosols which are photochemically formed in the air and some is introduced into the air as a result of various

Table 4.3

ADJUSTMENT OF OBSERVED
PARTICULATE MATTER CONCENTRATIONS

Air Basin	Adjustment	1970 Annual Geom. Mean Observed Maximum	Adjusted Maximum
North Coast	30	104	74
San Francisco Bay Area	30	74	44
North Central Coast	30	67	37
South Central Coast	30	72	42
South Coast	27	127	100
San Diego	30	87	57
Northeast Plateau	--	--	--
Sacramento Valley	30	57	27
San Joaquin Valley	40	169	129
Great Basin Valleys	--	--	--
Southeast Desert	40	128	88

From "The State of California Implementation Plan For Achieving and Maintaining the National Ambient Air Quality Standards," Air Resources Board, January 30, 1972. Appendix V.

natural phenomena such as wind-blown dust. The ambient levels of particulate matter reflect aerosols from each of these sources as well as directly emitted material.

A set of adjustments were assumed for the eleven air basins in the State in existence when the California Implementation Plan was developed. For the San Joaquin Valley and the Southeast Desert Air Basin a higher level was assumed because of the frequent occurrence of sandstorms and soil being carried by the wind. These adjustments are to be subtracted from the observed levels. Due to the variable nature of these natural phenomena, it is only possible to estimate them as annual geometric means. Table 4.3 presents the background estimates of pollutant used by the ARB [41].

A certain percentage of atmospheric particulate matter is generated by photochemical reaction. The following percentages are assumed for the South Coast Air Basin (SCAB) in 1970 [41]:

Source	Relative Contributions of Particulate Matter In SCAB by Source
Directly emitted particulate matter	40%
Photochemically generated particulate matter	40%
Naturally occurring particulate matter	20%

For future year particulate matter air quality estimates, photochemically generated aerosols must be considered. These aerosols are estimated on the basis of the above assumptions and the following methodology:

$$\text{Photochemically-generated aerosols for SCAB in 19xx} = \frac{\text{Photochemically-generated Aerosols in SCAB for 1970}}{\text{Reactive Organic Gases in SCAB for 1970}} \quad \text{Reactive Organic Gases in SCAB for 19xx}$$

Photochemically-generated aerosols for all other air basins were estimated in the State Implementation Plan using the following assumed relationship:

$$\text{Photochemically-generated aerosols in 19xx} = \frac{\text{Photochemically-generated Aerosols in SCAB for 1970}}{\text{Reactive Organic Gases in SCAB for 1970}} \quad \text{Reactive Organic Gases for 19xx}$$

Examples of Air Quality Estimates Using the Proportional Model

To estimate air quality using the proportional model, the following data are required:

1. Historical maximum concentration of pollutant of interest
2. Emission rate in study area of pollutant of interest based on emission inventory of the year in which historical maximum occurred
3. Naturally occurring background air quality
4. Estimated future year emission rate for study area

Similarly, to estimate the emissions allowable to achieve a certain air quality, the following data are required:

1. Historical maximum concentration of pollutant of interest
2. Emission rate for study area of pollutant of interest based on emission inventory of the year in which historical maximum occurred
3. Naturally occurring background air quality
4. Desired future year air quality

By substituting the four known values for either situation in the proportional relationship given above, the desired value is easily determined.

In Revision 4 to the State Implementation Plan [41], the following data for CO are given for the South Coast Air Basin:

	For Carbon Monoxide For SCAB			
Year	1970	1975	1977	1980
Projected Controllable Emissions (tons/day)	11548	6874	3033	2325
Ambient Air Quality (8 hour average in ppm)	41	X	Y	Z

To estimate future year air quality, the proportional model was used as follows: (NOTE: The CO background concentration was assumed to be zero.)

$$\frac{\text{1975 CO Air Quality}}{\text{1970 CO Air Qualtiy}} = \frac{\text{1975 CO Emissions}}{\text{1970 CO Emissions}}$$

$$\frac{\text{1975 CO Air Quality}}{\text{41 ppm for 8 hours}} = \frac{\text{6874 tons/day}}{\text{11548 tons/day}}$$

$$\text{1975 CO Air Quality} = \frac{(6874)}{(11548)} \text{ 41 ppm for 8 hours}$$

$$\text{1975 CO Air Quality} = \text{24.4 ppm for 8 hours} = X$$

Rounding off yields 1975 CO Air Quality = 24 ppm of CO for 8 hours. Referring to Table 2.1, this is above the standard of 9 ppm for 8 hours.

Similarly, for 1977 and 1980

$$\text{1977 CO Air Quality} = \text{1970 CO Air Quality } \frac{\text{1977 CO emissions}}{\text{1970 CO emissions}}$$

$$= (41)\ \frac{3033}{11549} = 10.8$$

Rounding values yields 1977 CO Air Quality = 11 ppm for 8 hours = Y. This value is still above the 8 hour standard for CO of 9 ppm.

$$\text{1980 CO Air Quality} = \text{1970 CO Air Quality } \frac{\text{1980 CO emissions}}{\text{1970 CO emissions}}$$

$$= (41)\ \frac{2325}{11548} = 8.25$$

Rounding, 1980 CO Air Quality = 8 ppm for 8 hours = Z. This estimate for CO air quality is below the 8 hour CO standard of 9 ppm.

In the original State Implementation Plan [41] the following data are given for the South Coast Air Basin:

	Highly Reactive Organic Gases				Particulates			
Year	1970	1975	1977	1980	1970	1975	1977	1980
Projected Emissions Directly Emitted (tons/day)	1785	475	404	349	235	140	146	143
Photochemically-generated Aerosols (tons/day)					235	X	Y	Z

To estimate future year levels of photochemically-generated aerosols (PGA), the following relationship was used:

$$\text{Photochemically-generated aerosols for SCAB in 19xx} = \frac{\text{Photochemically-generated aerosols in SCAB in 1970}}{\text{Reactive Organic Gases in SCAB for 1970}} \text{ Reactive Organic Gases in SCAB for 19xx}$$

1975 Aerosols (PGA) = $\frac{235}{1785}\,475$

1975 Aerosols (PGA) for 1977 and 1970 = 63 tons/day = X

1977 Aerosols (PGA) = $\frac{235}{1785}\,404$

1977 Aerosols (PGA) = 53 tons/day = Y

1980 Aerosols (PGA) = $\frac{235}{1785}\,349$

1980 Aerosols (PGA) = 46 tons/day = Z

Total particulate emissions are the sum of directly emitted particulates and photochemically-generated aerosols. Naturally occuring particulate matter was not incorporated in this proportional model analysis.

For the South Coast Air Basin, in accordance with the original State Implementation Plan:

Year	1970	1975	1977	1980
Directly Emitted Particulate Emissions (tons/day)	235	140	146	143
Photochemically-generated Aerosols (tons/day)	235	63	53	46
Projected Controllable Particulate Emissions (tons/day)	470	203	199	189

4.2.6-3 Larsen's Model for Relating Air Quality Estimates with Different Averaging Times

The importance of developing air quality estimates based on averaging times identical to the air quality standards was discussed previously. The Larsen Model [42,43] provides a mathematical basis for relating air quality estimates to the ambient air quality standards when the averaging time for the two air quality values are different.

The Larsen Model incorporates the following assumptions of air quality monitoring data [44]:

1. Pollutant concentrations are log normally distributed for all averaging times, i.e., a graph of frequency on the vertical axis vs. the logarithm of the corresponding concentration values on the horizontal axis has a normal (bell-shaped) distribution.

2. Median concentrations are proportional to averaging times raised to an exponent, i.e., the data can be plotted as a straight line on logarithmic graph paper.

3. The arithmetic mean concentration is the same for all averaging times.

4. Maximum concentrations are approximately inversely proportional to the averaging times raised to an exponent.

5. For the longest averaging time calculated (usually one year) the arithmetic mean, geometric mean, maximum concentration and minimum concentration are all equal. This is possible since for the longest averaging time only one data point will be determined.

6. The arithmetic mean is proportional to regional emissions, i.e., pollutant burden.

The principal statistical parameters used in the model are:

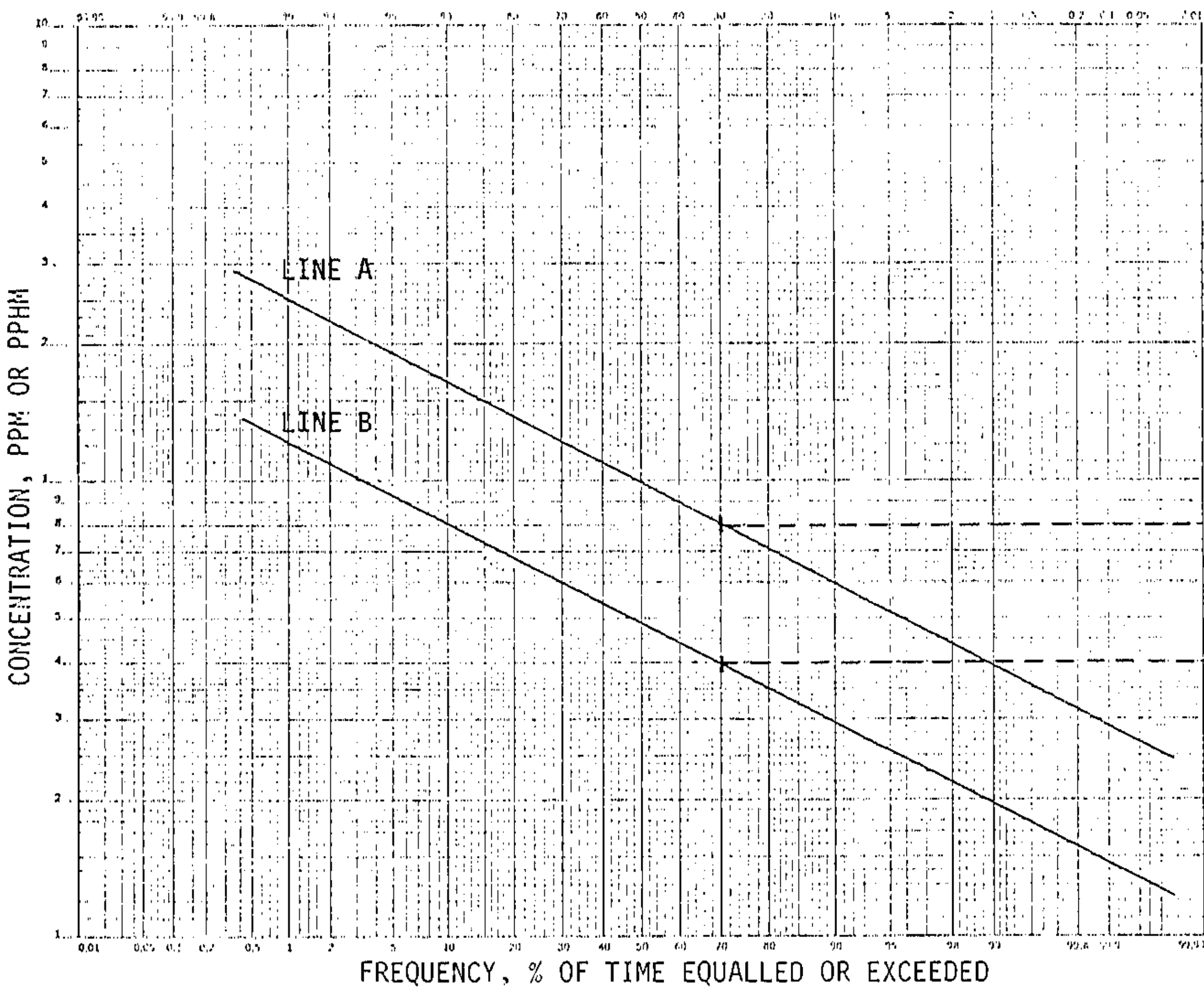
1. geometric mean or arithmetic mean
2. standard geometric deviation
3. maximum concentration expected once a year for a specified averaging time
4. frequency distribution of expected pollutant concentrations (this distribution is log-normal).

The Larsen model has been used to define expected maximum pollutant concentrations on the basis of historical data. In such an application, the data is plotted on special probability graph paper as shown in Figure 4.15 on a cumulative frequency basis (i.e., the percent of observations less than a given level). A best fit straight line (assuming the data is log-normally distributed) is then drawn through the upper portion of the data, and extended to the percentile representing a frequency of occurrence of once per year. The pollutant concentration corresponding to this point is interpreted to be the expected peak level for the data set. This technique has been useful in helping to determine whether a given peak concentration is reasonable or whether it is due to freak conditions of one kind or another.

A second application of the Larsen technique involves an implicit linear rollback assumption. A full year's worth of data is first plotted on log-probability paper. The arithmetic mean concentration, which is approximated by the 70 percentile value, is then interpreted to be proportional to emissions.

FIGURE 4.15

SAMPLE LARSEN ANALYSIS ON LOG-PROBABILITY PAPER



If the monitoring data follows Line A, then a 50% reduction in emissions would result in air quality defined by Line B. Given the arithmetic mean concentration of 8 ppm (70 percentile concentration), an emissions reduction of 50% inplies a new arithmetic mean concentration of 4 ppm.

The geometric standard deviation of the data is a measure of the variability of such variables as meteorological conditions, instrument changes, and emissions pattern changes. If the line defined by the data is raised or lowered proportionate to the expected change in regional emissions (using the 70 percentile point as a reference), the number of measurements above a given level (the air quality standard, for instance) expected to occur per year as a result of the emission change may be determined (Figure 4.15). Also the expected maximum value associated with the new level of emissions can be estimated.

Finally, a third application involves the coupling of the Larsen model with an annual average Gaussian plume model. Using annual average meteorological and emission input data, an appropriate Gaussian plume model would compute the annual mean concentration. By applying the Larsen analysis to historical monitoring data for a given region, the standard deviation of monitored pollutant concentrations may be determined and applied to the modeled average concentration to determine the projected peak concentration. This may be done for various averaging times, consistent with the averaging times used in the historical data. The Larsen analysis can be completed for each pollutant of interest using the historical air quality data for that pollutant.

As mentioned, the Larsen analysis assumes a log-normal distribution of concentration vs. averaging time. In practice, this analysis is applied only to the data for the higher recorded concentrations since other data may not approximate the log-normal distribution. This assumption of lognormality is not always valid [45] and its applicability to the air quality data for the study area should be evaluated before utilizing the Larsen technique. A further simplifying assumption is made, however, in order to bypass the need for a Gaussian plume analysis. This assumption is that the distribution of emissions does not change within the time frame of the analysis (i.e., that any emission increases or reductions occur proportionally throughout the region). Such an assumption may be valid over the short run, but is clearly not representative of what may be expected to occur over the long term.

The principal asset of the Larsen model is the minimization of requirements for sophisticated dispersion models without sacrificing the capability for estimating episode or worst-case situations.

Normally, the concentrations resulting from extreme meteorological conditions such as calm winds, recirculations, and fumigations cannot be handled very accurately by currently available dispersion modeling techniques. Moreover, any model which would be considered even reasonably suited to this task would be extremely sophisticated. Consequently, the air quality modeling for extreme meteorological conditions which are of greatest interest from an air quality standpoint has not met with a great deal of success [46].

When simpler methods are used to model air quality on a long-term averaged basis, the variance of air quality estimates are damped out. By using statistically based models such as the Larsen model, the variance lost by long-term averaging can be incorporated into the estimates.

The fundamental drawback to these statistical approaches, and indeed, to any approach which ignores the physical and chemical processes governing the accumulation and dispersion of air pollution is the fact that they are directly dependent on the conditions which prevailed at the time and place where their data base was gathered. Changes in emission patterns due to control programs or changes in urban form cannot be properly evaluated.

SECTION 4. - AIR QUALITY MONITORING AND AIR QUALITY MODELING

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