SECTION 4.0

BOATS

In order to assess the importance of air polluting emissions from pleasure and commercial boats an in-depth study of boat usage in California was conducted by KVB. The objectives of this study were twofold:

1. To develop a methodology to inventory emissions from pleasure and commercial boats which would be applicable in all areas of the state for the base year, 1977.

2. To use that methodology to compile an inventory of emissions from pleasure and commercial boats in the South Coast Air Basin (SCAB) for 1977.

The evolution of this inventory methodology and its application to the SCAB are described in this section.

4.1 APPROACH

Two separate methodologies were needed to inventory boat emissions, one for pleasure boats and another for commercial boats, because distinct and significant differences exist in boat usage and information sources.

4.1.1 Pleasure Boats

Our approach to inventorying emissions from gasoline-powered pleasure boats follows the work done by Arthur Young & Company, with appropriate modifications. Arthur Young & Company, in 1972 and 1973, published two reports for the California Department of Navigation and Ocean Development (DENOD). The 1972 report, Final Report on the State Gasoline Tax Paid on Gasoline Used in Propelling Boats During the 1971 Calendar Year (Ref. 1)* dealt only with annual

*References for Section 4.0 are listed on page 4-70.

gasoline usage by pleasure and documented* boats for the state of California. The 1973 Arthur Young & Company report, Boating Resources Development Planning Study (Ref. 2), described recreational boating uses and patterns throughout California. These two reports, in conjunction with AP-42 emissions factors, formed the framework for the methodology used by KVB to inventory emissions from gasoline-powered pleasure and documented boats. A separate procedure was developed by KVB to inventory the emissions from diesel-powered pleasure boats.

The objectives of Arthur Young & Company's first report (which formed the basis for the second) were to:

- Determine with reasonable validity, using recognized statistical sampling techniques where applicable, the amount of state gasoline tax attributable to gasoline used in propelling boats (in California) during the 1971 calendar year.
- Develop and recommend an equitable method for reasonably estimating, every year, the amount of state gasoline tax attributable to gasoline used in propelling boats.

In conducting their study, Arthur Young & Company obtained information on state boat registrations from the Department of Motor Vehicles (DMV) and the U. S. Coast Guard. California's registered boat population was initially subdivided into seven categories by boat length and propulsion method as follows:

Inboard, Outboard, Other
<14'
14<16'
16<18'
18<21'
21<26'
26<31'
>31'

*KVB uses the terms "documented" and "commercial" synonymously. The gasoline-powered documented boats included here are considered by KVB to be more for recreational than business (commercial) purposes. They therefore constitute part of the pleasure boating emissions inventory. Documented boats are registered by the U. S. Coast Guard.

Questionnaires were then sent to a selected sample of the 1971 boat owner population. The information obtained via these questionnaires was used to project fuel consumption for the entire state's boat population. Standard statistical methods were applied to determine the correct sample size and response rate required to arrive at a dependable estimate of the amount of gasoline purchased for boats in 1971. Information on fuel used, approximate number of days a boat was used per year, average hours a motor was used per day, and percentage of boating time spent in lakes, rivers, coastal waters, and other waterways was gathered in the questionnaires. The results are presented in Table 4-1, summarized into nine length/propulsion categories (as presented in Reference 1). Information on diesel fuel usage was not included in the Arthur Young study. The gasoline fuel consumption factors listed in Table 4-1 also include allowances for the following considerations:

- Purchase of gasoline out of state by Californians was deducted from the total gallons, since no California tax was paid on that gasoline.
- Estimated usage of gasoline in California by non-residents was added to the total.
- An estimate was made of the amount of gasoline used by Californians who own outboard engines but rent boats, since they were not included in the survey.
- Estimated gasoline usage by boats that were neither registered nor documented was added to the total estimate.

4.1.2 Commercial Boats

A literature search and numerous contacts were made to determine if any work had been done to estimate the quantity of fuel used or emissions generated by commercial boats in the size ranges we were dealing with. We concluded that no information on this subject existed. However, Mr. Bob Pata of the National Marine Fisheries Institute indicated that in 1977 his department had the task of determining the gallonage of diesel fuel sold to commercial and party fishing boats by coastal fuel docks. This information was incorporated into the commercial boating inventory. Previous emissions studies dealt with large ocean-going ships, which are outside the context of our study and, therefore, not included.

TABLE 4-1. FINAL RESULTS OF THE ARTHUR YOUNG & COMPANY REPORTS ON BOAT GASOLINE USAGE AND BOAT USAGE PATTERNS AND OCCURRENCES*

Boat Length	Method of Propulsion	Approx. Number of Days Boat Used Per Year	Avg. Gasoline Consumptions, Gal/Yr	Avg. Percent Use†			
				Coastal	Rivers	Lakes	Other
<16'	Inboard	29	400	19	16	62	3
	Outboard	22	88	19	16	62	3
	Other	25	5	19	16	62	3
16<26'	Inboard	34	380	44	14	40	2
	Outboard	29	250	44	14	40	2
	Other	41	17	44	14	40	2
≥26'	Inboard	51	780	79	14	4	3
	Outboard	55	210	79	14	4	3
	Other	58	42	79	14	4	3

Annual gallons consumed by documented vessels = (8,012.45) x (year-1871)

*Source: Refs. 1 and 2.

†Based on a engineering analysis of the data presented in Ref. 2.

4.2 DEVELOPMENT OF METHODOLOGY

4.2.1 Pleasure Boats

The information in the two Arthur Young & Company reports (Refs. 1 and 2) formed the framework for KVB's development of a methodology to inventory the emissions from pleasure boats. Pleasure boats include gasoline- and diesel-powered registered boats and gasoline-powered documented boats. KVB devised a new procedure for inventorying diesel-powered pleasure boats. Discussed in this section is the development of these methodologies.

A. Determine Pleasure Boat Population--

The first task was to determine the state's pleasure boat population by investigating registrations. All boat owners are required by law to register their boats either with the California DMV or the U. S. Coast Guard. (A boat cannot be registered with both agencies.) The DMV (Ref. 3) provided KVB with a copy of their 1977 fourth-quarter list of California's total vessel registration by county. Boat categories included by the DMV are pleasure, livery, dealer, manufacturer, commercial, youth group, and government-fee exempt. These same categories, as used by Arthur Young & Company, were also employed by KVB as indicating all pleasure boats. For the calendar year 1977, the DMV reported 542,725 registered boats. Of these, less than one percent were registered as commercial. KVB assumes that these commercial boats consume gasoline fuel, not diesel fuel. An inventory of outboard engine owners who rent boats was not made. However, an allowance for the fuel they consume is included in the Arthur Young & Company fuel-use figures.

The U. S. Coast Guard in California is composed of the Eleventh and Twelfth Districts. The number of boats registered as documented vessels by the U. S. Coast Guard, Eleventh District, was reported at approximately 4,000 (Ref. 4). Information was not obtained from the Twelfth District, but their documented vessel population was estimated by KVB to be approximately equal, or 4,000 vessels. The state total was thus estimated at 8,000 vessels.

Boats generally documented with the U. S. Coast Guard (1) are larger than five net tons; (2) haul passengers for hire; (3) are involved in strictly commercial trade; and (4) travel outside the boundaries of the United States. Boats meeting none of these criteria may still be documented if the owners wish.

What these facts imply is that most of the boats documented are diesel-powered commercial boats, with some gasoline- and diesel-powered pleasure boats. KVB did not add these documented vessels to the DMV's pleasure boat estimate. An allowance for gasoline-powered documented boats is contained in the Arthur Young & Company report and is used as such. Diesel-powered commercial boats are covered in our commercial boat inventory (paragraph 4.2.2) and therefore are not included in this pleasure boat emissions inventory.

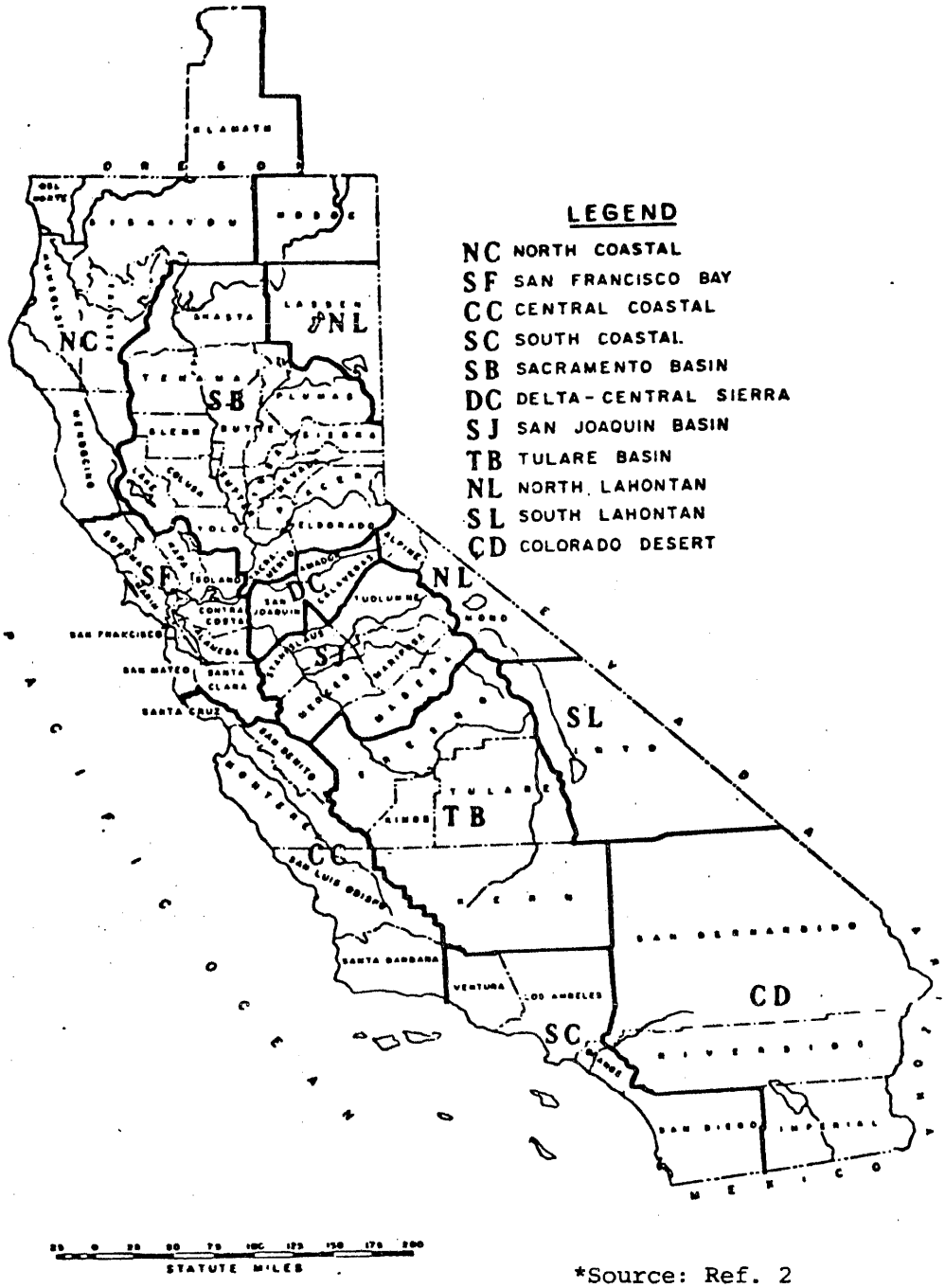
B. Determine Where Pleasure Boats Operate--

To determine where the estimated 540,000 pleasure boats operate, the state was divided into eleven water regions, as is done by the Department of Navigation and Ocean Development (DENOD, Ref. 2). Figure 4-1 shows these eleven water regions; a list of the counties in each region is provided in Table 4-2.

DENOD uses eleven water regions for economic planning purposes. KVB's intent is to use these regions as a framework for characterizing boating activity in a general area. By consolidating the eleven regions into four or five major boating areas, the state can be divided into general boating areas. To be statistically effective, each general boating area would have to include lake, river, and coastal waters. The basic assumption made by KVB is that boats registered in a large area offering all three forms of boating--lakes, rivers, and coastal--in sufficient quantity and quality, also spend nearly all their time in that same area, with occasional vacation migrations out of the area balanced by boats entering for the same reason. (Each region would have to be studied in detail to ascertain the validity of this assumption.)

As an example, to effectively inventory the emissions from pleasure boats in the South Coast Air Basin, the South Coastal and Colorado Desert Regions were combined to form one major Southern California boating area. There are basically two boating regions in the state, San Francisco Bay and South Coastal, which account for approximately 24 percent and 37 percent, respectively, of the total 1977 DMV boat registrations.

Contained in Reference 2 and another report, Inventory of California Boating Facilities, published by DENOD (Ref. 5), is substantial information on boating facilities for each region by county. Further investigation also



*Source: Ref. 2

Figure 4.1. California's Boating Water Regions*

TABLE 4-2. THE STATE'S ELEVEN WATER REGIONS AND THE COUNTIES WITHIN EACH*

North Coastal	Del Norte, Siskiyou, Humboldt, Trinity, Mendocino
San Francisco Bay	Sonoma, Napa, Marin, Solano, Contra Costa, San Francisco, Alameda, San Mateo, Santa Clara
Central Coastal	Santa Cruz, San Benito, Monterey, San Luis Obispo, Santa Barbara
South Coastal	Ventura, Los Angeles, Orange, San Diego
Sacramento Basin	Modoc, Shasta, Tehama, Plumas, Glenn, Butte, Sierra, Lake, Colusa, Sutter, Yuba, Nevada, Placer, Yolo, Sacramento, El Dorado
Delta-Central Sierra	Amador, San Joaquin, Calaveras
San Joaquin Basin	Stanislaus, Tuolumne, Merced, Mariposa, Madera
Tulare Basin	Fresno, Kings, Tulare, Kern
North Lahontan	Alpine, Mono, Lassen
South Lahontan	Inyo
Colorado Desert	San Bernardino, Riverside, Imperial

*Source: Ref. 2

showed that there is a wealth of information published on boating and boating facilities in California by DENOD, the California Department of Fish and Game, Triple A Auto Club, and numerous boating magazines and books. This information supported the assumption that the eleven regions could be studied in sufficient detail to consolidate the regions into fewer boating areas.

C. Determine Average Boat Usage/Fuel Consumption--

With the population of boats in California determined and a scheme developed for dividing the state into major boating areas, the next task was to obtain data on average boat usage in each area. To apply AP-42 emission factors, boats had to be inventoried in terms of fuel use (10^3 gallons, diesel or gasoline) and method of propulsion (inboard and outboard).

The two Arthur Young & Company reports (Refs. 1 and 2) contain information on average California pleasure boat usage, with respect to fuel consumption and boating days, by boat length, method of propulsion, and fuel type. The information presented in Table 4-1 represents the final results of these two studies. Boats are categorized by length ($<16'$, $16<26'$, $\geq 26'$), method of propulsion (inboard, outboard, other), gasoline-powered documented vessels, and percentage use on lakes, rivers, coastal, and other waters. Further investigation of the two reports revealed that the data could be broken down into 21 boat length/method of propulsion categories rather than the nine categories presented in Table 4-1. Table 4-3 presents the results of this alternate subdivision method. The average fuel consumption factors listed in Tables 4-1 and 4-3 include allowances for the following considerations:

- Purchase of gasoline out of state by Californians was deducted from the total gallons.
- Estimated usage of gasoline in California by non-residents was added to the total.
- An estimate was made for the amount of gasoline used by Californians who own outboard engines but rent boats, since they were not included in the survey.
- Estimated gasoline usage by boats that were neither registered nor documented was added to the total estimate.

A brief explanation follows of the data in Tables 4-1 and 4-3.

TABLE 4-3. SUMMARY OF THE 21 UNIQUE BOAT LENGTH/METHOD OF PROPULSION PLEASURE BOAT CATEGORIES AND PATTERNS OF OCCURRENCE*

Boat Length	Method of Propulsion†	Approx.No.Days Boat Used Per Year Boat Days/Yr§	Annual Avg.Gasoline Use Gal/Yr#§	Avg.Gasoline Used Per Boat Day Gal/Boat Day§	Avg. Percent Use By Length and Boating Water		
					Coastal	Rivers	Lakes
<14'	Inboard	49	610	12	19	19	62
	Outboard	23	59	2.6	19	19	62
	Other	24	3.1	0.129	19	19	62
14<16'	Inboard	23	210	9.1	18	16	66
	Outboard	22	117	5.3	18	16	66
	Other	27	8.2	0.3	18	16	66
16<18'	Inboard	31	320	10.3	20	17	63
	Outboard	27	250	9.3	20	17	63
	Other	27	16	0.59	20	17	63
18<21'	Inboard	32	370	11.6	39	16	45
	Outboard	29	250	8.6	39	16	45
	Other	44	9.0	0.20	39	16	45
21<26'	Inboard	42	580	13.8	72	12	16
	Outboard	31	270	8.7	72	12	16
	Other	50	22	0.44	72	12	16
26<31'	Inboard	50	720	14.4	79	14	6
	Outboard	61	180	3.0	79	14	6
	Other	58	42	0.72	79	14	6
≥31'	Inboard	51	830	16.2	79	16	5
	Outboard	44	270	6.1	79	16	5
	Other	57	41	0.72	79	16	5

#Annual gallons consumed by documented vessels (gasoline) = (8,012.45) x (year-1871).

*Source: Refs. 1 and 2.

†Inboard: Includes inboard, inboard/outboard, and jet powered craft which were shown in the survey to be the biggest consumers of gasoline.

Outboard: Includes only outboard powered craft which the survey data showed as the medium gasoline consumers.

Other: Includes auxiliary sail, rowboat, sailboat, canoe, and other varieties of boats which were shown to have very low average annual consumption by the survey data. Considered as outboard powered craft.

§Based on 1971 data. Due to the energy crisis these factors may not be valid beyond 1978.

Boat length is self-explanatory. The three types of propulsion--inboard, outboard, and other--are defined as follows:

Inboard	Includes inboard, inboard/outboard, and jet powered craft.
Outboard	Includes only outboard-powered craft.
Other	Includes auxiliary sail, rowboat, sailboat, canoe, and other varieties of boats. For emission inventory purposes, defined as outboard-powered craft by KVB.

The "Approximate Number of Days a Boat Was Used Per Year," called "Boat Days," lists Arthur Young & Company's estimate of the average number of days a boat of a certain category is used per year on lakes, rivers, and coastal waters. The next column, "Annual Average Gasoline Use," is also based on Arthur Young & Company's gasoline use tax study and lists the various annual fuel comsumption values for the 21 unique boat categories. The reader is cautioned that these figures are based on 1971 data which were still valid for the base year of this inventory, 1977,. However, since 1977 the energy crisis has caused a precipitous increase in fuel prices which could significantly change these factors for subsequent years especially for pleasure boating (see Section 4.5). The next column, "Average Gasoline Used Per Boat Day," was derived by dividing the annual fuel consumption by the boat days used per year for each boat category. The last column lists the average percent use by boat length and boating water. Arthur Young & Company uses four subdivisions as presented in Table 4-1. For our purposes, the "Other" water form was evenly divided among lakes and rivers; "Other" applies to unusual water environments such as, for example, Disneyland.

Presented at the bottom of Table 4-3 is a formula for the determination of the gallons of gasoline fuel used by documented vessels in coastal waters. Information on documented vessels was very scarce; therefore, KVB decided to use this formula as is. The formula, 8012.45 x (year - 1871) = gallons gasoline/year, was developed from Arthur Young & Company's gasoline use tax study in which 1,304 gasoline-powered documented vessels reported consuming approximately 801,245 gallons in 1971. A one percent population growth rate since 1871 was also predicted, as reflected in the formula.

The 21 unique categories of pleasure boats listed in Table 4-3 enable greater flexibility and detail in characterizing the boats registered in a county or area. For example, coastal counties show a greater proportion of >26-foot inboard-powered boats than most inland counties. In contrast, inland counties having lake or river waters show a greater proportion of less than 26-foot outboard-powered boats. Table 4-4 lists the information presented in Table 4-3 and its intended use as a means of estimating the gasoline fuel used by boats in lakes, rivers, and coastal waters.

TABLE 4-4. SUMMARY OF THE DATA PRESENTED IN TABLE 4-3 AND ITS INTENDED USE

Information	Intended Use
21 Unique length/method of propulsion categories	By application to an area's registered boat population, that area's registered boats can be classified: --by length --by method of propulsion --by percent inboard by percent outboard by percent other
Approximate number days boat used per year	Estimate the total boat days per year per study area by length and method of propulsion
Average percent use by length and boating water	Determine the percentage of total boat days in lakes, rivers, and coastal waters; waterway allocation scheme by boat length
Average gasoline used per boat day	Once an area's boat population/usage is determined in terms of boat length, method of propulsion, and total boat days, the annual fuel used by each category of boat per water area can be determined
Gallons consumed by Coast Guard-documented vessels 8012.45 x (year-1871)	Estimation of the total quantity of gasoline used per year by Coast Guard registered vessels

To apply the information in Table 4-3 as discussed in Table 4-4, the 1977 DMV boat registrations by county were extrapolated into a form compatible with the information presented in Table 4-3. The extrapolation was based on the 1973 DMV computer printout which was in this format (Ref. 2). 1973 was the last year the DMV annually provided boat registration data in such detail.

Taking the information in Tables 4-3 and 4-4 and the 1977 DMV boat registrations for the regions/counties in the study area, the total gasoline

fuel used by gasoline-powered pleasure and documented boats can be determined for lakes, rivers, and coastal waters. Pleasure boats using diesel fuel were found by KVB to be essentially nonexistent on lakes and rivers, but significant on coastal waters (including the Sacramento Delta). The best approach found by KVB to determine the quantities of diesel fuel used by pleasure boats operating in coastal waters was to conduct a survey of the fuel docks serving the marinas in the study area. Knowing the quantity of diesel fuel sold only to pleasure boats at each marina and the number of berths (or slips), a factor representing gallons of diesel fuel used per berth could be determined. Then, multiplying the total number of coastal berths in the study area by this fuel-use factor, the annual quantity of diesel fuel used by pleasure boats could be determined.

D. Spatial Distribution of Fuel Used--

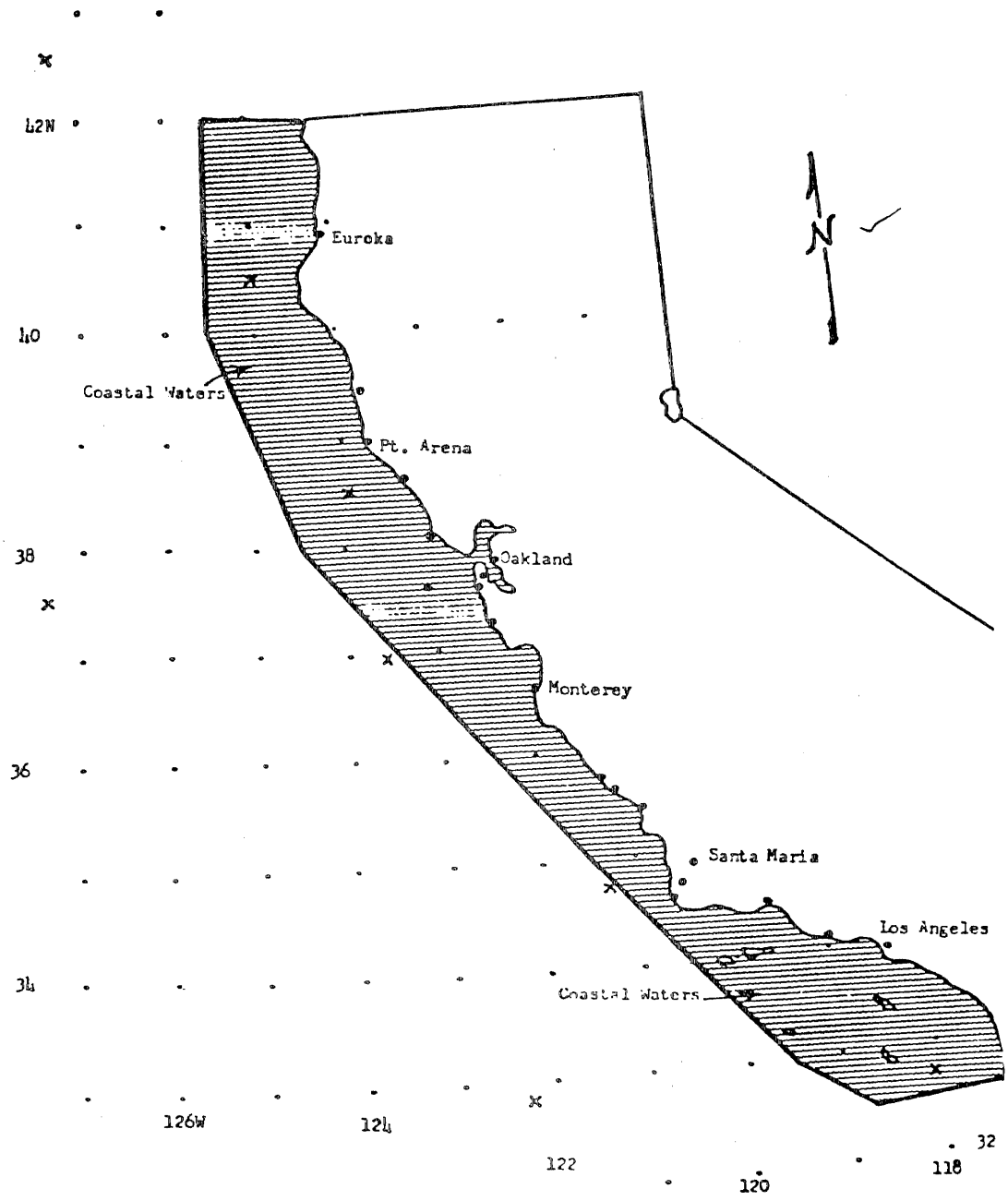
This completes the task of estimating the pleasure boat population and 1977 fuel consumption on lakes, rivers, and coastal waters. A method of verifying the results is described below. First, however, the estimated quantities of fuel used on each of the three forms of boating water--lake, river, and coastal--must also be spatially distributed. To do this for lakes, all the lakes in the area must be studied as to boat usage and then categorized as to the relative percentage of the total each lake is accountable for. For rivers, the same line of reasoning applies. Coastal distribution will involve identifying the marinas and major boating lanes along the coast. Fuel would then be apportioned accordingly. California's offshore air pollution boundaries, as defined by the ARB (Ref. 6), are displayed in Figure 4-2.

E. Temporal Distribution of Fuel Used--

As was expected, temporal distribution was found to coincide with available monthly fuel sales data and with the boating seasons of the year for each area in the state.

F. Crosschecking Methods--

In developing this methodology, various means of crosschecking the data obtained or derived were sought. The DMV boat counts do not need a cross check for accuracy, but the information presented in Arthur Young & Company's two reports and the way in which we are applying it do. The best method found by KVB to verify the accuracy of the fuel use estimates made for lakes, rivers,



Source: Ref. 6

Figure 4-2. California Offshore Air Pollution Boundaries.*

and coastal waters was to conduct either telephone or personal surveys of the fuel used (or sold) and the annual boat counts taken on lakes and rivers. For example, once the gasoline and diesel fuel-use estimates are made for a large marina such as Marina Del Rey, data on fuel sales from the fuel dock(s) serving the area should be collected. The quantities reported sold by the fuel docks can be compared against those estimated using the procedure outlined. Discrepancies could then be analyzed and adjustments made if needed. Taking a large lake such as Lake Elsinore, annual boat counts are normally made. Fuel is not sold at many of the lakes. Using boat counts as a check on our fuel-use estimate for Lake Elsinore, an average fuel consumption factor could be applied to the annual boat count to arrive at a reasonable fuel-use estimate. Another way of crosschecking is to obtain boat counts for a few years before and after 1977. In this way, upsets in the natural progression of boating (which the methodology relies upon) can be detected. During 1977 many of the lakes in California were experiencing lower-than-average water levels and boat counts due to a drought. The boat usage information presented in Table 4-3 represents average usage factors based on the 1973 study. Deviations from this average as reflected in lower boat counts (lower boat days) translate into lower boat usage and, therefore, lower fuel use. This same line of reasoning also applies to rivers. As a word of caution, discrepancies when found must be assessed as to whether they apply only to the specific body of water surveyed, all waters, or to the method of spatially distributing the total fuel-use estimate or any combination thereof.

G. Determine Emissions for Pleasure Boats--

Revisions to the initial gasoline and diesel fuel-use estimates could then be made as needed and a more accurate inventory made. The primary objective of this report was to determine the emissions from pleasure boats in California. Through calculating the fuel used by boats with known methods of propulsion (inboard or outboard) and fuel usage (gasoline or diesel), and applying appropriate emissions factors, the associated emissions could be determined.

AP-42 was judged by KVB as the best current source of emission factors for pleasure boats. Table 4-5 presents the emission factors in lbs/10^3-gallon units as listed in paragraphs 3.2.3 and 3.2.4 of AP-42 (Refs. 7 and 8).

TABLE 4-5. AP-42's AVERAGE EMISSION FACTORS FOR PLEASURE BOATS

Pollutant	AVERAGE EMISSION FACTORS FOR PLEASURE CRAFT		
	Inboard*		Outboard‡
	Based on fuel consumption		
	Diesel engine†	Gasoline engine§	Gasoline
	lb/10^3 gal	lb/10^3 gal	lb/10^3 gal
Sulfur oxides# (SO_x as SO_2)	27	6.4	6.4
Carbon monoxide	140	1240	3300
Hydrocarbons	180	86	1100**
Nitrogen oxides (NO_x as NO_2)	340	131	6.6

* Average emission factors are based on the duty cycle developed for large outboards ($\geq$48 kilowatts or $\geq$65 horsepower). The above factors take into account the impact of water scrubbing or underwater gasoline engine exhaust. Al values given are for single engine craft and must be modified for multiple engine vessels. Emission Factor Rating: D.

† Based on tests of diesel engines in Coast Guard vessels.

§ Based on tests of automotive engines. Fuel consumption of 11.4 liter/hr. (3 gal/hr) assumed. The resulting factors are only rough estimates.

Based on fuel sulfur content of 0.20 percent for diesel fuel and 0.043 percent for gasoline. Calculated using fuel density of 0.740 kg/liter (6.17 lb/gal) for gasoline and 0.854 kg/liter (7.12 lb/gal) for diesel fuel.

‡ Data in this table are emissions to the atmosphere. A portion of the exhaust remains behind in the water. Particulate emission factors are not available because of the problems involved with measurement from an underwater exhaust system but are considered negligible.

** Includes exhaust hydrocarbons only. No crankcase emission occur because the majority of outboards are 2-stroke engines that use crankcase induction. Evaporative emissions are limited by the widespread use of unvented tanks.

*Source: Refs. 7 and 8, respectively

Gasoline-powered documented vessels were considered as inboards. As discussed in AP-42 the exhaust from these small boat engines are discharged beneath the surface of the water. Emissions from these boats are somewhat reduced by the water scrubbing. However, the gas-liquid contact is poor and the contact time is short. Because of technical problems, no valid tests of particulate emissions have been conducted but they are considered to be negligible.

Spatial and temporal distribution of emissions will naturally coincide with the location of the boating waters and the time and length of the boating season.

The information presented in the two Arthur Young & Company reports is based on the boating habits of California boaters statewide in 1971. Taking this as a base year then, any significant deviation from boaters' activities during 1977 would be reflected in boat usage and, subsequently, fuel usage. 1977, which is the base year for KVB's study, was a year in which many of the lakes in Southern California recorded lower-than-normal boat usage due to a drought. Other than the effects of the drought on lakes and rivers, no significant deviations from 1971's boat activities are believed by KVB to have occurred. Taking into consideration this and the errors possible in the application of statewide boating information to specific areas, KVB has estimated the overall error in determining the emissions from pleasure boats using this methodology at $\pm$ 30 percent.

4.2.2 Commercial Boats

A. Basis for Methodology--

The methodology developed by KVB to inventory emissions from commercial boats operating in California, as defined by the ARB, was based on an inventory of the commercial boat population along the coast and the quantity of diesel fuel sold to these boats.

Commercial boats were defined by KVB to include the following:

- Commercial and party fishing boats
- Tug boats
- Work boats
- Lightering barges
- Excursion boats
- Miscellaneous small commercial utility craft
- U.S. Coast Guard vessels

These vessels account for essentially 100 percent of the commercial boat activity along the California coast (large ocean-going ships excluded). Also, essentially all of these vessels were found to burn only diesel fuel purchased from the many fuel docks located along the coast or directly from the oil companies. The major oil companies accounted for more than 95 percent of all the diesel fuel sold to all boats along the California coast (Refs. 9 to 21). By comparison, commercial boating activity on California's lakes and rivers is insignificant and was included in the pleasure boat emissions estimate (paragraph 4.2.1).

The fact that essentially all commercial boats considered in this study burn diesel fuel for propulsion and onboard electrical generation enabled us to design two independent methods for estimating the quantity of diesel fuel sold to and consumed by commercial boats operating in California waters.

B. Method One--

Method One, an oil company survey, involved the acquisition of information on the annual quantities of diesel fuel sold to all boats along the coast by major and independent oil companies. The response to KVB's request for data from the oil companies was surprisingly high. Approximately 70 million gallons of diesel fuel were reported sold to all boat types along the California coast in 1978 (Refs. 9 to 21). This 70 million gallons includes sales to all types of vessels operating along the California coast (pleasure as well as commercial). Additional information was needed to apportion the 70 million gallons to the respective consumers (i.e., tug boats, commercial fishing boats). The quantity of diesel fuel sold to large ocean-going vessels was found by KVB to be negligible compared to the fuel sold to the commercial boats considered by this project.* Data for 1977 were not available; however, 1978 fuel sales are believed to be essentially the same (Refs. 9 to 16).

C. Method Two--

Method Two, a National Marine Fisheries Service (NMFS) survey, involved the acquisition of information on the annual gallonage of diesel fuel

* Large ocean-going ships normally burn bunker "C" fuel or other heavy residual oils.

sold in California to commercial and party fishing boats only. The objective of the NMFS study was to inventory the quantity of diesel fuel needed, by location, by commercial and party fishing boats in the event of another fuel shortage (Ref. 22). The NMFS accomplished this task by contacting all the fuel docks serving commercial fishing vessels along the California coast and asking them how much diesel fuel they sold in 1978 to commercial and party fishing vessels. Approximately 69 million gallons of diesel fuel were reported to have been sold to these vessels. The preliminary results of the NMFS survey are presented by geographical areas in Table 4-6. 1977's figures, if surveyed, are not believed to be appreciably different than 1978's. The geographical areas in the table are in accordance with those employed by the California Department of Fish and Game to summarize California's fisheries statistics (see Figure 4-3). The coastal waters considered by the ARB to be included in KVB's boating emissions inventory are shown in Figure 4-3. Although the numbers reported in Table 4-6 are considered preliminary by the NMFS, their study is essentially complete, and no significant additions, deletions, or changes are predicted.

D. Methods Summary--

To summarize the two methods, the oil company survey (Method One) yielded information on the total diesel fuel sold in California in 1978 to all boats (70 million gallons). The NMFS survey (Method Two) yielded information on the diesel fuel sold by California coastal fuel docks to commercial and party fishing boats only (69 million gallons). To compare the results of the two surveys, the data obtained from the oil company survey were adjusted to indicate only that gallonage sold to commercial and party fishing boats. The NMFS survey's figure is only for commercial and party fishing boats.

E. Determine Emissions from Commercial Boats--

Calculation of the pollutant emissions associated with commercial diesel-powered boats involved the use of AP-42's Average Emissions Factors for Commercial Motorships by Coastal Waterway Classification (Ref. 36). Unlike the pleasure boats, most of the commercial boats considered in this study discharge their engine exhaust above the waterline. To account for particulate

TABLE 4-6. SUMMARY OF THE QUANTITY OF DIESEL FUEL REPORTED SOLD TO COMMERCIAL AND PARTY FISHING BOATS IN CALIFORNIA IN 1978*

Geographical Fishing Area	Specific Area	1978 Diesel Fuel Sales 10^3 Gal/Yr
Eureka	Crescent City	1,200
	Eureka	1,001
	Fort Bragg	771
San Francisco	Bodega Bay	324
	San Francisco/Oakland	2,000
	Half Moon Bay	2,300
Monterey	Santa Cruz	81
	Moss Landing	589
	Monterey	418
Santa Barbara	Port San Luis Obispo/ Morro Bay	236
	Santa Barbara	600
	Ventura	160
	Oxnard/Port Hueneme	500
Los Angeles	San Pedro/Terminal Island	10,000
	Newport	126
	Dana Point	255
San Diego	Oceanside	19
	San Diego	48,700
	Total	69,280

*Source: Ref. 22. Data are considered preliminary, and no changes are expected, according to Mr. Pata of the National Marine Fisheries Service.

emissions from diesel-powered inboard engines, the following ratio between SO_x and particulates, based on information contained in AP-42 on diesel-powered industrial engines, was used:

$$\frac{\text{Diesel-Powered Industrial Engines: } 33.5 \text{ lb/}10^3 \text{ gal. total suspended particulates}}{31.2 \text{ lb/}10^3 \text{ gal. } SO_x} = \frac{\text{Diesel-Powered Inboard Marine Engines: } 29.0 \text{ lb/}10^3 \text{ gal. total suspended particulates}}{27.0 \text{ lb/}10^3 \text{ gal. } SO_x}$$

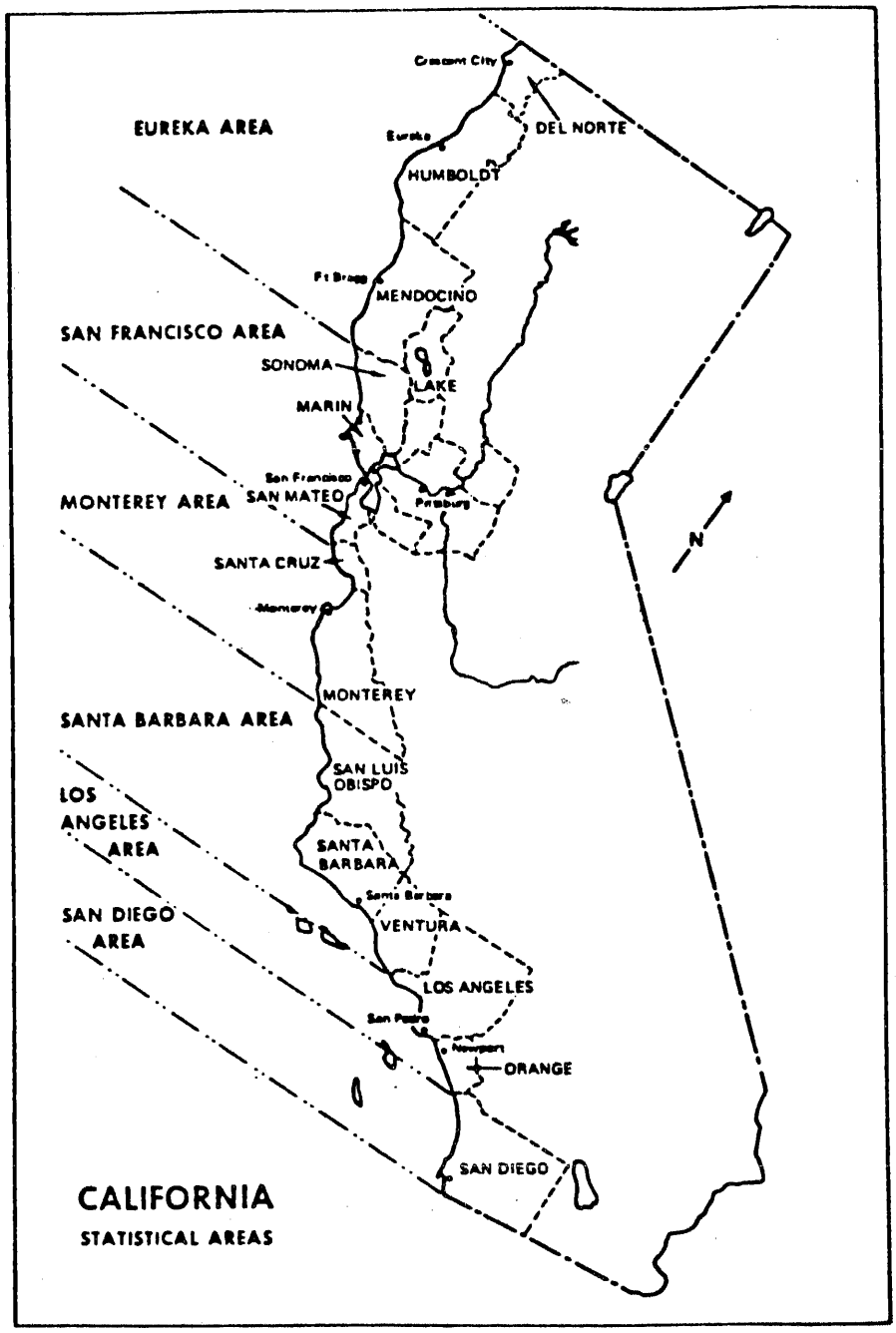


Figure 4-3. Geographical areas by which California fisheries statistics are summarized.
Source: California Department of Fish and Game, (Ref. 23).

Table 4-7 summarizes the emission factors applicable to commercial diesel-powered boats.

TABLE 4-7. AVERAGE EMISSION FACTORS FOR COASTAL DIESEL-POWERED COMMERCIAL BOATS

Emissions, lb/10^3 Gal.				
SO_x	CO	HC	NO_x	Part.
27	110	50	270	29

The greatest possibility for error in a study like this may come from necessary reliance on subjective data obtained through telephone communications with many different sources of varying reliability. However, good agreement among the many sources contacted was continually encountered, which added to the level of confidence on nearly all of the conclusions drawn. As much of the data as possible was also cross-checked with other sources to verify accuracy. The error associated with this methodology, based on an analysis of the many variables, is estimated by KVB as ±20 percent.

4.2.3 Separate Study, California Coastal Fuel Dock Sales

To arrive at the adjustment of oil company survey figures totaling sales of 70 million gallons (see paragraph B, page 4-18) to indicate only that gallonage sold to commercial and party fishing boats, the diesel fuel sold to all other boats was calculated. This was accomplished by inventorying the population of all other diesel-consuming boats in California and then estimating the quantity of diesel fuel sold by California's coastal fuel docks or oil companies to these boats.

A. Pleasure Boats--

The quantity of diesel fuel sold to and consumed by pleasure boats statewide is based on the project's diesel fuel consumption factor and the number of marina slips in the state (as discussed in paragraph 4.4). The following quantity of diesel fuel is estimated to have been sold to pleasure boats statewide:

70 gallons/year/slip x 53,988 slips = 3,800,000 gallons/year

B. Commercial Boats--

Boats other than commercial fishing and party boats that consume significant amounts of diesel fuel include:

- Tug boats
- Work boats
- Lightering barges
- U. S. Coast Guard vessels
- Excursion boats
- Pleasure boats
- Small commercial utility boats

Table 4-8 presents a summary of the estimated diesel fuel used by these boats. The calculations followed in arriving at these fuel estimates are as follows. Tug boats and work boats were found to consume most of the fuel used in this category. The quantity of diesel fuel consumed by lightering barges* and miscellaneous small commercial utility boats is estimated by KVB to be minimal by comparison and is included in the tug boat, work boat and excursion boat fuel estimate. A survey of two large tug boat companies operating in Los Angeles Harbor disclosed that the average tug boat or work boat consumes approximately 57,000 gallons/year (Refs. 24 and 25). Based on this information and an inventory of the boat population along the California coast, Table 4-9 was developed.

C. Survey Comparisons/Analyses--

Approximately 11 million gallons of diesel fuel were estimated by KVB to have been sold to commercial boats as listed in Table 4-8.

To compare the 70-million-gallon value (all boats) obtained from the oil company survey to the 69-million-gallon value (only commercial fishing boats) obtained from the NMFS survey, the following calculation was made:

70,000,000 gallons, all boats
-11,000,000 gallons, see Table 4-10
59,000,000 gallons for commercial and party fishing boats

*Tug boats or work boats generally provide the power to propel lightering barges to their destination. Generally, the fuel used by a lightering barge is consumed by onboard IC engines which are used to pump the fuel.

TABLE 4-8. SUMMARY OF THE QUANTITIES OF DIESEL FUEL CONSUMED BY BOATS OTHER THAN COMMERCIAL AND PARTY FISHING BOATS

Category	1977 Diesel Fuel Consumption* 10^3 Gal./Yr. Unadjusted†	Adjusted†
Tug boats, work boats, lightering barges, and miscellaneous small commercial utility boats	4,400	4,900
U.S. Coast Guard	2,000	2,300
Excursion Boats	1,000	1,110
Pleasure Boats	3,800	3,800
Totals	11,200	12,100

*Includes the diesel fuel used for onboard electrical generation as well as for vessel propulsion.

†The unadjusted values represent the results of the project's first estimation. The adjusted values represent the values corrected for the averaging of the oil company survey and the NMFS survey's fuel sales data (see Table 4-9).

TABLE 4-9. CALCULATION OF THE TUG BOAT AND WORK BOAT STATE POPULATION AND ANNUAL DIESEL FUEL CONSUMPTION*

Geographical Area	Estimated Boat Population	Avg Fuel Consumption 10^3 Gal./Yr	Total Diesel Fuel Consumed 10^3 Gal./Yr
San Francisco†	30	57	1,710
Long Beach/Los Angeles	35	57	2,000
San Diego	12	57	680
Total			4,400

*Source: Refs. 24 to 30.

†Includes the Sacramento Delta area.

The following ratio was then applied to estimate the NMFS total commercial vessel diesel fuel consumption:

$$\frac{\text{Oil company survey, commercial fishing}}{\text{Oil company survey, total diesel fuel sales}} = \frac{\text{NMFS, commercial fishing}}{\text{NMFS, total diesel fuel sales}} = \frac{59,000,000}{70,000,000} \simeq \frac{69,000,000}{82,000,000}$$

Table 4-10 presents a summary of the results obtained from the comparison of the two fuel sales surveys. Due to possible inaccuracies in both surveys, the average value of the two surveys, 76 million gallons, was taken as the best estimate of the total diesel fuel sold to all boats along the California coast.

With the total quantity of diesel fuel sold to all boats computed, the next task was to determine what portion of the 76 million gallons was actually burned in California's coastal waters as defined by the ARB (see Figure 4-2). To accomplish this task, information was gathered from many different sources to estimate the actual quantity of diesel fuel consumed per commercial boat category within California's coastal waters.

1. U. S. Coast Guard Vessels--The U. S. Coast Guard is comprised of the Eleventh and Twelfth Districts in California. Information on the quantity of diesel fuel consumed per year and the spatial distribution of Coast Guard vessels was obtained from the Eleventh District (Ref. 31). Based on that information, the Twelfth District's annual fuel consumption was estimated:

Eleventh District	641,590 gallons/year, 1978
Twelfth District	1,400,000 gallons/year, 1978

2. Excursion Boats--Due to the reluctance of many excursion boat companies to provide information on boat numbers or annual fuel consumption, little data for this category of commercial boats was obtained. Using the limited information gathered, KVB estimated that approximately one million gallons of diesel fuel were sold to and consumed by excursion boats operating in California waters.

D. Commercial Boat Spatial Distribution--

Since each commercial boat category is a study in itself, each category of commercial boats is discussed separately; the results are presented below.

TABLE 4-10. SUMMARY OF THE ADJUSTED OIL COMPANY AND NMFS SURVEY DIESEL FUEL SALES DATA*

Method	Reported Fuel Information 10^3 Gal./Yr	Estimated Commercial Fishing Fuel Consumed 10^3 Gal./Yr	Estimated Fuel Consumption by "Other" Commercial Vessels, 10^3 Gal./Yr†	Total Estimated Commercial Vessel Fuel Consumption 10^3 Gal./Yr
Oil Company Survey	70,000 (all boats)	59,000	11,200	70,000
NMFS Survey	69,000 (Commercial and party fishing boats only)	69,000	13,000	82,000
Average		64,000	12,100	76,000

*Includes the diesel fuel used for onboard electrical generation as well as for vessel propulsion.

†"Other" includes the following types of boats: tug boats, work boats, miscellaneous small commercial utility boats, excursion boats, U.S. Coast Guard boats, and diesel-powered pleasure boats.

1. Tug Boats, Work Boats, Miscellaneous Small Commercial Utility Boats, Lightering Barges, and Excursion Boats--Through discussions with numerous people (Refs. 24 through 30) involved with the operation of these boats, it was learned that essentially all their time is spent within the boundaries depicted in Figure 4-2. The larger tug boats occasionally venture to Hawaii, or to waters north or south of the state, but most of their time is spent within a few miles of shore. Based on this information, we assumed that 100 percent of the 6 million gallons estimated to have been purchased by these boats was also expended within a few miles of shore.

2. U. S. Coast Guard Vessels--Based on information provided by the Eleventh District (Ref. 31) on their ship movements, approximately 370,000 gallons of the reported total 641,590 gallons used were estimated by KVB to have been consumed within the Los Angeles and San Diego geographical areas (see Figure 4-3). Information requested from the Twelfth District had not been received at the time this report was being completed. Therefore, based on the percentage of fuel used by the Eleventh District's vessels within the confines of California's coastal air pollution boundaries, the Twelfth District's coastal fuel apportionment was estimated at approximately 810,000 gallons for the coastal area they serve.

3. Pleasure Boats--The spatial (geographical) distribution of the 3.8 million gallons of fuel consumed by pleasure boats is discussed in the project's pleasure boating emissions inventory and was considered here only for accounting purposes.

4. Commercial and Party Fishing Boats--Due to the transitory nature of commercial fishing, this category was the most difficult to define in terms of total fuel used and spatial fuel use. The scheme followed in estimating spatial fuel use was one of (1) characterizing the commercial and party fishing boats as to boats registered, fish caught, and geographical areas fished, and (2) applying the data obtained to the 64 million gallons of diesel fuel estimated to have been sold to these vessels (see Table 4-10).

1. Step 1, Characterizing California's registered commercial fishing boats--The California Department of Fish and Game (Refs. 32 and 33) reported 8,261 vessels registered as commercial fishing boats in 1977. Total fish landings for 1977 were not yet available; however, through linear regression

analysis of the preceding ten years' data, the following information could be derived:

1977 Fish Landings, Millions of Pounds*	
From California waters	494
From waters north of California	5
From waters south of California	397
Total landings (less shipments)	896

Most of the fish caught in waters south of the state were yellowfin and skipjack tuna landed by the small and large tuna fleets operating out of San Diego. These two fleets consist of approximately 200 boats each (Ref. 34). A smaller fleet of tuna boats is stationed in San Pedro. Their boat population was unavailable, but their organization consists of 40 members. Most of their fishing is done in California waters, and they often catch fish other than tuna.

The term "small tuna fleet" generally indicates tuna boats capable of carrying 20 to 120 tons. "Large tuna fleet" includes purse seiners whose carrying capacity ranges from 200 to 2200 tons (Refs. 34 and 35).

Information on the number of boats registered, individuals licensed, and pounds of fish landed annually in connection with commercial fishing as reported by the Department of Fish and Game (Ref. 33) for the last ten years is presented in Figure 4-4. Linear regression analysis of the data displayed in Figure 4-4 indicated that over the past ten years, all three parameters have been increasing at a rate of approximately five percent per year.

From the data contained in the Department of Fish and Game's fish bulletins, information was developed on the average percent by weight of fish landed (from California waters) and the percent of commercial fishing boats registered per geographical fisheries area (see Figure 4-3). These data, estimated for 1977 and based on a ten-year average, are presented in Table 4-11.

*"Fish landings" means that the fish unloaded by a boat are also the fish caught by that boat. Fish caught by one vessel and transported by another are termed "fish shipments."

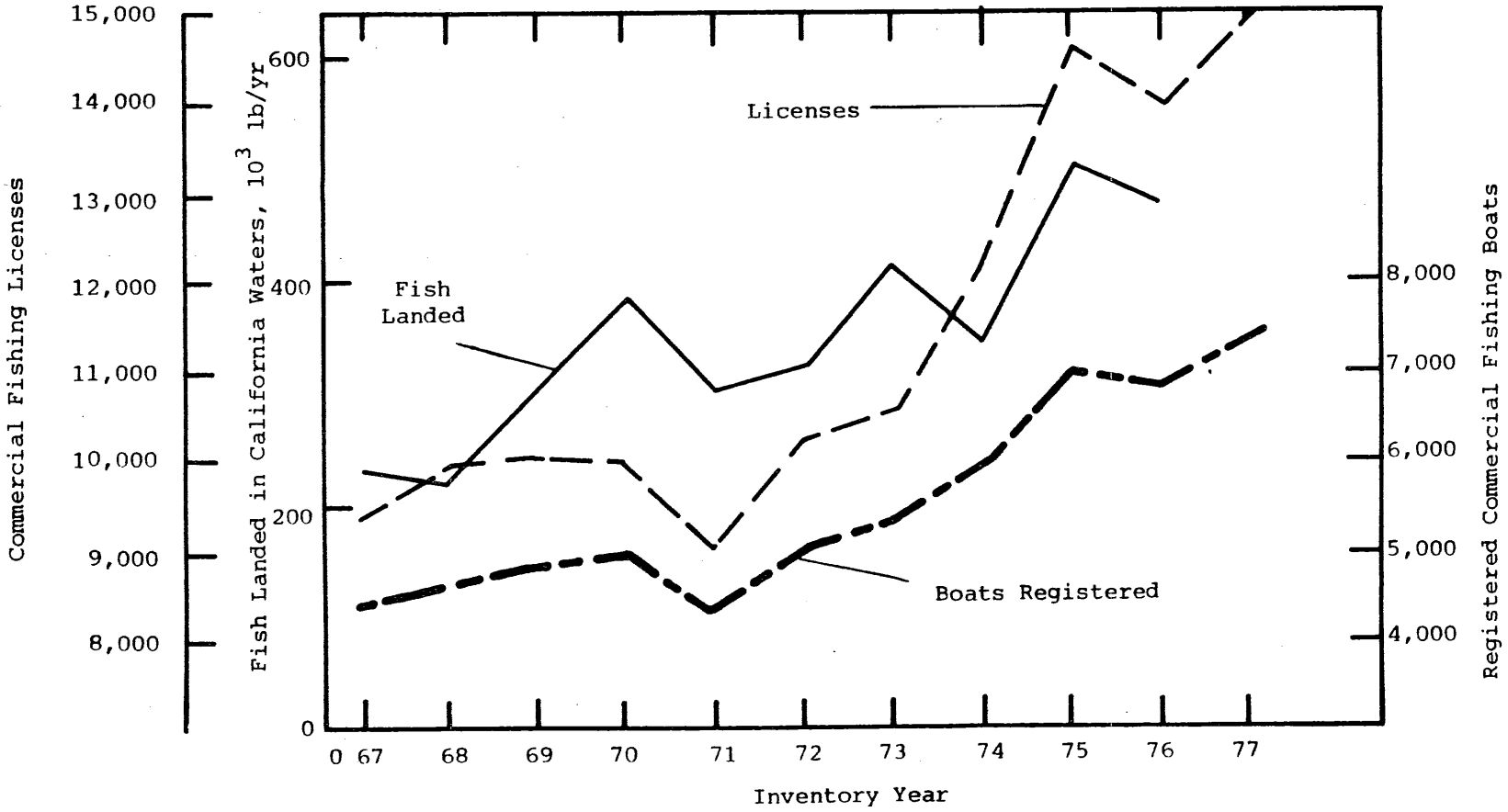


Figure 4-4. Summary of the fish landed, fishermen licensed, and commercial fishing boats registered for the past 10 years in California.

Source: Ref. 33

TABLE 4-11. SUMMARY OF THE PERCENT OF FISH LANDED AND BOATS REGISTERED BY GEOGRAPHICAL AREA IN CALIFORNIA IN 1977*

Geographical Area	Fish Landings (Calif. Waters) Percent by Weight	Boats Registered Percent
Eureka	14.7	18.2
San Francisco	4.6	23.4
Monterey	9.8	8.4
Santa Barbara	13.1	10.0
Los Angeles	56.7	19.1
San Diego	1.1	14.7
Other	NA	6.2
Outside the State (Less Tuna)	1	

*Source: KVB analysis of information in Ref. 33

The information in Table 4-11 enabled us to approximate the relative degree of fishing activity by geographical area for the state of California. The next step was to apply the information obtained in Step 1 to the 64 million gallons of diesel fuel estimated to have been sold in California to commercial and party fishing boats during 1977.

2. Step 2, Calculating the fuel consumed in California waters by registered commercial fishing boats--Research (Refs. 9, 22,32, 34, and 35) indicated that the large and small tuna fleets operating out of San Diego purchased approximately 90 percent or 44 million gallons of the 49 million gallons reported to the National Marine Fisheries Service as being sold in San Diego (see Table 4-6). Although this fleet consists of approximately 400 boats or approximately 5 percent of the state's 8,261 registered commercial fishing vessels, sources (Refs. 9, 22, 32, 34, and 35) estimate that in an average year the entire tuna fleet in San Diego could consume upwards of 75 to 100 million gallons of diesel fuel. This is not surprising considering the fact that a single purse seiner (large tuna boat) can hold as much as 200,000 gallons of fuel and consume roughly one million gallons of fuel a year (Refs. 34 and 35).

A large fraction of the 75 to 100 million gallons of fuel was purchased outside the United States. The tuna fleets operating out of San Diego do not fish in California waters (or U. S. waters) but rather in waters south of the state (i.e., off Chile, Peru, and Samoa). Very little skipjack and yellowfin tuna is caught in California waters, and these are the types of fish mainly sought after by tuna fleets. The price of diesel fuel in foreign ports now, and to a greater extent in the future, can alter the quantities of fuel purchased in San Diego versus elsewhere in the world.

The only diesel fuel burned in California waters by the San Diego tuna fleet is used while transiting in and out of the area to southern waters and to the four canneries located in California--two in San Pedro and two in San Diego (Refs. 9, 34, and 35).

The small tuna fleet in San Pedro, unlike the tuna fleet in San Diego, spends most of its time in California waters. This is because they also fish for fish other than tuna throughout the year, which helps support their activity in California waters. Whatever fuel is burned outside the state is normally burned off Baja California. However, it is estimated by KVB that the fuel burned outside the state by this fleet is balanced by the fuel used by commercial fishing boats of California registry, but of foreign ports, fishing in California's waters. Of the 8,261 boats registered, approximately 6 percent or 500 boats from Alaska, Washington, Oregon, and Mexico (Ref. 33) are involved in this.

To calculate the quantity of diesel fuel actually used by commercial fishing boats in California waters for 1977, the 44 million gallons consumed by the San Diego tuna fleet in waters south of the state were subtracted from the estimated 64 million gallons sold to all commercial fishing boats in the state (see Table 4-10):

64 million gallons - 44 million gallons = 20 million gallons

For the transit time spent by the tuna fleets hauling their catches to the four canneries in the state, an allowance was made based on the distance traveled to each port, the quantity of fish hauled, and the quantity of fuel burned in transit. After discussions with References 34 and 35, KVB estimated that approximately 100,000 additional gallons of fuel are consumed in the San Diego geographical area and 40,000 gallons in the Los Angeles geographical area.

The total of the two fuel-use estimates--20 million plus 140,000--equals the project's estimated commercial fishing diesel fuel consumption for California for 1977. To spatially distribute this fuel throughout the state's coastal waters, the average fuel consumed in each geographical area per quantity of fish landed and boats registered was used. Table 4-12 presents the results of this computation. The reason for taking the average is that early in the program it was realized that once the total quantity of diesel fuel consumed was determined, spatial distribution of this fuel would be a function of the quantity of fish caught and the number of boats involved in the catch. The rising selling price of fish has justified more boats fishing for less fish per boat.

To further apportion the quantities of diesel fuel estimated per geographical area for commercial fishing boats, fish block maps provided by the California Department of Fish and Game can be used. These fish block maps divide each geographical area into squares which indicate the annual quantities of fish caught per square. Using this method, fuel can be apportioned according to the relative percentage of fish caught.

4.2.4 Methods and Information Sources That Did Not Work

At the beginning of this program numerous information sources initially believed to be of value were contacted. Many later proved not to be. However, Tables 4-13 and 4-14 list most of these with an indication of their response. These data are offered here to forestall what otherwise might be a series of "Why didn't you try . . ?" questions. Chances are we did try.

4.3 STATEWIDE EMISSIONS INVENTORY

4.3.1 Pleasure Boats

Emissions associated with the operation of pleasure boats in California occur on California's lakes, rivers, and coastal waters. All counties in the state offer facilities for pleasure boating. California's offshore air pollution boundaries, as defined by the ARB, are presented in Figure 4-2. Fuel used outside these boundaries, although of interest for accounting purposes, does not enter into the state's emissions inventory. Spatial distribution of emissions naturally coincides with an area's fuel-use estimate. Temporal distribution may vary widely within the same area depending on location

TABLE 4-12. CALCULATION OF THE SPATIAL DISTRIBUTION OF THE DIESEL FUEL CONSUMED BY REGISTERED COMMERCIAL AND PARTY FISHING BOATS IN CALIFORNIA WATERS

Geographical Area	Fish Landings (Cal. Waters) Percent Weight*	Boats Registered Percent*	Total Fuel Consumption 10^3 Gal/Yr	1977 Fuel Consumption 10^3 Gal/Yr by Fish Landed	1977 Fuel Consumption 10^3 Gal/Yr by Boats Registered	1977 Fuel Consumption 10^3 Gal/Yr Average
Eureka	14.7	18.2	20,000	3,000	3,700	3,400
San Francisco	4.6	23.4		930	4,700	2,900
Monterey	9.8	8.4		2,000	1,700	1,900
Santa Barbara	13.1	10.0		2,600	2,000	2,400
Los Angeles	56.7	19.1		11,400	3,800	7,700
San Diego	1.1	14.7		220	3,000	1,700
Other†	N.A.	6.2			1,200	
Outside of State (less tuna)	1					

* KVB analysis of the information contained in Ref. 33.

† "Other" applies to commercial fishing boats that have home ports outside of California but occasionally fish in California waters (as defined by the California Department of Fish and Game).

TABLE 4-13. POTENTIAL SOURCES OF INFORMATION FOR PLEASURE BOATS THAT DID NOT MATERIALIZE

Type of Information	How Used	Source of Data	Reason
Number of recreational boats in harbor listed by: Number Location of port Owner and address Dollar value No differentiation between sail and power, engine types: Includes fresh water and salt water data Home location of trailered boat owners over $400-value listed only.	Gives number of boats in spatial distribution for each county; must be combined with sampling count to use it for spatial distribution data for various sizes, dollar values.	County Assessors Aircraft and Boat Division Tax rolls	Too time consuming.
Number of boats in harbor or marina. Recreational boat numbers not distinguishing between sail and power, approx. size. Marina maintenance. Boats by size, type.	Spatial distribution combined with on-site sampling gives spatial and temporal distribution, definition of size for emission factor.	Marina Managements Administration Harbor Patrol	Information available only in very general form.
Gasoline consumption data by boats, for state of California by months.	With some means to apportion these data to the study, provides part of overall emission assessment for the Basin.	State Board of Equalization, Statistical Research & Consult. Office Sacramento	Information based on the two Arthur Young & Co. reports used.

TABLE 4-13. (continued)

Type of Information	How Used	Source of Data	Reason
Detailed count of boats and traffic in harbors including: Recreational Commercial Industrial	Spatial and part temporal distribution confined to defined area.	Harbor Police Sheriff's Dept. of County Business and Moorings Office	Information in such detail not compiled.
Harbor traffic in general detailed on commercial fishing boats, harbor crafts: Number Sizes Hours of operation	Spatial and temporal data on harbor for commercial boats; data is only partial.	U. S. Department of Transportation Coast Guard, District Commander	Not studied in sufficient detail to be of use.

TABLE 4-14. POTENTIAL SOURCES OF INFORMATION FOR COMMERCIAL BOATS THAT DID NOT MATERIALIZE

Type of Information	Intended Use	Source of Data	Reason
Bulk diesel sales tax for marine sales.	Temporal and spatial information on fuel sales.	State Board of Equalization, Statistical Research Consulting Division, Sacramento, California.	Diesel fuel is not taxed at the pump.
Information on tug, work, lightering, and excursion boat population.	Same	Crowley Maritime, largest company of its kind on the coast.	Did not want to cooperate.
Information on average fuel use for commercial fishing boats. Forecasting.	Same	University of California Sea Grant	Do not collect such data.
Information on diesel fuel used by commercial boats. Forecasting.	Same	California Depart. of Fish and Game.	Do not collect such data.
Information on the diesel fuel used by documented and commercial fishing boats. Info on the location of fishing boats.	Same	U.S. Coast Guard.	Do not collect such information.
Information on boat populations, fuel use, fishing habits, forecasting.	Same	Fishing organizations along the coast.	Generally, uncooperative.

TABLE 4-14. continued

Type of Information	Intended Use	Source of Data	Reason
Bulk gasoline sales to marine vessels.	Temporal and spatial distribution of gasoline fuel.	State Board of Equalization, Statistical Research Consulting Division, Sacramento, California.	Do not segregate marine sales from all sales. Only give rebates to those going out past three miles. Very few file for these rebates.
Fuel use information.	Same	Department of Motor Vehicles.	Do not collect such data.

(i.e., altitude). AP-42 was used as the sole source of pleasure boat emission factors.

A. Inventory Boating Facilities--

DENOD has historically divided the state into eleven water/economic regions as presented in Figure 4-1 and Table 4-2. To inventory the emissions associated with the operation of pleasure boats in a specific area, the general boating area of which the study area is part must be defined. The eleven DENOD regions should be used as a preliminary guide in accomplishing this task. An inventory of all lakes, rivers, and coastal water/boating facilities must be made, as was done for the South Coast Air Basin. As much detail as possible must be collected and analyzed. Some sources of information available to accomplish this task are listed in References 5, 38, 39, 42, and 49. Additional information sources unique to each area also must be contacted as needed. The basic assumption made by KVB (as in the South Coast Air Basin Study) is that boats registered in a large area providing ample boating facilities will remain in their general area of registration, with temporary migration out balanced by transient boaters entering. Exceptions to this assumption are possible and would have to be assessed as they are encountered.

B. Categorize Boat Registration by Region--

Once the general boating region is defined, the expanded 1977 DMV boat registrations for the study area should be acquired. The 27 unique boat length/method of propulsion categories listed for each county should then be summarized into a single region's boat population consisting of only 21 unique boat categories compatible with those listed in Table 4-3.

Based on the raw data presented in Table 4-3 the data listed below should be calculated for the boating region being studied and reduced to the nine unique boat length/method of propulsion categories: >16', 16<26', $\geq$26', inboard, outboard, and other:

1. Approximate number of boat days per year.
2. Average gallonage of gasoline used per boat day.
3. Average percent use by length and boating waters.

The total annual boat days can then be calculated for lakes, rivers, and coastal waters by multiplying the approximate number of boat days per year

per boat type by the region's boat population. This total is then multiplied by the average percent use by length and boating water factors to arrive at the annual boat days attributable to boating on lakes, rivers, and coastal waters.

C. Determine Emissions on Lakes--

This involves determining the emissions associated with the operation of pleasure boats on lakes. (Paragraphs D and E following cover the emissions from boats on rivers and coastal waters, respectively.)

Before the emissions from boats operating on lakes can be determined, the initial boat day estimate for lakes must be verified and then the associated gasoline fuel consumption calculated. Diesel fuel use on lakes in California was found to be essentially nonexistent.

To verify the initial boat day estimate for lakes, boat counts must be obtained for as many of the lakes as possible. Many of the larger or busier lakes that charge admission keep records of annual boat admissions. By obtaining boat count data for a few years before 1977 and the years afterward, distortion of 1977's lake/boat usage by the drought can be determined and adjustments to the total boat day estimate made.

The total gasoline consumed on all lakes by boat type can be determined by multiplying the total (adjusted) boat day estimate per nine boat types by the average annual gasoline consumption factors calculated in paragraph B. This will give the total quantity of gasoline used on all lakes. To determine the fraction of this total quantity of fuel used on each lake in the study area, the information on lakes and their boat usage obtained in paragraph A should be applied. Fuel distribution can be based on the subjective judgment of the personnel conducting the inventory. As a final check, the boat count information collected can be compared against the quantity of fuel allotted to that lake to see if a reasonable average-annual-gasoline-fuel-consumption-per-boat-day factor is obtainable.

The emissions associated with the operation of pleasure boats on lakes are then determined through the application of the proper emission factors as listed in Table 4-5.

D. Determine Emissions on Rivers--

Calculation of the fuel used and emissions generated by boats on rivers is similar to that outlined for lakes. Once again, the drought's and surrounding environment's impact on the total boat day estimated must be determined and adjustments made.

Boat count information similar to that acquired for lakes is also needed for rivers or sections thereof. Fuel consumption and distribution are also determined in the same manner as for lakes. No hard and fast rule was found for the distribution of fuel other than research used in conjunction with sound judgment. Diesel fuel use on rivers was found by KVB to be essentially nil. Emissions are calculated through the use of the emission factors listed in Table 4-5.

E. Determine Emissions Along the Coast--

Inventorying the fuel consumed and emissions generated by pleasure boats operating along the coast is the most challenging of the three water/boating areas. Three separate aspects are involved:

1. Berthed and trailered pleasure boats.
2. Gasoline-powered documented vessels.
3. Diesel-powered pleasure boats.

This is the same format followed to determine the South Coast Air Basin's coastal boating emissions.

The total boat day estimate made for coastal boating in paragraph B applies only to berthed and trailered pleasure boats and not to documented vessels or diesel-powered pleasure boats. To divide the coastal boat day estimate into berthed and trailered boat days, a survey of the marinas in the area must be made to determine the types of boats occupying the berths in the study area. Once this is determined, the steps followed to accomplish this task for the SCAB (paragraph C, pages 4-57 to 4-61) should be followed. Essentially, based on the marina boat profile developed in conjunction with the approximate boat-days-per-year factors from paragraph B, the total boat days attributable to berthed boats are determined. Subtracting this total from the total coastal boat day estimate, the boat days attributable to trailered boats are determined. Through the application of the proper average boat day

gasoline fuel consumption factors, the total gasoline fuel used by coastal pleasure boats is arrived at.

As a crosscheck on the accuracy of the coastal pleasure boat fuel consumption model just developed, 1977 gasoline and diesel fuel sales data should be obtained from the fuel docks serving the coastal area. The quantity of gasoline sold can be compared with that estimated for berthed pleasure boats. Discrepancies can be analyzed and adjustments made if necessary.

Spatial distribution of this fuel depends on the location of the marinas and, most importantly, of the waters normally used. Emissions are calculated after spatial distribution of the fuel is completed, as was done for lakes and rivers. Appropriate inboard and outboard emission factors are listed in Table 4-5.

F. Determine Emissions by Documented Pleasure Boats--

To determine the quantity of gasoline used by documented vessels classified by KVB as pleasure boats, the formula 8012.45 x (year - 1871) = gallons gasoline consumed per year, originated by Arthur Young & Company, should be used. This formula applies to the entire state, however. KVB estimated that approximately 50 percent of the gasoline-powered documented vessels are berthed south of Santa Barbara County; the remainder are berthed north of and including Santa Barbara County. Assuming fuel use is homogeneous among all these vessels, fuel consumption should be apportioned according to the relative percentage of berths in an area.

Emissions are then calculated based on the gasoline-powered inboard pleasure craft emission factors presented in Table 4-5.

G. Determine Diesel Fuel Consumed by Diesel-Powered Pleasure Boats--

To complete the inventory of pleasure boats, the diesel fuel consumed by diesel-powered pleasure boats must be calculated. KVB developed a 70-gallons-per-marina-berth annual diesel fuel consumption factor for these boats for Southern California. Diesel fuel use may differ for boats operating in waters north of Southern California. To develop a fuel-use factor similar to that developed KVB, divide the diesel fuel sales data obtained from the marina fuel dock survey by the number of berths serviced by each fuel dock. Subtract the quantity of diesel fuel sold to commercial boats and the U. S.

Coast Guard from the total diesel fuel reported sold prior to carrying out this division since you are concerned only with that fuel used by pleasure boats.

Total 1977 diesel fuel consumption is then calculated by multiplying the number of coastal berths in the study area by the gallons of diesel per marina berth fuel consumption factors. Spatial distribution should follow that found for gasoline-powered pleasure boats.

The diesel-powered inboard pleasure craft emission factors listed in Table 4-5 can then be applied to the distributed diesel fuel to determine associated emissions.

H. Overall Error Estimate--

The overall error associated with the application of this methodology as assessed by KVB at ±30 percent.

4.3.2 Commercial Boats

A. Introduction--

As previously discussed, one of the primary objectives of this report is to outline a procedure for inventorying emissions from off-road vehicles studied for all California counties. In the case of commercial boating, this procedure applies only to the coastal counties because the commercial boat population on California's inland waterways (excluding the Sacramento Delta area) was found by KVB to be minimal. The basis for the methodology developed to accomplish this task was discussed in paragraph 4.2. Presented in this section is the methodology designed by KVB to inventory the fuel consumed and emissions generated by commercial boats operating within California's offshore air pollution boundaries in 1977.

Referring to paragraph 4.2, the procedure followed to estimate fuel used by commercial boats included calculating the total quantity of diesel fuel sold to all boats along the state's coast, determining what types (or categories) of boats used this fuel, and discovering where they burned it. The results are presented in Table 4-15.

The diesel fuel consumed and emissions generated by commercial boats operating in the South Coast Air Basin's coastal waters are calculated in paragraph 4.4.2. The task of calculating the fuel consumed and emissions

TABLE 4-15. SUMMARY OF THE ESTIMATED DIESEL FUEL PURCHASED PER COMMERCIAL BOAT CATEGORY BY GEOGRAPHICAL AREA

Geographical Area*	1977 Estimated Diesel Fuel Consumption Per Boat Category, 10^3 Gal/Hr				
	Commercial and Party Fishing	Tug, Work, Lightering and Small Utility	Excursion	U.S. Coast Guard	
Eureka	3400	Neg.	33		
San Francisco	2900	1910	440	1660 +	12th Dist.
Monterey	1900	Neg.	33		
Santa Barbara	2400	Neg.	34	80	
Los Angeles	7700	2200	440	250	11th Dist.
San Diego	1700	790	110	100	
Totals	20,000	4,900	1,110		

*As defined by the California Department of Fish and Game.

+Represents the total fuel estimated by KVB to have been purchased by the Twelfth District. Additional information on ship movements is needed to distribute the fuel to where it was used.

generated by commercial boats for the remainder of the state involves acquiring additional information on ship movements and areas fished per designated geographical area.

The data presented in Table 4-15 are defined in terms of six geographical areas and four main categories of commercial boats. To determine the emissions from commercial boats for any county along the coast, the fraction of fuel consumed in each geographical area's air pollution boundaries must be calculated. The average emission factors for commercial boats, listed in Table 4-7, can then be applied to the fuel estimate. The state's coastal air pollution boundaries are shown in Figure 4-2.

The first step in computing a county's or area's commercial boating emissions is to determine which of the six geographical water areas the study area is part of. Next, refer to Table 4-15 and locate the geographical area of concern and the quantity of fuel sold and/or used by the four commercial boat categories listed. Information on boat usage and waters fished must be collected and analyzed as to fuel usage. For example, further research is needed to spatially distribute the fuel computed to have been used by the U. S. Coast Guard, Twelfth District.

B. Commercial and Party Fishing Boats--

For commercial and party fishing boats the fuel-use figures listed in Table 4-15 were determined by KVB to also be equivalent to the fuel actually used in that area. To apportion the quantity of fuel consumed in an entire geographical area to just that area considered to be within a county's offshore air pollution boundaries, fish block maps are used. These maps, published by the California Department of Fish and Game, list the pounds of fish caught per geographical area by one-square-mile grids. By determining which grids are located within a county's offshore air pollution boundaries, adding up the pounds of fish caught in all of these grids, and dividing by the total pounds for the map, the relative fraction of fish caught in the area studied can be calculated. Assuming that fuel use is directly related to fish poundage, the fraction of the total fuel consumed within a geographical area can be determined for the specific area in question. The emissions associated with this fuel are then calculated by using the emission factors listed in Table 4-7.

C. Tugs, Workboats, Lightering Barges, Utility Craft--

These boats were found by KVB to operate within a few miles of their home port and within a few miles of shore. Also, as presented in Table 4-15, only those areas having major ports along the coast were found to have appreciable populations of these boats.

To spatially apportion the fuel used by these boats, the major shipping harbor(s) within the geographical area studied should be located. Next, 80 percent of the fuel used by these boats is assigned to the area immediately around the harbor and the remaining 20 percent to a five-mile strip paralleling the coast for the entire width of the geographical area. The emissions for this category of boat are also calculated through the use of the emissions factors listed in Table 4-7.

D. Excursion Boats--

Excursion boat population and usage information was scant. Personnel associated with operation of these boats in Southern California were generally unwilling to cooperate with the inventory. Based on the limited information available the diesel fuel used by these boats statewide was estimated. All that remains to estimate the emissions from these boats is to apply the emission factors in Table 4-7. These boats generally operate within a few miles of home port. Therefore, spatial distribution of their emissions is also within this area.

E. U. S. Coast Guard Vessels--

U. S. Coast Guard vessels are partially subdivided by geographical area. The U. S. Coast Guard's Eleventh District's (south from the northern borner of Santa Barbara County to the Mexican border) 1977 diesel fuel consumption within the Santa Barbara, Los Angeles, and San Diego geographical area was determined by KVB based on information obtained from the Eleventh District. The South Coast Air Basin's portion was estimated at approximately 370,000 gallons. This leaves 80,000 gallons for the San Diego area and approximately 60,000 gallons for that portion of Santa Barbara County within the Eleventh District's jurisdiction. The remaining 132,000 gallons reported used by the Eleventh District were burned outside the state's air pollution boundaries or in transiting to waters north of Santa Barbara.

The total diesel fuel used by the Twelfth District (north from the northern border of Santa Barbara County to the Oregon border), as estimated by KVB, is 1.66 million gallons. However, further information on vessel movements is needed from the Twelfth District to apportion this total to the areas located within the state's offshore air pollution boundaries. This information has been requested from the Twelfth District but had not been received at the time this report was written. Future inquires should be made to:

Commander (flp)
Twelfth Coast Guard District
630 Sansome Street
San Francisco, California 94126

Emissions associated with these boats are also computed based on the average emission factors presented in Table 4-7. Spatial distribution can be assumed to be homogeneous in the area studied unless specific data indicate otherwise.

Specific information on boat usage for an area should be used in place of the estimated values listed in Table 4-15 when available. This methodology should work well for all the coastal areas in the state. The error associated with this inventory is estimated by KVB to be ±20 percent.

4.4 SOUTH COAST AIR BASIN EMISSIONS INVENTORY

4.4.1 Pleasure Boats

A. Combined Water Areas--

DENOD's South Coastal and Colorado Desert Regions (see Figure 4-1) were combined to form one major boating region encompassing the South Coast Air Basin. These two regions include the counties of Ventura, Los Angeles, Orange, San Diego, San Bernardino, Riverside, and Imperial. The assumption made by KVB is that people owning boats in the South Coastal and Colorado Desert Regions mainly use the boating facilities in these regions. This assumption was based on the writer's personal experience, discussions with a Sea magazine editor (Ref. 38), and numerous discussions with recreational boaters. However, the Sea magazine editor indicated that the lakes located in Kern County should be included as being among the lakes used by boaters registered in the two regions even though Kern County is not in either region.

By characterizing the boating habits, fuel consumption, and emissions for a large area in which migration in and out of the area is minimal, the South Coast Air Basin's portion of that larger area could be defined.

An inventory of the boating facilities in the seven counties was conducted. The results are presented in Tables 4-16 and 4-17 for lakes and coastal waters, respectively. The only river in the area where motor boating occurs is the Colorado River. Since it is outside the South Coast Air Basin, its facilities (other than being recognized as a major source of river boating) were not studied in detail. The Colorado River will be examined when emissions from boats statewide are studied.

All of the lakes listed in Table 4-16 permitted power boating (gasoline or diesel) in 1977. Lakes forbidding gasoline-powered motor boats are not listed since boats on these lakes would produce no emissions.

The launch ramps or water surface areas for each lake are not listed as indicators of usage because KVB found no correlation between them and annual fuel usage on lakes. The primary factors determining boat usage on lakes were location and permissibility of water skiing activities. The two major sources of information on lakes were Sea magazine and a booklet entitled Lake Recreation in Southern California for Weekenders (Ref. 39). This booklet should be consulted for specific information on each lake.

The data presented on coastal boating facilities in Table 4-16 were extracted from a 1977 DENOD report entitled "Inventory of California Boating Facilities" (Ref. 5). In this report is a list of all the coastal, lake, and river boating facilities for the state in terms of the items listed in Table 4-17.

To determine the types and numbers of boats using the waters and facilities listed in Tables 4-16 and 4-17, the expanded 1977 DMV boat registrations indicating 27 unique boat length/method of propulsion categories were used. Table 4-18 lists registered boats by county.

Los Angeles County alone accounts for approximately 46 percent of the total boat population; the remainder is divided among the other six counties as follows: Orange, 20 percent; San Diego, 14 percent; Riverside, 6 percent; Ventura, 5 percent; and San Bernardino, 8 percent.

TABLE 4-16. LAKES LOCATED IN THE SOUTH COASTAL AND COLORADO DESERT REGIONS THAT ALLOW GASOLINE-POWERED BOATS*

County	Lake
Ventura	
	Casitas
	Piru
	Sherwood
Los Angeles	
	Castaic†
	Elizabeth
	Hughes
	Littlerock
	Puddingstone†
	Pyramid†
Orange	
	Anaheim†
	Irvine†
San Diego	
	Cuyamaca
	El Capitan
	Henshaw
	Hodges
	Jennings
	Miramar
	Murray
	Otay, Lower
	Wohlford
Imperial	
	Salton Sea
	Sunbeam
Riverside	
	Angler's†
	Cahuilla
	Elsinore†
	Hemet†
	Perris†
	Salton
	Vail†
San Bernardino	
	Arrowhead†
	Big Bear†
	Gregory†
	Silverwood†

*Source: Ref. 39.

†Located in South Coast Air Basin.

TABLE 4-17. SUMMARY OF THE COASTAL BOATING FACILITIES IN THE SOUTH COASTAL REGION*

County and Location	Moorings	Total Berths	Transient Berths	Dry Storage	Launch Lanes
Ventura					
Port Hueneme	0	12	0	0	0
Ventura Marina	0	1138	0	160	9
Channel Island Harbor	0	1771	113	350	14
Subtotal	0	2921	113	520	23
Los Angeles					
Alamitos Bay	24	2544	20	591	20
Catalina Island	685	0	0	0	0
Long Beach Marine Stadium	0	0	0	0	20
Los Angeles/Long Beach Harbor	560	4549	9	198	13
Marina Del Rey	3	6062	14	39	14
Redondo Beach-King Harbor	0	1508	2	5	0
Santa Monica Bay	50	0	0	40	0
Subtotal	1325	14663	43	873	67
Orange					
Balboa Bay	10	0	0	0	0
Dana Point	0	2450	70	365	20
Huntington Beach	0	1954	24	160	7
Newport Bay	256	6170	30	1542	24
Subtotal	266	10574	124	2067	51
San Diego					
Mission Bay	47	1618	295	394	26
Oceanside	3	736	30	0	10
San Diego Bay	68	5220	36	955	39
Snug Harbor	12	0	0	20	3
Subtotal	130	7574	361	1369	78
Grand Total	1721	35732	641	4819	219
SCAB Total	1591	25237	167	2940	118

*Source: Ref. 5

TABLE 4-18. SUMMARY OF THE BOATS REGISTERED IN THE SOUTH COASTAL AND COLORADO DESERT REGIONS IN 1977

Length	Method of Propulsion	South Coastal and Colorado Desert Region Counties Registered Boats						
		Ventura	Los Angeles	Orange	San Diego	Imperial	Riverside	San Bernardino
<16'	Inboard	188	1265	514	315	11	133	213
16<26'	Inboard	2364	17500	10265	4546	146	1999	3128
≥26'	Inboard	448	6098	2858	1873	12	272	254
<16'	Outboard	4989	41551	15598	13168	1022	6529	8957
16<26'	Outboard	1974	17672	6751	5123	318	2265	3328
≥26'	Outboard	24	338	120	85	0	13	22
<16'	Other	1258	10253	6375	4237	73	883	1206
16<26'	Other	652	5674	3012	2421	13	288	386
≥26'	Other	263	2638	1206	793	3	75	72
Totals*		12163	106,984	46701	32562	1601	12459	17574

*Correct totals. Addition of column plus round-off of error equals total.

Since our basic assumption is that boats are used in their region(s) of registration, the registered boat populations for each of the seven counties were summed into one single boat population as presented in Table 4-19. This single population, comprised of many different types of boats, has the mobility to travel anywhere within the seven counties any number of times throughout the year.

To determine the number of 1977 boating days* during which each boat category was in use, the boat counts listed in Table 4-19 were multiplied by the average-boat-days-used-per-year factors listed in Table 4-19. The results of this computation are also listed in Table 4-19. The derivation of the factors is explained in paragraph 4.2.

Approximately 6.7 million boating days were estimated to have been spent on lakes, rivers, and coastal waters located in the two boating regions. To determine this number, the data in Table 4-19 were consolidated into three boat-length categories: <16', 16<26', and >26'. The results are presented in Table 4-20.

The average percent use by length and boating water factors listed in Table 4-3 were applied to the three boat-length categories listed in Table 4-20. The results are also presented in Table 4-20. Approximately 3.1 million days were estimated as having been spent on lakes, 1.0 million days on rivers, and 2.6 million days on coastal waters. (It would have been best to calculate the boating days spent on lakes, rivers, and coastal waters by boat length and method of propulsion. However, due to the unavailability of data on percent usage by boat length and method of propulsion, percent usage by boat length only is presented as the best information available.)

B. Lakes--

During 1977 Southern California experienced a drought which lowered the water level of many of the lakes listed in Table 4-16. This reduced the ability of many lakes to accommodate the normal influx of boaters, resulting in a decrease in the number of boating days, as indicated by lower boat counts. Although many lake managers do not take annual boat counts or were unwilling

*A boating day is any day during which a boat is being used for any period.

TABLE 4-19. TABULATION OF THE PLEASURE BOAT POPULATION AND ANNUAL USE BY BOAT LENGTH AND METHOD OF PROPULSION FOR THE SOUTH COASTAL AND COLORADO DESERT REGIONS*

Boat Length	Method of Propulsion	Boat Population†	Avg. Days Used/Yr.#	Total Days Used/Yr.
<16'		2,642	28.6	75,441
16<26'	Inboard	43,958	33.7	1,481,860
≥26'		11,816	50.8	600,686
Subtotal		58,416		2,157,987
<16'		91,907	22.2	2,039,240
16<26'	Outboard	37,446	27.4	1,026,469
≥26'		599	55.3	33,139
Subtotal		129,952		3,098,848
<16'		24,293	25.1	610,247
16<26'	Other	12,325	41.3	508,493
≥26'		4,988	57.8	288,302
Subtotal		41,606		1,407,042
TOTALS		230,000		6,700,000

*Ventura, Los Angeles, Orange, Riverside, San Bernardino, Imperial, and Riverside Counties. Table excludes documented vessels.

†Source: See Table 4-18.

#Source: Ref. 2.

TABLE 4-20. CALCULATION OF ANNUAL BOATING DAYS SPENT ON LAKES, RIVERS, AND COASTAL WATERS BY BOAT LENGTHS*

Boat Length	Boat Population	Total Days Used/Year (from Table 4-16)	Use by Boating Waters Days/Yr., Percent		
			Lakes	Rivers	Coastal
<16'	188,842	2,724,928	1,788,911 (65.6%)	429,176 (15.8%)	506,837 (18.6%)
16<26'	93,729	3,016,822	1,273,099 (42.2%)	425,372 (14.1%)	1,318,351 (43.7%)
≥26'	17,403	922,127	49,795 (5.4%)	143,852 (15.6%)	728,480 (79.0%)
TOTALS	230,000	6,700,000	3,100,000	1,000,000	2,600,000
Documented Vessels	3,100	Not Available	Negligible	Negligible	100%

*Ventura, Los Angeles, Riverside, San Bernardino, Imperial, and San Diego Counties.

to supply information, people at three of the busiest lakes did respond. Two major water skiing lakes in Riverside County, Lake Perris and Lake Elsinore, reported approximately 13 percent lower boat counts in 1977 than in 1978 (80,500 to 93,000 and 60,400 to 70,000, respectively, Ref. 40). Castaic Lake, another major water skiing lake, in Los Angeles County, reported a 26 percent drop in boat counts (65,000 to 48,000, Ref. 41). Further research indicated that Castaic Lake was impaired by the drought more than Lakes Perris and Elsinore because it also furnishes water to Los Angeles County. Considering that water skiing (which is a very-high-fuel-use water sport) is one of the main boating activities on lakes (and rivers) in Southern California and that the average fuel-use factors listed in Tables 4-1 and 4-3 account for both water skiing and fishing (which is a low-fuel-use water sport), a 10 percent reduction in annual boat days from the normal average was estimated as appropriate for 1977. This assumption is based on the fact that water skiing is the major form of recreation on most of Southern California's lakes and rivers. Fishing activities generally consume less fuel than water skiing activities. Therefore, to make up for a lower fuel-use estimate based on statewide fuel-use factors, a slightly smaller reduction in annual boat days on lakes than was actual for 1977 was subsequently used by KVB.

Data representing application of the 10 percent boat day reduction to the annual lake boat days listed in Table 4-20 are presented in Table 4-21. To complete the inventory of boat days on lakes, the adjusted annual boat days were then subdivided into inboard, outboard, and other propulsion classes.

To determine the fuel used by these boats during the days listed, the average fuel consumption factors listed in Table 4-3 were applied to the DMV's 1977 expanded boat registrations for the seven counties. Weighted fuel consumption factors based on these registrations were then developed for the nine unique boat length/method of propulsion categories listed in Table 4-21. Approximately 16.1 million gallons of gasoline fuel were estimated to have been consumed on the lakes considered. The use of diesel-powered boats on lakes in the study area was found by KVB to be essentially zero.

To determine the fraction of fuel used on each lake listed in Table 4-16, we talked with Refs. 38, 40, and 42; and we consulted a book, Lake Recreation in Southern California for Weekenders (Ref. 39). Each lake was studied and its relative boat usage as part of the whole lake system determined. Fuel distribution was then solely based on the subjective judgment of KVB and Ms. Elyse Mintey of Sea magazine. No correlation between fuel use and the number of launch ramps or surface acres of water was ever found. Boat counts are not taken at most of the lakes. The percentage and quantity of gasoline used on each lake are listed in Table 4-22. As mentioned, the lakes in Kern County were included in this inventory. Approximately 5 percent of the 16.1 million gallons was assigned to the four lakes in Kern County.

Determination of the fuel used on lakes located in the South Coast Air Basin was made by adding up only those lakes. Approximately 10.6 million gallons were consumed. The associated emissions were then calculated by applying the AP-42 emission factors listed in Table 4-5; the results are presented in Table 4-23. The fraction of fuel attributable to inboards and outboards is taken from Table 4-21. Spatial distribution of emissions is obvious since the location of each lake is known. Temporal distribution was based on the typical boating mode of each lake.

TABLE 4-21. CALCULATION OF THE ANNUAL GASOLINE FUEL CONSUMPTION AND ASSOCIATED EMISSIONS FROM BOATING ACTIVITY ON LAKES IN THE SOUTH COASTAL AND COLORADO DESERT REGIONS IN 1977

① Boat Length	② Total Boating Days/Year	③ KVB Adj. Factor	④ Boating Days/Year ②x③	⑤ Boating Propulsion Profile	⑥ Estimated Boating Days Per Propulsion Type Days/Yr ④x⑤	⑦ Avg. Fuel Consumption Gals/Day	⑧ 1977 Gasoline Consumption Gals/Yr ⑤x⑥
<16'	1,788,911	0.9	1,610,020	2.8% Inboard	45,081	10.4	468,842
				74.8% Outboard	1,204,295	4.1	4,937,609
				22.4% Other	360,644	0.2	72,129
						Subtotal	5,478,580
16<26'	1,273,099	0.9	1,145,789	49.1% Inboard	562,582	11.6	6,525,951
				34.0% Outboard	389,568	9.1	3,545,069
				16.9% Other	193,639	0.4	77,456
						Subtotal	10,148,476
≥ 26'	49,795	0.9	44,815	65.1% Inboard	29,175	15.4	449,295
				3.6% Outboard	1,613	3.8	6,129
				31.3% Other	14,027	0.7	9,819
						Subtotal	465,243
						GRAND TOTALS	16,100,000

TABLE 4-22. LIST OF THE LAKES LOCATED IN THE SOUTH COASTAL AND COLORADO DESERT REGIONS AND THE PERCENTAGE AND GALLONAGE OF GASOLINE USED ON EACH LAKE

County / Lake	Relative Fuel Use %	Relative Fuel Use 10^3 Gal/Yr
Ventura	8	1300
Casitas	50	650
Piru	30	390
Sherwood	20	260
Los Angeles	25	4000
Cartaic*	40	1600
Elizabeth	4	160
Hughes	4	160
Littlerock	2	80
Puddingstone*	10	400
Pyramid*	40	1600
Orange	4	40
Anaheim*	40	16
Irvine*	60	24
San Diego	10	1610
Cuyamaca	15	240
El Capitan	5	80
Henshaw	10	161
Hodges	5	80
Jennings	5	80
Miramar	15	240
Murray	10	161
Otay, Lower	10	161
Wohlford	5	80
Imperial	5	800
Salton Sea	90	720
Sunbeam	10	80
Riverside	25	4000
Angler's*	5	200
Cahuilla	5	200
Elsinore*	45	1800
Hemet*	10	400
Perris*	25	1000
Salton Sea	8	320
Vail*	2	80
San Bernardino	22	3500
Arrowhead*	25	860
Big Bear*	40	1380
Gregory*	<5	173
Silverwood*	30	1040
Kern†	5	800
Buena Vista	20	160
Frazier	10	80
Isabelle	60	480
Ming	10	80

Total, all lakes 16,100 x 10^3 Gallons/Year (1977)
Total, SCAB lakes 10,600 x 10^3 Gallons/Year (1977)

*Indicates lakes located in the South Coast Air Basin.
†Although not located in the two regions, its boating fuel consumption was subtracted from.

TABLE 4-23. GASOLINE FUEL CONSUMPTION AND ASSOCIATED EMISSIONS FOR PLEASURE BOATING ON LAKES IN THE SOUTH COAST AIR BASIN IN 1977

County*	1977 Gasoline Fuel Use 10^3Gal/Yr	Pollutant Emissions Tons/Year SOx	CO	HC	NOx
SCAB	10,600	36	12,500	3,400	340
Los Angeles	3,600	12.1	4,200	1,140	116
Orange	40	0.134	47	12.6	1.29
Riverside	3,500	11.7	4,100	1,100	113
San Bernardino	3,500	11.7	4,100	1,100	113

* Includes only that portion of each county located in SCAB.

C. Coastal Waters--

Boats for coastal pleasure boating, as defined by this project, include gasoline-powered trailered, berthed, and documented boats, and diesel-powered pleasure boats.

Approximately 2.6 million boat days were estimated to have been spent by gasoline-powered berthed and trailered boats on Southern California's coastal waters as presented in Table 4-20. Trailered boats normally range in size up to 21 feet; those over 21 feet are not considered trailerable. This relationship suggests that the majority of boats over 21 feet in length are berthed and used mainly in coastal waters, and those under 21 feet are trailered and used on lakes, rivers, and coastal waters (Ref. 2). The number of boats $\geq$21 feet registered in coastal counties versus inland counties also supports this assumption. Of course, exceptions to this generalization occur, but it is assumed by KVB that they are small in comparison. This relationship, in conjunction with a marina boat profile developed by KVB, formed the basis for determining the population and annual boat days for trailered and berthed boats.

To determine the number of berthed boats, the boating facilities along the coast (South Coastal Region) were inventoried; results are presented in Table 4-17. Approximately 35,732 berths, 1,721 moorings, and 641 transient berths were counted (Ref. 5). Based on discussions and personal visits to four of the major marinas in the area--Marina Del Rey, Long Beach, Dana Point, and Oceanside--it was estimated that there was a 100 percent occupancy of berths and approximately one-third occupancy of moorings and transient berths (Refs. 43 to 48). The total full-time pleasure boat occupancy along the coast was then estimated at 35,732 + 1/3 (1721) + 1/3 (641) = 36,519 boats.

Based on discussions and on-site visits to these four marinas, and the percentage breakdown of inboards, outboards, and others in the 1977 DMV boat registration, the following profile of berthed boats at Southern California coastal facilities was developed:

COASTAL BERTHED BOAT PROFILE, GASOLINE POWERED

	50% Power		50% Other
Boat Length	Inboards (95%)	Outboards (5%)	Sail + Aux. Sail
<26'	68%	50%	67%
≥26'	32%	50%	33%
	↓	↓	↓
	Boat Population		Boat Population
	Inboards	Outboards	Sail + Aux. Sail
<26'	11,796	456	12,233
≥26'	5,551	457	6,026
Subtotal	17,347	913	18,259
TOTALS	18,260		18,259

As indicated, 50 percent of the population was found to be power boats and 50 percent was found to be sail boats. However, further investigations revealed that there were approximately 3,100 documented vessels also residing along the Southern California coast (Ref. 4). Realizing that documented vessels are generally >26 feet in length, powered by inboard motors, and also berthed at such places as marinas, KVB assumed that 80 percent or 2,480 vessels of the 3,100 total were counted in the 5,551 ≥26-foot inboard marina boat class. To minimize the chances of double counting, the 5,551 figure was reduced by 2,480, resulting in a ≥26-foot marina pleasure boat count of 3,071.

To determine the total boating days spent on coastal waters by berthed boats and by trailered boats, the total number of boat days attributable to berthed boats alone was calculated; the difference as assigned to trailered boats operating only on coastal waters. The results are presented in Table 4- 24. Trailered boats operating on lakes and rivers are not included in this estimate as outlined in Table 4-20.

Approximately 1.44 million days of the 2.6 million total coastal boat days are attributable to berthed boats. The difference, approximately 1.11 million days, was assigned to trailered boats. Through the application of the average fuel consumption factors listed in Table 4- 21, the quantity of gasoline fuel used by berthed and trailered boats in 1977 was then calculated; the results are presented in Table 4- 25.

TABLE 4- 24. CALCULATION OF BOATING DAYS ATTRIBUTABLE TO COASTAL PLEASURE BOATS FOR 1977 (BY BERTHED AND TRAILERED BOATS)

Total Coastal Boating Days per Year (see Table 4-18)

16<26' 1,318,351 days/year
≥26' 728,480 days/year

ANNUAL MARINA BOATING USE

① Boat Description		② Berthed Boat Population	③ Avg. Days Used Days/Yr.	Total Days of Boating Activity Per Year by Boat Length ④ All ② x ③	⑤ 16<26'	⑥ >26'
Inboard	<26'	11,796	33.7	397,525	397,525	
Inboard	≥26'	3,071	50.8	156,007		156,007
Outboard	<26'	456	27.4	12,494	12,494	
Outboard	≥26'	457	55.3	25,272		25,272
Sail	<26'	12,233	41.3	505,223	505,223	
Sail	≥26'	6,026	57.8	348,303		348,303
				1,444,824	915,242	529,602

Coastal Boating Days Allocated to Trailered Boats

16<26'	1,318,351 days/yr. -	915,242 days/yr.	= 403,109 days/yr.
≥26'	728,480 days/yr. -	529,602 days/yr.	= 198,878 days/yr.
<16'	506,837 days/yr. -	0	= 506,837 days/yr.
		Total	1,108,824 days/yr.

TABLE 4-25. CALCULATION OF THE GASOLINE FUEL USED BY BERTHED AND TRAILERED PLEASURE BOATS OPERATING IN COASTAL WATERS

Berthed Boats ① Boat Length	② Marina Boat Population Profile	③ Avg. Boat Days Used Days/Yr.	④ Total Boating Days ②x③	⑤ Avg. Fuel Consumption Gal./Day	⑥ 1977 Fuel Consumption Gals/Yr. ④x⑤
<26'	11,796 Inboard	33.7	397,525	11.6	4,611,290
	456 Outboard	27.4	12,494	9.1	113,695
	12,233 Other	41.3	505,223	0.4	202,089
				Subtotal	4,927,074
≥26'	3,071 Inboard	50.8	156,007	15.4	2,402,505
	457 Outboard	55.3	25,272	3.8	96,034
	6,026 Other	57.8	348,303	0.7	243,812
				Subtotal	2,742,351
				Totals	7,700,000

Trailered Boats ① Length	② Total Boating Days/Year	③ Boating Propulsion Profile	④ Estimated Boating Days per Propulsion Type Days/Yr. ②x③	⑤ Avg. Fuel Consumption Gals/Day	⑥ 1977 Gasoline Consumption Gal/Yr. ④x⑤
<16'	506,837	2.8% Inboard	14,191	10.4	147,586
		74.8% Outboard	379,114	4.1	1,554,367
		22.4% Other	113,532	0.2	22,706
				Subtotal	1,724,659
16<26'	403,109	49.1% Inboard	197,926	11.6	2,295,942
		34.0% Outboard	137,057	9.1	1,247,219
		16.9% Other	68,126	0.4	27,250
				Subtotal	3,570,411
≥26'	198,898	65.1% Inboard	129,483	15.4	1,994,038
		3.6% Outboard	7,160	3.8	27,208
		31.3% Other	62,255	0.7	43,578
				Subtotal	2,064,824
				Totals	7,400,000

Approximately 15.1 million gallons of gasoline were estimated to have been used by berthed and trailered pleasure boats in the South Coastal Boat region. Applying the Arthur Young & Company-based fuel-use factors presented in Table 4-21 to the 2.6 million coastal boating days gave a gasoline usage estimate of 21 million gallons. To resolve the discrepancy in the berthed boat fuel-use estimate, gasoline sales data were obtained from the fuel docks serving the four marinas surveyed.

To the right of the reported fuel sales column are KVB's estimates of the fuel used by the berthed boats at each marina, based on the model set up by KVB and based on KVB's interpretation of the data contained in the two Arthur Young & Company reports (Refs. 1 and 2). The gallonage derived based on KVB's model is approximately one and one half to two times that reported. The gallonage derived through KVB's interpretation of the two Arthur Young & Company reports is two and one half to three and one half times as great. Further research revealed that approximately 10 percent of the fuel used by boats >26' is purchased elsewhere than at the fuel docks (Ref. 1). This fuel is not included in the fuel sales figures listed in Table 4-26 and would therefore increase the actual fuel sold at marinas by approximately 10 percent. Taking into account the possible errors involved in (1) the berthed and trailered boat estimate, (2) the gasoline sales figures reported by the fuel docks, and

TABLE 4-26. MARINA FUEL SALES SURVEY

Marina	Berths	Reported Gasoline Sales 10^3 Gallons*	Estimated Gasoline Usage 10^3 Gallons KVB Model	KVB/Arthur Young & Co.
Marina Del Rey	6062	240	1,370	2,400
Long Beach	1850	300	420	740
Dana Point	2484	290	560	990
Oceanside	789	110	178	310

*Sources: Refs. 43, 44, 49, and 50.

(3) the possibility of not accounting for every coastal berth, the gallonage estimated by KVB was felt to be reasonable.

D. Documented Pleasure Vessels--

The U. S. Coast Guard reported that there were approximately 3,100 documented vessels registered in Southern California (Ref. 4). Data on the fraction of these vessels burning gasoline are unavailable; however, their total is believed to be very low. In general, documented vessels are longer than 26' and powered by inboard diesel engines.

A method was developed by Arthur Young & Company to calculate the annual gasoline consumption of gasoline-powered documented vessels for the entire state of California. Since data on documented vessels are very scarce, KVB decided to use this method: 8012.45 x (year - 1871) - gallons gasoline/ year, a formula developed from a 1971 boating survey in which 1304 gasoline-powered documented vessels reported consuming approximately 801,245 gallons in 1971. A one percent population growth rate was also predicted, which is reflected in the formula.

In using this method, KVB estimated that 50 percent of the gasoline-powered documented vessels (1304 for the state in 1971) resided in Southern California. Based on this assumption, the following gasoline consumption estimate for 1977 was made:

$$8012.45 \times (1977 - 1871) \times 0.5 = 424{,}660 \text{ gallons/year}$$

The diesel fuel consumed by the remainder of the documented vessels is considered in calculating the fuel used by commercial boating and diesel fuel used by pleasure boating.

E. Diesel-Powered Pleasure Vessels--

Information on the quantities of diesel fuel consumed by boats on lakes and rivers in Southern California is scarce. All indications are that very little diesel, if any, is used on these water areas. The majority of diesel fuel use by pleasure boats occurs on coastal waters. Information on that was also scarce.

To determine the quantity of diesel fuel consumed by pleasure boats on coastal waters, a fuel-use factor (gallons per marina slip) was developed.

Based on a KVB survey of the diesel fuel sold to pleasure boats at four local marinas (Refs. 43, 44, 49, and 50), a factor of 70 gallons/slip was developed. Multiplying the total marina slip population of 35,632 vessels by the 70-gallon/slip factor gives 2.5 million gallons of diesel consumed by pleasure boats operating in Southern California in 1977.

To determine the fuel used by these boats in the waters off Los Angeles and Orange Counties (South Coast Air Basin), the coastal boating facilities in these two counties (see Table 4-16) were inventoried and the habits of boaters studied. Allowances were then made for the fuel used in these two counties by boats transiting. For example, Catalina Island is a very popular spot for boaters in all of Southern California. People embarking from San Diego parallel the coast until they reach the Los Angeles area, and then head out to sea for Catalina. Pleasure boaters generally stay within three to five miles of shore when transiting or cruising. With this in mind, KVB estimated approximately 10.1 million gallons of gasoline and 1.73 million gallons of diesel were consumed by boaters within the waters off Los Angeles and Orange Counties. The offshore area considered by KVB to be part of the South Coast Air Basin is presented in Figure 4-2.

Table 4-27 presents the results of our calculations for pleasure boats. Emissions were calculated by applying the AP-42 emission factors listed in Table 4-5.

Table 4-28 presents a summary of the fuel used and emissions generated by boats in the South Coast Air Basin. Approximately 21 million gallons of gasoline and 1.73 million gallons of diesel were consumed by pleasure boaters in 1977. The error associated with this emissions inventory is estimated by KVB at $\pm$30 percent.

4.4.2 Commercial Boats

A summary of the fuel consumed and emissions generated by commercial boats operating in the South Coast Air Basin's coastal waters (see Figure 4-5) is presented in Table 4-29. The methodology discussed in paragraph 4.2 was used to compute most of the information contained in Table 4-29. The population of boats for this area was not specifically determined. Boats are continually transiting in and out of the area. For this reason, inventorying the fuel used by boats operating in the area over a year's period rather than counting the boat population was chosen.

TABLE 4-27. SUMMARY OF THE FUEL CONSUMED AND EMISSIONS GENERATED BY PLEASURE BOATS OPERATING ON COASTAL WATERS IN THE SOUTH COAST AIR BASIN IN 1977

County	1977 Fuel Consumption 10^3 Gal/Yr		Pollutant Emissions Tons/Yr			
	Gasoline	Diesel	SOx	CO	HC	NOx
SCAB	10,100	1,730	55	8,800	2,400	810
Los Angeles	4,700	790	25	4,100	1,470	380
Orange	5,400	940	30	4,700	960	430

TABLE 4-28. SUMMARY OF THE FUEL CONSUMED AND EMISSIONS GENERATED BY ALL PLEASURE BOATS OPERATING ON LAKES AND COASTAL WATERS LOCATED IN THE SOUTH COAST AIR BASIN IN 1977

County	1977 Fuel Consumption 10^3 Gal/Yr		Pollutant Emissions Tons/Yr			
	Gasoline	Diesel	SOx	CO	HC	NOx
SCAB	21,000	1,730	90	22,000	5,800	1,100
Los Angeles	8,300	790	37	8,300	2,600	500
Orange	5,400	940	30	4,700	970	430
San Bernardino	3,500	0	11.7	4,100	1,100	113
Riverside	3,500	0	11.7	4,100	1,100	113

TABLE 4-29. SUMMARY OF DIESEL FUEL CONSUMED AND EMISSIONS GENERATED BY COMMERCIAL BOATS OPERATING IN THE SOUTH COAST AIR BASIN IN 1977

County	1977 Diesel Fuel Consumption 10^3Gal/Yr	Pollutant Emissions, Tons/Yr				
		SOx	CO	HC	NOx	Part.
SCAB*	12,200	164	670	300	1640	176
Los Angeles	10,500	141	580	260	1410	151
Orange	1,730	23	90	40	230	25

*See Figure 4-5 for definition of the South Coast Air Basin's offshore boundaries.

Referring to paragraph 4.2.2, commercial boats were subdivided into four main categories: commercial and party fishing boats; tug and workboats;* excursion boats; and U. S. Coast Guard vessels. Each boat category was then inventoried separately as to fuel use or general operating location. To determine the diesel fuel used by these commercial boats operating within the South Coast Air Basin's coastal waters throughout the inventory year, each boat category was once again considered individually.

Commercial and party fishing boats use most of the diesel fuel consumed by the four categories in the South Coast Air Basin and in the state. Looking at Table 4-12, approximately 9.4 million gallons of diesel fuel was estimated by KVB to have been consumed by commercial fishing boats in the geographical/statistical areas of Los Angeles and San Diego during 1977 (see Figure 4-3).

Adding to this figure the 140,000 gallons estimated for transit time spent in these two areas by the San Diego tuna fleet brings the total to 9.5 million gallons of diesel. However, the two statistical areas initially used encompass more area than is considered located in the South Coast Air Basin. To further apportion the 9.5 million gallons, fish block maps provided by the

*Includes an allowance for small commercial utility boats and lightering barges.

California Department of Fish and Game were used. These maps indicate the quantities of fish caught per square mile. The relationship between fuel used and fish caught was found by KVB to be the best information available for apportioning fuel to this area.

Analyzing the fish block map for Southern California, approximately 97 percent of the poundage of fish caught for 1976 was caught in the South Coast Air Basin. 1977's data were not yet available; however, 1977 is not expected to be significantly different from 1976. Based on this determination, approximately 9.2 million gallons of diesel fuel or 97 percent of the total for these two geographical areas was consumed in the South Coast Air Basin.

The calculation of the diesel fuel used in the South Coast Air Basin for the other three categories of commercial boats was not as complicated as for commercial and party fishing boats. Fuel apportionment for tugs and workboats and excursion boats involved gathering information on boat populations for the study area. To this population annual fuel-use factors were applied as discussed in paragraph 4.2.2. Approximately 2.6 million gallons of diesel were estimated for the South Coast Air Basin using this procedure.

To determine the fuel used by the Eleventh District, U. S. Coast Guard, in the South Coast Air Basin, information on annual fuel consumption and ship movements was obtained from the Eleventh District (Ref. 31). Based on an analysis of this information, KVB estimated that 370,000 gallons of diesel fuel were consumed in the South Coast Air Basin.

Twelfth District vessels rarely enter the Eleven District's jurisdiction. Therefore, their fuel use is not a consideration in this study.

Table 4-30 summarizes the estimated fuel consumption and associated emissions for the four categories of commercial boats. Emissions were calculated based on the AP-42 emission factors presented in Table 4-7, paragraph 4.2.2. The fuel used for on-board electrical generation is also included in the estimated fuel totals. The exact amount used for this was not known, but all indications are that it is minimal when compared with the quantity of fuel used for propulsion.

The error associated with estimating SCAB's portion of the total distribution of this fuel and the emissions inventory is estimated by KVB at $\pm$20 percent.

TABLE 4-30. SUMMARY OF THE DIESEL FUEL CONSUMED AND EMISSIONS GENERATED BY COMMERCIAL BOATS BY CATEGORY FOR THE SOUTH COAST AIR BASIN IN 1977

Commercial Boat Category	Estimated 1977 Diesel Fuel Consumption 10^3Gal/Yr	Pollutant Emissions, Tons/Yr				
		SOx	CO	HC	NOx	Part.
Commercial & Party Fishing	9,200	124	510	230	1,240	133
Tug, Work, & Excursion*	2,600	35	143	65	350	38
U.S. Coast Guard	370	5.0	20	9.2	50	5.4
Total	12,200	164	670	300	1,640	176

*Includes fuel used by lightering barges and small commercial utility boats.

4.5 EMISSIONS FORECAST

4.5.1 Pleasure Boats

Predicting the future of pleasure boating in Southern California involves the consideration of such unpredictable factors as increasing fuel costs, availability of new boating facilities, weather conditions, the general state of the economy, and new boat sales. All of these affect each other. Dominant is the rapid rise in fuel prices. This will induce changing trends in boat sales. For example, the current population distribution of inboards, outboards, and others (including sail boats) is expected to shift toward sail boats and other types of fuel-efficient boats. This trend will be most noticeable along the coast where sailing is prevalent. Boating on lakes and rivers generally involves fuel use; thus it will be subject to the most change as a result of fuel price rises.

Based on information obtained from the DMV, boat registrations for the state and Southern California have increased approximately 3.5 percent per year since 1972. However, given the current world energy situation, it is doubtful that this trend will continue into the foreseeable future. Due to the extreme

instability of the fuel situation, KVB has determined that a prediction of future boating emissions would be totally unreliable and has elected, therefore, not to make one.

4.5.2 Commercial Boats

The only categories of commercial boats expected to increase appreciably in the South Coast Air Basin over the next 5-, 10-, and 15-year periods are commercial and party fishing boats. The population and fuel use of tug boats, work boats, lightering barges, small commercial utility craft, and excursion boats are not expected to increase significantly over those time spans based on the little information available. Factual data could not be obtained, and none of the persons connected with the operation of these vessels would offer any comment. The reason given was the extreme variability among such business enterprises. The U. S. Coast Guard, Eleventh District, reported the planned addition of only one new 82-foot cutter some time during the next ten years, with no comment thereafter. The diesel fuel consumption for such a vessel was estimated by KVB at approximately 60,000 gallons a year with approximately 80 percent consumption within the SCAB's offshore boundaries. Resulting emissions would be as follows:

Emissions, Tons/Year

SO_x	CO	HC	NO_x	Part.
0.65	2.6	1.2	6.5	0.70

To determine the increase in diesel fuel consumption and the associated emissions for commercial and party fishing boats, the annual five percent increase in boats registered, individuals licensed, and pounds of fish caught based on a linear regression analysis of these data for the last ten years were used. The basic assumption is that the quantity of fuel used is directly related to these three parameters. The exact relationship is impossible to determine and will change with time. For example, as the price of fish increases at a greater rate than everything else connected with fishing, more boats burning more fuel will be justified in fishing for smaller catches than in previous years. Also, during the past five years the Los Angeles and San Diego geographical areas have accounted for approximately 70 percent of the state's total fish catch. Assuming that the preceding trends continue and that more

boats will be fishing for fewer fish, the five percent statewide increase was applied to the Los Angeles and San Diego areas.

Based on the five percent annual growth rate for the state's commercial fishing industry, predictions were made that are presented in Table 4-31. Due to the extreme variability of this industry, these predictions should be used only as a guide and not in absolute terms.

The total predicted diesel fuel consumption and associated emissions increases for the South Coast Air Basin are also presented in Table 4-31. The addition of the diesel fuel and associated emissions for the new Coast Guard cutter did not alter the original figures enough to be detectable when rounded to two significant places.

TABLE 4-31. FUTURE DIESEL FUEL CONSUMPTION AND ASSOCIATED EMISSION PROJECTIONS FOR COMMERCIAL BOATS OPERATING IN THE SOUTH COAST AIR BASIN

Calendar Year	Est. Diesel Fuel Consumption 10^3 Gal/Yr	Emissions, Tons/Yr and Percentages				
		SO_x	CO	HC	NO_x	Part.
1977	9,200	124	510	230	1240	133
		1.25	1.25	1.25	1.25	1.25
1982	11,500	155	640	290	1550	166
		1.50	1.50	1.50	1.50	1.50
1987	13,800	186	760	340	1860	199
		1.75	1.75	1.75	1.75	1.75
1992	16,100	220	890	400	2200	230

SECTION 4.0

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SECTION 5.0

INDUSTRIAL VEHICLES

The objectives of the industrial vehicle study were to develop an emission inventory methodology applicable to each county in the state, and to use that methodology to generate an inventory for the South Coast Air Basin (SCAB). The methodology was based on vehicle population and use rates from which fuel consumption and emissions were derived. Industrial vehicle population data were developed on a statewide basis using two independent vehicle population studies: (1) a nationwide study by Hare et al (Ref. 1)* and (2) a Los Angeles County study by KVB. The nationwide results were scaled down to the state level, and the L.A. County results were scaled up to the state level using a measure of the amount of manufacturing activities at the respective levels. This activities measure is called "value added by manufacture," an econometric parameter reflecting the value of shipments less the cost of materials. The two vehicle inventory values were then averaged at the state level to produce a base inventory which can then be allocated to any county or air basin on the basis of value added by manufacture, population, or other scaling parameters. For the SCAB, adjustments were made to first compute an inventory for the four counties included in the air basin--Los Angeles, Orange, Riverside, and San Bernardino--and then to deduct from that inventory the sections of these counties lying outside of the SCAB.

5.1 DEVELOPMENT OF THE METHODOLOGY

The industrial off-road vehicle population in California, multiplied by the amount of fuel consumed per vehicle, determines the number of gallons of fuel consumed. AP-42 emission factors are presented in units of pounds of pollutant per 1000 gallons of fuel and per hour of operation. KVB's task was to determine California's industrial vehicle population and, by using vehicle usage, fuel consumption, and AP-42 emission factors, to determine emissions.

* References for Section 5.0 are listed on page 5-27.

5.1.1 Industrial Vehicle Definition

From the available literature we determined that our initial task would be to decide what industrial vehicle types comprise this emissions category. First, our study concerns only off-road vehicles; thus on-road industrial vehicles were eliminated. Next, the off-road vehicles were identified by the industrial use of the engine. This was done because the available nationwide inventory information was reported in terms of engine characteristics. Our research identified the following off-road industrial engine categories:

- Forklifts
- Non-forklifts
- Industrial/construction-type equipment

Non-forklifts include portable generators, mobile fluid handling equipment, mobile cranes and lifts, and light-duty construction equipment. Industrial construction-type equipment includes heavy-duty off-road equipment such as is used in logging, mining, and quarrying. Engines were excluded if used in stationary service, railway motive service, or in small, general utility service.

5.1.2 Vehicle Population

The industrial off-road vehicle population for forklifts and non-forklift vehicles in California was determined by averaging two independent methods. Method one, a modification of the method employed in an investigation by Hare (Ref. 1), estimates the industrial gasoline and diesel engine population in the United States. KVB applied the value-added-by-manufacture factor to relate California's industrial engine population to the national engine population. Method two, developed by KVB, extrapolates the industrial forklift and non-forklift vehicle population for Los Angeles County to the California vehicle population.

The industrial/construction vehicle population for the SCAB was determined by KVB in a separate survey in conjunction with the construction study discussed in Section 2.0. It was related to the state population by using an economic/production factor.

A. Method One--

The Hare report estimates the annual production of industrial gasoline and diesel engines in the United States. The estimate adjusts for the difference in exports and imports and for the service life of an engine.

KVB determined that engine population is equivalent to vehicle population. We used the value-added-by-manufacture indicator to relate the national industrial vehicle population cited by Hare to the California industrial vehicle population.

A KVB survey found only a small use of industrial diesel engines in the SCAB. We assumed that this also would be true statewide. Therefore, we estimated a 10 percent diesel engine population. Estimates of diesel-driven vehicles were adjusted in a manner similar to the adjustment made for the gasoline-driven vehicle population described below.

The annual average production of internal combustion gasoline engines for the period 1968 to 1977 is 1,170,000, as presented in Table 5-1. This total includes 88 percent small, general-utility engines (Ref. 1) that are excluded from this report in accordance with contract specifications. These utility engines are characterized as having engine ratings less than 55 horsepower. The remaining 12 percent represent 140,000 industrial gasoline engines produced annually in the United States. Diesel engine population was similarly adjusted.

This number of industrial engines (gasoline or diesel) in operation in the U.S. requires an adjustment of the annual production figures to account for the difference in exporting and importing. Exports of industrial engines exceeded imports by 10 percent (Refs. 2 and 3). The annual average number of gasoline engines remaining in the U.S. is 141,000 (industrial gasoline engines) less 10 percent, or 127,000 vehicles.

TABLE 5-1. INDUSTRIAL IC ENGINES, 1968-1977, ANNUAL PRODUCTION IN THE UNITED STATES*

Year	Industrial Engine Population	
	Gasoline	Non-Automotive Diesel
1968	1,135,000	252,000
1969	1,249,000	254,000
1970	1,074,000	23,000
1971	1,058,000	45,000
1972	1,115,000	47,000
1973	1,222,000	45,000
1974	1,079,000	68,000
1975	1,458,000	93,000
1976	1,222,000	82,000
1977	1,135,000	80,000
Average	1,170,000	99,000

*Source: Refs. 4 and 5

KVB assumes that the export-to-import ratio was constant for the period 1968 to 1977.

Computation of the number of industrial engines in operation in the U.S. requires a second adjustment to account for engine life. Engine life, (called service life in the Hare report), is equivalent to vehicle life. The Hare report cited an 8.3-year engine life. As a check, KVB contacted local forklift dealers who estimate vehicle life at 10 years (Refs. 6 and 7), which indicates that the 8.33 used by Hare is reasonable. This value was, therefore, used for Method One as a constant for the period from 1968 to 1977. The national industrial gasoline engine population may then be computed as follows:

$$127{,}000 \begin{pmatrix}\text{Industrial gasoline engines operating annually in the U.S.}\end{pmatrix} \times 8.33 \begin{pmatrix}\text{Years of engine life per engine}\end{pmatrix} = 1{,}060{,}000 \begin{pmatrix}\text{Industrial gasoline engines operating in the U.S.}\end{pmatrix}$$

KVB assumed that the number of industrial vehicles operating in California is related to national industrial vehicle operation in accordance with an economic/production indicator called value added by manufacture. This indicator is derived by subtracting the total cost of materials (including materials, supplies, fuel, electric energy, cost of resales, etc.) from the value of shipments and adjusting the resulting amount by the net change in finished products and work-in-progress inventories between the beginning and end of the year (Refs. 8,9). It is considered to be the best measure available for comparing the economic importance of manufacturing among industries and geographical areas. Therefore, we assumed that the use of off-road vehicles by industry is in direct proportion to the value added by manufacture. Therefore, industrial vehicle use in California is related to the industrial vehicle use in the U.S. as the value added by manufacture in California is related to the U.S. That was 9.05 percent (Refs. 8,9). The number of gasoline engines in California is then:

$$1{,}060{,}000 \begin{pmatrix}\text{Industrial gasoline}\\ \text{engines in the U.S.}\end{pmatrix} \times 0.0905 = 96{,}000 \begin{pmatrix}\text{Industrial gasoline}\\ \text{engines in California}\end{pmatrix}$$

Diesel engines in California, as mentioned previously, were estimated at 10 percent of the number of gasoline engines or 9,600 industrial diesel engines in California. The total number of industrial engines is the sum of the gasoline and diesel engines, or 106,000 industrial engines in California.

A KVB telephone survey found a one-to-one correspondence between forklift vehicles and forklift engines in the SCAB (Refs. 6 and 7). We assumed that this relationship was also true for non-forklift vehicles. Vehicles were assumed to equal engines; thus 106,000 forklift and non-forklift vehicles were found to be operating in California.

KVB also found that 10 percent of these vehicles were on-road and 90 percent were off-road (Refs. 6, 7, 10 to 16). Therefore, we introduced a final adjustment:

$$106{,}000 \times 0.9 \text{ (Percent of off-road vehicles)} = 95{,}000 \begin{pmatrix}\text{Industrial off-}\\ \text{road forklift}\\ \text{and non-forklift}\\ \text{vehicles}\end{pmatrix}$$

Industrial/construction vehicles are assumed to be unique to an area such that they are not a part of the number of engines found in Method One.

B. Method Two--

KVB developed its own methodology for industrial vehicle population in California. KVB surveyed the industrial vehicle dealers in the SCAB. We considered the dealers' responses to comprise a reliable estimate of the forklift and non-forklift population in Los Angeles County and the industrial/construction vehicle population in the four counties of the SCAB. These county population estimates were extrapolated to state estimates using the value-added-by-manufacture indicator.

The major forklift dealers in the Los Angeles area estimated that an average of 3000 forklifts had been leased or sold annually in Los Angeles County over the past ten years (Refs. 6, 7, 10 to 16). KVB used L. A. County's industrial vehicle population because a statewide industrial vehicle population was unavailable.

The number of forklifts in operation in an area depends on the forklift's service life. Our survey resulted in an estimated 10-year service life (Refs. 6 and 7), somewhat higher than the 8.33 years reported by Hare (Ref. 1). The higher number used for the L.A. County area is due to the greater use of LPG in L.A. than in the nation. LPG fuel is very clean-burning and extends engine life. LPG engines are normally converted from gasoline engines and are reported in the population totals as gasoline engines. The number of forklifts in Los Angeles County may be computed as follows:

$$3{,}000 \text{ (forklifts produced)} \times 10 \text{ year service life} = 30{,}000 \left(\begin{array}{l}\text{Forklifts in}\\ \text{operation in}\\ \text{Los Angeles}\\ \text{County}\end{array}\right)$$

Forklifts comprised approximately 80 percent of the forklift and non-forklift industrial vehicle population in Los Angeles County (Refs. 6, 7, 10 to 16). The total number of forklifts and non-forklifts may be computed as follows:

$$30{,}000 \left(\begin{array}{l}\text{forklifts}\\ \text{in L.A.}\\ \text{County}\end{array}\right) \div 0.80 = 37{,}500 \left(\begin{array}{l}\text{forklifts and non-forklifts}\\ \text{in L.A. County}\end{array}\right)$$

We assumed that the relationships used to compute the Los Angeles County totals are also valid for state vehicle population totals. The county vehicle population is related to the state vehicle population by the value added by manufacture.

For 1977 the value added by manufacture in Los Angeles County was 45 percent of that for the entire state (Ref. 8). The state forklift and non-forklift population may be computed as follows:

$$37{,}500 \begin{pmatrix}\text{forklifts and}\\ \text{non-forklifts}\\ \text{in L.A. County}\end{pmatrix} \div 0.45 = 83{,}000 \begin{pmatrix}\text{state forklifts and non-forklifts}\\ \text{in L.A. County}\end{pmatrix}$$

C. Comparison of Two Methods--

The statewide numbers of forklift and non-forklift industrial vehicles determined by the two methods are 95,000 and 83,000, respectively. The average number is 89,000, and the total disagreement is 13 percent. Considering that the two methods are completely independent, we feel that the agreement is very good and that the average total of 89,000 vehicles is a good number to use for estimates to be made when calculating individual emissions in air basins.

Note that this number includes forklift and non-forklift vehicles only. The 1140 industrial/construction vehicles, as discussed in the following paragraph, must be added to this to bring the statewide industrial vehicle total to 90,000.

D. Industrial/Construction Vehicles--

The major heavy-duty construction vehicle dealers in Southern California estimated that 660 heavy-duty construction vehicles were operating in the four-county area in 1977 (Ref. 17). The value added by manufacture for Los Angeles, Orange, Riverside, and San Bernardino counties was 58 percent in 1977 (Ref. 9), and it represents the 660 vehicles. The state industrial/construction vehicle total is assumed to be equal to the following relationship:

$$660 \text{ (industrial/construction vehicles)} \div 0.58\% = 1140 \begin{pmatrix}\text{industrial/construc-}\\ \text{tion vehicles in}\\ \text{California}\end{pmatrix}$$

5.1.3 Vehicle Usage and Fuel Consumption

Calculation of emissions from the 89,000 industrial off-road forklift and non-forklift vehicles and the 1140 industrial/construction vehicles is based on the vehicle usage and fuel consumption rates presented in Table 5-2. This information, including the forklift-to-non-forklift ratio, was collected from the major forklift dealers in SCAB (Refs. 6, 7, 10 to 14) and from AP-42 Sections 3.3.3 (Ref. 18) and 3.2.7 (Ref. 19). All information used in SCAB was assumed to be appropriate for use statewide.

The calculation of annual fuel consumption for forklifts and non-forklifts was simplified using the formulas below:

$$\begin{pmatrix}\text{industrial}\\ \text{vehicle}\\ \text{population}\end{pmatrix}\begin{pmatrix}0.80,\\ \text{forklifts}\end{pmatrix}\begin{pmatrix}0.40\text{ gasoline}\\ \text{or}\\ 0.60,\text{ LPG}\end{pmatrix}\begin{pmatrix}1200\text{ hours/year,}\\ \text{annual average}\\ \text{operation}\end{pmatrix}\begin{pmatrix}1\text{ gallon/hour,}\\ \text{average fuel}\\ \text{consumption}\\ \text{rate}\end{pmatrix}=\begin{pmatrix}\text{annual fuel}\\ \text{consumption}\\ 10^3\text{ gallons/}\\ \text{year}\end{pmatrix}$$

$$\begin{pmatrix}\text{industrial}\\ \text{vehicle}\\ \text{population}\end{pmatrix}\begin{pmatrix}0.20,\\ \text{non-}\\ \text{forklifts}\end{pmatrix}\begin{pmatrix}0.20\text{ gasoline}\\ \text{or}\\ 0.80,\text{ diesel}\end{pmatrix}\begin{pmatrix}1200\text{ hours/year,}\\ \text{annual average}\\ \text{operation}\end{pmatrix}\begin{pmatrix}1\text{ gallon/hour,}\\ \text{average fuel}\\ \text{consumption}\\ \text{rate}\end{pmatrix}=\begin{pmatrix}\text{average fuel}\\ \text{consumption}\\ 10^3\text{ gallons/}\\ \text{year}\end{pmatrix}$$

TABLE 5-2. SUMMARY OF INDUSTRIAL FORKLIFT AND NON-FORKLIFT VEHICLE USAGE FACTORS

- Forklift to non-forklift vehicle ratio, 80:20
- Fuel profile:

  Forklifts 40% gasoline-powered
  60% LPG-powered

  Non-forklifts 20% gasoline-powered
  80% diesel-powered
- Fuel consumption rate, 1 gal/hr (average) for both forklifts and non-forklifts
- Vehicle usage rate, 1200 hrs/yr (average)
- Percentage of gasoline-powered forklifts previously accounted for in construction, 5%.

5.1.4 Emission Factors

The industrial off-road-vehicle AP-42 emission factors are presented in Table 5-3. A composite emission factor for industrial/construction vehicles was computed using the factor for each individual vehicle as presented in the profile in Table 5-4.

To calculate emissions from the LPG-powered forklifts where fuel consumption is rated in gal/hr, the units for AP-42's Emission factors for Heavy-Duty Natural-Gas-Fired Pipeline Compressor Engines (Ref. 20) were modified. AP-42's $lb/10^6$ SCF emission factors were converted to $lb/10^3$-gallon emission factors (excluding SOx) through the following calculations:

$$lb\ pollutant/10^6\ SCF\ N.G. \times 86.2\ SCF^*/gal = lb\ pollutant/10^3\ gal\ NG$$

The following AP-42 emission factor conversions were made:

NOx 3400 $lb/10^6$ SCF ⟶ 290 $lb/10^3$ gal
CO 430 $lb/10^6$ SCF ⟶ 37 $lb/10^3$ gal
HC 1400 $lb/10^6$ SCF ⟶ 120 $lb/10^3$ gal

Distribution of industrial/construction vehicles is presented in Table 5-5. A profile of the equipment comprising this category (Ref. 17) and the estimated annual operation (Ref. 19) are included.

5.1.5 Temporal and Spatial Distribution of Emissions

The temporal and spatial distribution of industrial off-road vehicle emissions may be determined by using the average normal work schedule and the location of the industrial activity. Sources of information that may aid in distributing emissions include county land use maps, discussions with chambers of commerce, and personal experience.

5.1.6 Comments

The approach used for inventorying the emissions from industrial off-road vehicles in California permits the use of any representative county to

* 86.2 SCF of natural gas when liquefied is equivalent to 1 gallon.
Source: Ref. 21

TABLE 5-3. SUMMARY OF THE EMISSION FACTORS APPLICABLE TO INDUSTRIAL OFF-ROAD VEHICLES

Source, AP-42	Industrial Vehicle-Fuel	Emission Factors SOx	CO	HC	NOx	HCOH	Part.
	Forklift & Non-forklift			($lb/10^3$ Gal)			
Section 3.3.3	Gasoline	4.35	2960	157	16.3	2.64	5.25
Section 3.3.3	Diesel	31.2	102	37.5	469	7.04	33.5
Section 3.3.2	LPG	N.A.	37	120	290	N.A.	N.A.
	Industrial/ Construction			(lb/hr)			
Section 3.2.7	Diesel	199	574	212	2810	45.4	172

TABLE 5-4. INDUSTRIAL/CONSTRUCTION VEHICLE PROFILE AND ESTIMATED ANNUAL OPERATION

Vehicle Profile* Type	Fraction of Total Population	Estimated Annual Operation Hr/Yr†
Tracked tractors	0.0910	1050
Wheeled tractors	0.0121	740
Wheeled dozers	0.0076	2000
Scrapers	0.0483	2000
Motor graders	0.0453	830
Wheeled loaders	0.0695	1140
Tracked loaders	0.0347	1100
O.H. trucks	0.0121	2000
Miscellaneous	0.6790	1000

* Source: Ref. 17

† Source: AP-42, Ref. 19

be used as a basis. The value added by manufacture is a credible indicator of a county's industrial off-road vehicle population. The Census of Manufacturers (Ref. 8) considers this indicator to be the best measurement available for comparing the relative economic importance of manufacturing among industrial and geographic areas.

Many of the sources of information used to develop our emissions inventory methodology are republished annually and may be used to update information as needed. The emission factors published in AP-42 are the best factors available at this time. Any AP-42 updates which affect this report should be incorporated into the emissions data.

The percentage and type of forklift and non-forklift fuels were assumed to be relatively constant for all portions of the state in 1977. There is a trend toward greater use of LPG and electric-powered forklifts, which will reduce the emissions generated, but increases in vehicle population may offset this. Data on the national sale and shipment of industrial gasoline and diesel engines by the Bureau of the Census (Ref. 4) should be valuable in assessing vehicle population.

The assumptions relative to the value added by manufacture represent the most significant sources of error in the emissions inventory. The lack of credible literature regarding vehicle populations resulted in much of the data's being obtained by telephone surveys. Engineering judgment was continually applied to the evaluation of the data to minimize errors. Where possible, the data were corroborated through independent sources to ensure their reliability. KVB estimates the error associated with the many variables and assumptions used in our methodology to be ±25 percent.

5.2 SOUTH COAST AIR BASIN INVENTORY

The methodology used to inventory industrial off-road-vehicle emissions in SCAB was similar to the methodology developed in paragraph 5.1. The state's forklift and non-forklift vehicle population, obtained by the averaging of Methods One and Two, and the state's industrial/construction vehicle population, obtained by the KVB survey, were proportioned to the total SCAB vehicle population by the use of the value-added-by-manufacture factor.

Vehicle populations were multiplied by fuel consumption rates, fuel usage rates,and AP-42 emission factors to calculate vehicle emissions. The SCAB inventory necessitated the inventorying of one large industrial plant that is the only one of its kind in the state.

5.2.1 Vehicle Population

A. Forklifts and Non-Forklifts--

The state's forklift and non-forklift population was estimated to be 89,000 vehicles. The 1977 values added by manufacture for Los Angeles, Orange, Riverside, and San Bernardino counties were 45.36, 9.41, 1.16, and 2.12 percent of the California total, respectively (Refs. 3 and 8). Table 5-6 presents each county's forklift and non-forklift population; the Column 3 calculations were made by assuming that the percentage of county vehicle populations in the state were equal to the county value added by manufacture.

Only Orange County lies completely within the SCAB. KVB assumed that a county's vehicle population within SCAB was proportional to the percentage of a county's human population within SCAB. Population statistics were obtained from the Southern California Association of Governments (Ref. 22). Table 5-5 presents the forklift and non-forklift populations in SCAB by county.

B. Industrial/Construction--

The major heavy-duty construction equipment dealers in SCAB estimated that there were 660 industrial/construction vehicles in Los Angeles, Riverside, San Bernardino, and Orange Counties (Ref. 17). The industrial/construction vehicle total used to calculate this vehicle category's state total, discussed in paragraph 5.1.2D,was also used to calculate the number of vehicles for each county within SCAB. The 530 industrial/construction vehicles in SCAB were spatially distributed to each county with respect to the percentage of major sand and gravel operations within each county (Refs. 23 to 25). KVB assumed that the heavy industrial off-road vehicles were better related to the number of sand and gravel operations than to human population. Table 5-6 presents the numbers of these vehicles operating in each county of SCAB and a profile of the types and numbers of heavy-duty vehicles operating in SCAB.

TABLE 5-5. INDUSTRIAL OFF-ROAD VEHICLE POPULATION*

County	Value Added by Manufacture Fraction of State Total†	State's Ind. Vehicle Population§	County's Ind. Vehicle Population	Fraction Located in SCAB#	Ind. Vehicle Population in Scab‡
Los Angeles	0.4536	89,000	40,000	0.987	40,000
Orange	0.0941	89,000	8,400	1.000	8,400
San Bernardino	0.0212	89,000	1,900	0.825	1,600
Riverside	0.0116	89,000	1,000	0.706	700
Total	0.5805	89,000	51,000	3.508	50,000

* Heavy-duty construction equipment used as part of an industrial plant's equipment is excluded here and accounted for in Table 5-7.

† Reference 17

§ See paragraph 5.2 of this report.

Values indicate the fraction of a county's population residing within the SCAB. Population data were obtained from the Southern California Association of Governments (Ref. 22).

‡ $$\frac{\text{Industrial off-road vehicles within county (1) in SCAB}}{\text{Industrial off-road vehicles within county (1)}} = \frac{\text{Population of county (1) in SCAB}}{\text{Population in county (1)}}$$

TABLE 5-6. DISTRIBUTION OF THE INDUSTRIAL/CONSTRUCTION VEHICLES LOCATED WITHIN THE SOUTH COAST AIR BASIN FOR 1977 (BY COUNTY)

Industrial/Construction		Vehicle Profile	
Equipment	Units	Fraction within SCAB, Units[†]	
Four-County Totals			
Tracked Tractors	60	SCAB	0.80 of total, 530
Wheeled Tractors	8	Los Angeles	0.50 of SCAB, 265
Wheeled Dozers	5	Orange	0.19 of SCAB, 101
Scrapers	32	San Bernardino	0.17 of SCAB, 90
Motor Graders	30	Riverside	0.14 of SCAB, 74
Wheeled Loaders	46		
Tracked Loaders	23		
O.H. Trucks	8		
Miscellaneous	448		
Totals	660		

[*] Los Angeles, Orange, San Bernardino, and Riverside counties.

[†] References 22 to 27.

5.2.2 Vehicle Usage, Fuel Consumption, and Vehicle Emissions

A. Forklifts and Non-Forklift Vehicles--

The vehicle usage for forklift and non-forklift vehicles is presented in Table 5-2. Table 5-7 presents the distribution of vehicle population by county using the vehicle usage percentages. The calculation of annual fuel consumption as presented in Table 5-8 was simplified by the use of the information presented in the formulas in paragraph 5.1.3. This information would also be used for the state inventory.

The vehicle usage multiplied by the fuel consumption multiplied by the AP-42 vehicle emission factors results in vehicle emissions. Emissions are also presented in Table 5-8.

B. Industrial/Construction Vehicles--

Industrial/construction vehicle usage and the vehicle type profile presented in Table 5-4 were used to calculate the annual operating hours per vehicle in Los Angeles, Orange, Riverside, and San Bernardino counties. Vehicle emissions were computed using AP-42 emission factors. A composite emission factor was obtained by averaging the individual vehicle-type emission factors. The vehicle emissions for the four counties were adjusted to SCAB emissions by using the percentage of county sand and gravel operations located in SCAB. The industrial/construction vehicle emissions for each county in SCAB are presented in Table 5-9. Diesel was assumed to be the fuel used in these vehicles.

5.2.3 Inventory of an Industrial Plant in SCAB

The inventory of emissions for the industrial off-road vehicles of a large industrial plant located in SCAB is shown below. To ensure the confidentiality of the plant's identity, only the emission totals are presented.

Emissions, Tons/Yr					
SOx	CO	HC	NOx	HCHO	Particulate
34	110	34	490	7.8	32

TABLE 5-7. DISTRIBUTION OF FORKLIFT AND NON-FORKLIFT VEHICLES BY COUNTY AND TYPE OF FUEL CONSUMED FOR THE SOUTH COAST AIR BASIN

Vehicle Type / Fuel	1977 Vehicle Population*				
	Los Angeles	Orange	San Bernardino	Riverside	Totals
Forklifts (80%)					
Gasoline† (40%)	11,200	2,300	450	196	14,100
LPG (60%)	19,200	4,000	770	340	24,000
Non-Forklifts§ (20%)					
Gasoline (20%)	1,600	350	60	28	2,000
Diesel (80%)	6,400	1,350	260	112	8,000
TOTALS	38,400	8,000	1,500	676	48,000

*Includes only that portion of a county within SCAB.

†Includes a 5% population adjustment factor to account for the forklifts previously accounted for in the project's construction off-road vehicle emissions inventory. Actual industrial gasoline-powered forklift population = (county forklift total x 0.3) - (county forklift total x 0.05).

§Non-forklift vehicles include mobile cranes and lifts; generator and fluid handling services for utilities, airports, and state organizations; and light-duty construction equipment.

TABLE 5-8. SUMMARY OF THE FORKLIFT AND NON-FORKLIFT VEHICLE FUEL CONSUMPTION AND ASSOCIATED EMISSIONS FOR THE SOUTH COAST AIR BASIN (BY COUNTY), 1977

County	Vehicle	1977 Fuel Consumption 10^3 Gal/Yr			Pollutant Emissions, Tons/Year					
		Gasoline	Diesel	LPG	SOx	CO	HC	NOx	HCOH	Part.
SCAB	Forklifts	16,900	---	29,000	37	26,000	3,100	4,400	22	45
	Non-forklifts	2,400	9,700	---	158	4,200	370	2,300	37	170
	Totals	19,300	9,700	29,000	195	30,000	3,500	6,700	59	210
Los Angeles	Forklifts	13,440	---	23,040	29.2	20,317	2,437	3,450	17.7	35.5
	Non-forklifts	1,920	7,680	---	124.2	3,234	295	1,817	29.6	134
	Subtotal	15,360	7,680	23,040	153.4	23,551	2,732	5,267	47.3	169
Orange	Forklifts	2,760	---	4,800	6.0	4,174	505	718	3.6	7.3
	Non-forklifts	420	1,620	---	26.2	705	63	383	6.2	28.2
	Subtotal	3,180	1,620	4,800	32.2	4,879	568	1,101	9.8	35.5
San Bernardino	Forklifts	540	---	924	1.17	816	97	138	0.71	1.43
	Non-forklifts	72	312	---	5.03	123	11.6	74	1.19	5.42
	Subtotals	612	312	924	6.20	939	109	212	1.90	6.85
Riverside	Forklifts	235	---	408	0.51	355	42.9	61.1	0.31	0.62
	Non-forklifts	34	134	---	2.16	57	5.2	31.7	0.51	2.33
	Subtotal	269	134	408	2.67	412	48.1	92.8	0.82	2.95

TABLE 5-9. CALCULATION OF INDUSTRIAL/CONSTRUCTION EQUIPMENTS ANNUAL HOURS OF OPERATION AND ASSOCIATED EMISSIONS FOR THE FOUR-COUNTY AREA AND THE SOUTH COAST AIR BASIN IN 1977

Equipment Profile		Estimated Annual Operation	Pollutant Emissions tons/yr					
Type	Units	Hrs/Yr†	SOx	CO	HC	NOx	HCOH	Part.
Four-County Totals*								
Tracked Tractors	60	1,050	4.3	12	3.5	46	0.8	3.5
Wheeled Tractors	8	740	0.3	6.4	0.4	2.9	0.1	0.4
Wheeled Dozers	5	2,000	1.7	3.7	1.2	25	0.3	0.8
Scrapers	32	2,000	15	47	20	199	4.6	13
Motor Graders	30	830	2.9	2.7	0.7	13	0.1	0.8
Wheeled Loaders	46	1,140	4.8	14	4.9	63	1.1	4.5
Tracked Loaders	23	1,100	1.0	2.0	0.4	7.4	0.1	0.7
O.H. Trucks	8	2,000	3.6	11	3.5	61	0.9	2.0
Miscellaneous	450	1,000	3.2	93	35	511	7.0	3.1
Totals	660		66	190	70	930	15	57
SCAB Totals§								
SCAB	80% of total		53	152	56	744	12	46
Los Angeles	50% of SCAB		26	76	28	372	6	23
Orange	19% of SCAB		10	29	11	141	2	9
San Bernardino	17% of SCAB		9	26	9	127	2	8
Riverside	14% of SCAB		8	21	8	104	2	6

* Los Angeles, Orange, San Bernardino, and Riverside counties. Source: Reference 17

† Source: AP-42, Reference 19

§ Source: References 22-27

The vehicle emissions from this plant were inventoried separately because they are concentrated in one location.

5.2.4 Summary

The summary of the SCAB's 1977 industrial off-road vehicle emissions is presented in Table 5-10. This table accounts for the emissions from forklifts, non-forklift vehicles, industrial/construction vehicles, and the industrial vehicles of a large plant.

Except for industrial/construction vehicles, emissions were spatially distributed by the location of the vehicle population. Industrial/construction vehicles were spatially distributed according to the location of major sand and gravel operations. The location of the special manufacturing plant is the preferred method to use in distributing information, but such information was not available in any usable means.

Emissions were temporally distributed to coincide with a normal work schedule of eight hours per day (7 a.m. to 4 p.m.) and five days per week (M,T,W,Th,F).

The error associated with the SCAB inventory is estimated to be ±25 percent. Sources of error include using the production/economic indicator to relate average state emission totals to emission totals for SCAB and relating human population to vehicle population.

5.3 STATEWIDE METHODOLOGY

One of the primary objectives of this report is to develop a procedure for inventorying the emissions of industrial off-road vehicles for any county or air basin in the state. The objective of this section is to present that

TABLE 5-10, SUMMARY OF THE SOUTH COAST AIR BASIN'S INDUSTRIAL OFF-ROAD-VEHICLE EMISSIONS, 1977

County	Pollutant Emissions, Tons/Yr					
	SOx	CO	HC	NOx	HCOH	Part.
SCAB						
Forklifts & non-forklifts	195	30,000	3,400	6,700	59	210
Industrial/construction*	87	260	90	1,230	19.8	78
Total	280	30,000	3,500	7,900	79	290
Los Angeles						
Forklifts & non-forklifts	153	24,000	2,700	5,300	47	169
Industrial/construction	26	76	28	372	6	23
Total	179	24,000	2,700	5,700	53	192
Orange						
Forklifts & non-forklifts	32	4,900	570	1,100	9.8	35
Industrial/construction	10	29	11	141	2	9
Total	42	4,900	580	1,200	12	44
San Bernardino						
Forklifts & non-forklifts	6.2	939	109	212	1.9	6.8
Industrial/construction	9	26	9	127	2	8
Total	15.2	960	118	330	3.9	14.8
Riverside						
Forklifts & non-forklifts	2.7	412	48	93	0.82	2.9
Industrial/construction	8	21	8	104	2	6
Total	10.7	430	56	197	2.8	8.9

* Includes the emissions from the one unique industrial plant; see paragraph 5.2.3.

procedure. The methodology derived in paragraph 5.1 and applied in paragraph 5.2 is restated here for routine application.

5.3.1 Industrial Vehicle Population

To inventory any area, such as a county or air basin, begin with the state's industrial off-road vehicle population. The state vehicle population is assumed to relate to the area's percentage of the value added by manufacture for the state.

The 1977 state population of forklifts and non-forklifts was 89,000 vehicles. Non-forklift vehicles included portable generators and mobile fluid-handling equipment used for utilities, airports, and state organizations; mobile cranes and lifts; and light-duty construction equipment. The state vehicle population excluded vehicles with small general-utility engines of less than 55 horsepower. The 1977 state population of industrial/construction vehicles was 1000 vehicles. This category included heavy-duty vehicles used in logging, mining, and quarrying.

The value added by manufacture is published by the Department of Commerce, Bureau of the Census (Ref. 8). Table 5-11 presents a list of each county's percentage of the total value added by manufacture for California in 1977.

If a county or a combination of counties are to be inventoried, the county's value-added-by-manufacture percentage is multiplied by the state vehicle population to determine the county's vehicle population.

If an air basin is to be inventoried, a county may cross the boundary of more than one air basin. This situation exists in the SCAB inventory as only Orange County lies entirely within it. The industrial off-road vehicle population for the portion of the county located within an air basin may be apportioned in accordance with the percentage of the human population located there.

TABLE 5-11. SUMMARY OF THE VALUE ADDED BY MANUFACTURE FOR CALIFORNIA IN 1977*

COUNTY	VALUE ADDED BY MANUFACTURE FRACTION OF STATE TOTAL
Alameda	0.0423
Amador	0.0006
Butte	0.0020
Contra Costa	0.0133
Del Norte	0.0011
El Dorado	0.0006
Fresno	0.0117
Glenn	0.0005
Humboldt	0.0015
Imperial	0.0008
Kern	0.0063
Kings	0.0019
Lassen	0.0005
Los Angeles	0.4536
Madera	0.002
Marin	0.0017
Mendocino	0.0021
Merced	0.004
Monterey	0.0057
Napa	0.003
Nevada	0.0009
Orange	0.0941
Placer	0.0017
Plumas	0.0005
Riverside	0.116
Sacramento	0.0119
San Benito	0.0011
San Bernardino	0.0212
San Diego	0.0168
San Francisco	0.0193
San Joaquin	0.0135
San Luis Obispo	0.0015
San Mateo	0.0170
Santa Barbara	0.0068
Santa Clara	0.0683

Continued

TABLE 5-11. Continued

COUNTY	VALUE ADDED BY MANUFACTURE FRACTION OF STATE TOTAL
Santa Cruz	0.005
Shasta	0.0024
Siskiyou	0.0016
Solano	0.0040
Sonoma	0.006
Stanislaus	0.0113
Sutter	0.0015
Tehama	0.0012
Trinty	0.0004
Tulare	0.005
Tuolumne	0.0005
Ventura	0.0096
Yolo	0.0033
Yuba	0.0004
	0.9982
All Other Counties (Includes: Alpine, Calaveras, Colusa, Inyo, Lake, Mariposa, Sierra)	0.0018
	1.0000

Source: Ref. 8

5.3.2 Industrial Vehicle Usage and Fuel Consumption

The summary of forklift and non-forklift vehicle usage factors was presented in Table 5-2. The calculation of fuel consumption is simplified by using the information shown in Table 5-3.

The vehicle usage and equipment profile for industrial/construction vehicles is given in Table 5-4. Table 5-12 provides a sample of how the industrial/construction vehicles operating usage may be calculated.

5.3.3 Vehicle Emission

Industrial off-road vehicle emissions are calculated by using the AP-42 emissions factors in Table 5-3. Forklift and non-forklift vehicle emissions are calculated by multiplying AP-42 emission factors with units of pounds of pollutant/10^3 gallons times the vehicle fuel consumption with units 10^3 gallons/year. Industrial/construction vehicle emissions are calculated by multiplying a composite emission factor with units of pounds of pollutant/hours of operation, presented in Table 5-3, times the vehicle usage with units of hours of operation/year.

5.3.4 Comments

The spatial distribution of industrial off-road vehicle emissions may be determined from human population distribution. Manufacturing plants that employ industrial vehicles are normally located within or near populated areas, which justifies the correlation between distribution of human population and vehicle population.

The temporal distribution of vehicle emissions is related to the normal working hours employed in the industrial area that is inventoried.

The methodology explained in this section may be used to inventory the emissions from industrial off-road vehicles for most counties, air basins, or areas in California. Numbers and types of industrial off-road vehicles are greatly dependent on the type of industry in an area, and industrial/ construction vehicles are the most dependent. Unusual industrial activity

TABLE 5-12. CALCULATION OF A COUNTY'S INDUSTRIAL/CONSTRUCTION EQUIPMENT PROFILE AND ANNUAL OPERATION*

Industrial/Construction Equipment Profile	Fraction of Total Population (1)	County or Area Equipment Profile, 1 x (County or Area Population)† (2)	Est. Annual Operations Hr/Yr§ (3)	Total Operations Hr/Yr (2) x (3)
Tracked Tractors	0.091		1050	
Wheeled Tractors	0.0121		740	
Wheeled Dozers	0.0076		2000	
Scrapers	0.0483		2000	
Motor Graders	0.0453		830	
Wheeled Loaders	0.0695		1140	
Tracked Loaders	0.0347		1100	
O.H. Trucks	0.0121		2000	
Miscellaneous	0.679		1000	
Total				

* See paragraph 5.2 for origin of data.

† Multiply the county or area total by the fraction of total value to obtain a county's equipment profile.

§ Source: AP-42 Section 3.2.7 (Ref. 19).

may distort the population assumptions derived by the use of the economic/ production indicator, value added by manufacture.

KVB estimates that the error in our methodology is ±25 percent. Although our methodology is based essentially on published data and documented telephone communications, many assumptions were necessary to correlate the data.

5.4 FORECAST OF EMISSIONS

Emissions from industrial off-road vehicles are not expected to change appreciably in the SCAB over the next 20 years (through the year 2000) unless some controls are placed on their engines.

Examining the economy and value added by manufacture for California versus the rest of the country revealed that (1) the country's GNP has been increasing approximately 3.8 percent per year since 1970, (2) California's fraction of the value added by manufacture has been increasing approximately 0.15 percent per year since 1967, and (3) SCAB's fraction of the state's value added by manufacture has been decreasing by approximately 0.87 percent per year since 1967.

Using the value added by manufacture as an industrial vehicle population indicator reveals that SCAB's industrial vehicle population is on a decline with respect to the state as a whole. This fact, in conjunction with the trend towards greater use of LPG and electric forklifts in California, should not increase the emissions from industrial vehicles appreciably.

SECTION 5.0

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SECTION 6.0

COMPUTERIZED DATA BASE

The non-automotive-vehicle emissions developed for the SCAB on this study were computerized using the ARB area source format. A magnetic tape containing the entire data base was delivered to the ARB along with a user's manual for the file. A printed report of these emissions was delivered to ARB in the form of a computer printout in two sections.

The file list printout contains activity, process information, and pollutant data related to the major inventory categories of construction, farming, industry, and boating. The printout format was produced directly from CARB's Area Source Emission System and was designed to help identify errors in the data.

From the program design, the printout reports several error messages, such as identifying digits 005 as an inproper air basin and declaring U.T.M. coordinates as out of area range. Each of the reported error messages has been checked and the data are correct.

To aid in reading the coding on the printout, a sample has been prepared:

Table 6-1 defines the fields and data input which corresponds to the bracket fields and circled numbers on the sample.

For key data used in this inventory, a summary of all data used is presented in Table 6-2.

SAMPLE PRINTOUT OF
AREA SOURCE DATA WITH
FIELDS IDENTIFIED ON TABLE 6-1

(3) (4) (5) KEY DATA	(6)	(7)	(8)	(9)	(10)	(12)	(13)	(15)	(16)	(17)	(18)	(19)	(20)	(22)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)	(33)	(34)	(35)	FLD#	ERRORS COL#	ERROR DESCRI
4200 005 8102 09	7274	50024	1113 70037																								2	7	INVALID CODE
																											17	80	OUT OF RANGE
																											19	89	OUT OF RANGE
																											20	93	OUT OF RANGE
				36055 60381 00430 03780 04260 37580 41003 75803 96037 330 0 50505 10101 31515 05050																							21	98	OUT OF RANGE
																											23	107	OUT OF RANGE
																											25	116	OUT OF RANGE
																											27	125	OUT OF RANGE
				505 0 00000 00000 00012 12121 21204 12121 20000 00000 00000 00																							30	135	NOT NUMERIC
																											43	160	NOT NUMERIC
4200 005 8102 09	06011	1110 50002 0																									2	7	INVALID CODE
																											10	26	OUT OF RANGE
4200 005 8102 09	P1232	10279 274							779	07023 00000																	2	7	INVALID CODE
																											6	16	INVALID CODE
																											6	16	INVALID CODE
																											15	75	INVALID CODE
											02574	00000	3	KV B TO ARB C ONTRA CT A7 -167- 30													17	93	INVALID CODE
																											20	98	INVALID CODE
																											16	83	NOT NUMERIC
4200 005 8102 09	P1232	10200 00027 274																									2	7	INVALID CODE
																											6	16	INVALID CODE
																											6	16	INVALID CODE
																											10	24	NOT NUMERIC
4200 005 8102 09	P1232	10243 10179 27400 00035 .5003 7907																									2	7	INVALID CODE
																		4AP.4 2 3.2 .7									6	16	INVALID CODE
																											6	16	INVALID CODE
																											12	34	NOT NUMERIC
																		LB /1000 GAL. COMPO SITE KVBTO ARB C											
4200 005 8102 09	P1232	10211 10179 27400 00002 0.003 7907																									2	7	INVALID CODE
																		4AP.4 2 3.2 .7									6	16	INVALID CODE
																											6	16	INVALID CODE
																											11	24	INVALID CODE
																		LB /1000 GAL. COMPO SITE KVBTO ARB C									12	34	NOT NUMERIC
4200 005 8102 09	P1232	10242 10179 27400 00073 .8503 7907																									2	7	INVALID CODE
																		4AP.4 2 3.2 .7									6	16	INVALID CODE
																											6	16	INVALID CODE
																											12	34	NOT NUMERIC
																		LB /1000 GAL. COMPO SITE KVBTO ARB C											
4200 005 8102 09	P1232	10242 40179 27400 00024 .6503 7907																									2	7	INVALID CODE
																		4AP.4 2 3.2 .7									6	16	INVALID CODE
																											6	16	INVALID CODE
																											12	34	NOT NUMERIC
																		LB /1000 GAL. COMPO SITE KVBTO ARB C											
4200 005 8102 09	P1232	10242 60279 27400 00033 1.403 7907																									2	7	INVALID CODE
																		4AP.4 2 3.2 .7									6	16	INVALID CODE
																											6	16	INVALID CODE
																											12	34	NOT NUMERIC
																		LB /1000 GAL. COMPO SITE KVBTO ARB C											

TABLE 6-1. FIELDS AND DATA INPUT

	FIELD	DATA INPUT
1.	Action Code	Add Data
2.	Transaction Identification	A-Category/Activity Level
3.	County	Los Angeles
4.	Air Basin	SCAB
5.	Category	Construction Vehicles
6.	Transaction Date	79274
7.	State and AQCR	California
8.	UTM Zone	11
	Source Type	Line
	UTM Coordinates	Horizontal/Vertical Area Description Determining Los Angeles County's Boundaries
9.	Monthly Thru-put	January thru December
10.	Hourly Thru-put	7:00 a.m. thru 4:00 p.m.
11.	Transaction Identification (Key data, fields 1, 3, 4, 5 remains constant for each county and category)	B-Category/Activity Level
12.	Hours per Day	8 hour/day
	Days per Week	5 days/week
	Weeks per Year	50 weeks/year
13.	Ratio of Thru-put	002.0
14.	Transaction Identification	C-Process Data
15.	Emission Producing Process	P1-Combustion of Fuels
	Process Application	232-Construction Equipmnet
	Fuel Consumed	Diesel Fuel
16.	Inventory Year	1977
17.	Source Classification Code	90702300 Diesel Fuel Off-Highway
18.	Yearly Process Rate/Units	2574.0 thousand gallons throughput/yr.
19.	Confidence Rating	3-Fairly Reliable
20.	Agency Supplying the Data	KVB to ARB
21.	Transaction Identification	D-Process Data
22.	Maximum Hourly Fuel Process Rate	2.574 gal. diesel/fuel
23.	Transaction Identification	E-Pollutant Data
24.	Pollutant	43101-Hydrocarbons
25.	Emission Factor	35.56
26.	Source Providing the Factor (constant for all pollutants)	AP42 3.2.7

Table 6-1. (continued)

	FIELD	DATA INPUT
27.	Emission Factor Comments Method of Conversion (constant for all pollutants)	Pound/1000 gallons Composite
28.	Pollutant	11101-Particulates
29.	Emission Factor	20.0 for Part
30.	Pollutant	42101-Carbon Monoxide
31.	Emission Factor	73.85 for CO
32.	Pollutant	42401-Sulfur Oxides
33.	Emission Factor	24.65 for SOx
34.	Pollutant	42602-Nitrogen Oxides
35.	Emission Factor	331.4 for NOx

TABLE 6-2. SUMMARY OF KEY DATA USED FOR THIS INVENTORY

4200 - Los Angeles County
5440 - Orange County
6420 - Riverside County
6700 - San Bernardino County
005 - South Coast Air Basin
8102 - Construction
8103 - Industry
8104 - Farming
8107 - Boating (Pleasure Craft)
8602 - Boating (Commercial Craft)
05 - California

PROCESS APPLICATION

P1 - Combustion of Fuels
220 - Industry
231 - Farming
232 - Construction
250 - Pleasure Boating
350 - Commercial Boating
90702300 - Diesel Fuel/Industry
90602300 - Gasoline/Industry
90702300 - Diesel Fuel/Farming
90602300 - Gasoline/Farming
90702300 - Diesel Fuel/Construction
90602300 - Gasoline Construction
90904230 - Diesel Fuel/Boating
90904430 - Gasoline/Boating
06 - Units of Thousand Gallons Throughput
43101 - Hydrocarbons
11101 - Particulate
42101 - Carbon Monoxide
42401 - Sulfur Oxides
42602 - Nitrogen Oxides