Mail Out MSC 98-34

NOTICE OF PUBLIC MEETING TO CONSIDER THE APPROVAL OF CALIFORNIA'S PLEASURE CRAFT EXHAUST EMISSIONS INVENTORY

The Air Resources Board (ARB) will conduct a public meeting at the time and place noted below to consider approving the pleasure craft emissions inventory.

DATE: December 10, 1998

TIME: 8:00 A.M.

PLACE: Air Resources Board
Board Hearing Room, Lower Level
2020 L Street
Sacramento, California

This item will be considered at a two-day meeting of the ARB commencing at 8:00 a.m., December 10, 1998, and continuing at 8:30 a.m., December 11, 1998, if necessary. This item may not be considered until December 11, 1998. Please consult the agenda for this meeting, which will be available at least ten days before December 10, 1998, to determine the day on which this item will be considered.

This facility is accessible to persons with disabilities. If accommodation is needed, please contact the Clerk of the Board at (916) 322-5594 or TDD (916) 324-9531 or (800) 700-8326 for TDD calls from outside the Sacramento area, by November 30, 1998.

INFORMATIVE DIGEST OF PROPOSED ACTION/PLAIN ENGLISH POLICY STATEMENT OVERVIEW

Proposed Actions: The ARB staff recommends the Board approve the update to the pleasure craft emissions inventory.

Background: California's emissions inventory for pleasure craft is an estimate of the amounts and types of pollutants emitted from thousands of pieces of equipment used in recreational marine applications. The development of the emissions inventory is a multi-agency effort. The ARB compiles the final, statewide inventory.

Section 39607(b) of the California Health and Safety Code has, for many years required the ARB to inventory emissions from sources of air pollution. The ARB has published inventories and updates for over 25 years. Improvements have been made periodically to maintain and provide the most complete, accurate, and up-to-date inventory practicable.

SB 2174 (Health and Safety Code section 39607.3), passed in 1996, requires the Board to approve, at a non-regulatory public meeting, the emissions inventory for criteria pollutants including emissions from mobile, stationary, area-wide, and nonanthropogenic sources. While the Board met its H&SC 39607.3 obligation by approving the statewide emissions inventory in December 1997, staff at that time committed to return to the Board for

approval of the OFFROAD inventory as it becomes available. Staff is therefore proposing this update to the pleasure craft portion of the new off-road inventory both to meet its H&SC 39607(b) commitment, and to fulfill its promise to the Board.

AVAILABILITY OF DOCUMENTS AND CONTACT PERSON

The ARB staff has prepared a Staff Report entitled "Public Meeting To Consider Approval Of California's Pleasure Craft Emissions Inventory" (Staff Report), which includes a summary of the proposed action. Copies of the Staff Report may be obtained from the California Air Resources Board, Public Information Office, 2020 L Street, Sacramento, California, 95814, (916) 322-2990.

Copies of the Emissions Inventory for pleasure craft can be obtained by calling ARB's Mobile Source Control Division at (626) 575-6800.

Further inquires regarding this matter should be directed to Mark Carlock, Chief, Motor Vehicle Analysis Branch, 9528 Telstar Avenue, El Monte California 91731, (626) 575-6608.

SUBMITTAL OF COMMENTS

The public may present comments relating to this matter verbally or in writing. To be considered by the Board, written submissions must be addressed to, and received by the Clerk of the Board, Air Resources Board, P.O. Box 2815, Sacramento California 95812, no later than 12:00 noon, December 9, 1998, or received by the Clerk of the Board at the meeting.

The Board requests, but does not require, that 20 copies of any written statement be submitted and that all written statements be filed at least ten days prior to the meeting. The ARB encourages members of the public to bring any suggestions for modification of the proposed action to the attention of staff in advance of the meeting.

CALIFORNIA AIR RESOURCES BOARD

Michael P. Kenny
Executive Officer

Date:

California Environmental Protection Agency

AIR RESOURCES BOARD

PUBLIC MEETING TO CONSIDER APPROVAL OF CALIFORNIA'S PLEASURE CRAFT EXHAUST EMISSIONS INVENTORY

Air Resources Board
Mobile Source Control Division

November 1998

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Acronyms Used in Staff Report

ARB	Air Resources Board
Board	Air Resources Board
CO	Carbon Monoxide
CO_2	Carbon dioxide
CY	Calendar Year
EEA	Energy and Environmental Analysis, Inc.
g/bhp-hr	Grams per Brake-Horsepower-Hour
g/kW-hr	Grams per kilowatt-Hour
HC	Hydrocarbons
H&SC	Health and Safety Code
HP	Horsepower
LF	Load Factor
MY	Model Year
NMMA	National Marine Manufacturers Association
NO_X	Oxides of Nitrogen
OB	Outboards
PM	Particulate Matter
PSR	Power Systems Research
pwc	Personal watercraft
SAI	Systems Applications International, Inc.
SB	Senate Bill
SIP	State Implementation Plan
SO_X	Oxides of Sulfur
tpd	Tons per Day
US EPA	United States Environmental Protection Agency

PUBLIC MEETING TO CONSIDER APPROVAL
OF CALIFORNIA'S
PLEASURE CRAFT EMISSIONS INVENTORY

RECOMMENDATION

The staff recommends the Air Resources Board (ARB or Board) approve the draft, statewide, annual average, Emissions Inventory for pleasure craft. This inventory utilizes the latest data available including information on industry trends provided through the public comment process. This ensures that projections of this inventory are accurate. The 1990 inventory, as presented in Table 1, represents the reference year from which all projections are made.

The staff will use the approved inventory to produce other types of inventories, such as inventories for past and future years, and inventories used for planning and air quality modeling purposes. Senate Bill 2174 requires the Board to review the emission inventory at a minimum of every three years. Staff intends to follow this three year schedule, however, staff may seek Board review of portions of the inventory sooner than three years if significant changes with major policy implications are suggested by new information.

Table 1
Pleasure Craft Emissions Inventory for Calendar Year 1990
(Statewide - Tons per Day)

Fuel	Type	ROG	CO	NOx	PM
Gasoline	**2 STROKE**	84.60	166.14	0.85	4.88
	4 STROKE	56.03	896.18	28.04	0.33
Diesel		0.41	0.98	2.34	0.07
Total		141.04	1063.30	31.23	5.28

CHAPTER I. INTRODUCTION

California’s pleasure craft emissions inventory is an estimate of the amount and types of pollutants emitted from thousands of pieces of equipment used in recreational marine applications.

The Air Resources Board and local districts use emissions inventories to describe and compare the contribution of various sources to air pollution, to establish priorities for developing methods of emission control, to prepare air quality plans, develop rules, and assess the progress of the State’s air pollution control program.

Statutory Requirement

The California Health and Safety Code (H&SC) section 39607(b) for many years has required the Air Resources Board to inventory emissions from sources of air pollution. Staff has periodically updated and published statewide emissions inventories.

Senate Bill 2174 (H&SC section 39607.3), signed by Governor Wilson on September 21, 1996, requires the Board to approve at a public meeting, the emissions inventory for criteria pollutants including emissions from mobile, stationary, area-wide, and non-anthropogenic sources. The Board's initial approval was required no later than January 1, 1998 and subsequent updates to the inventory are required at least every three years.

The Board approved the emissions inventory in December of 1997. However, because the new computer model for the estimation of the off-road emissions inventory called "**OFFROAD**" was not complete, the Board approved the existing inventory for off-road mobile sources. At that time, staff made a commitment to bring the revised estimates before the Board as they become available. The staff is seeking Board approval of the revisions to the pleasure craft emissions inventory per this process. Staff is therefore proposing this update both to meet its H&SC 39607(b) commitment, and to fulfill its promise to the Board.

CHAPTER II. PUBLIC PROCESS AND PUBLIC AVAILABILITY

The revisions to the pleasure craft emissions inventory were performed through a public process in which input was solicited from various agencies, air quality management districts, engine manufacturers, and technical consultants. ARB staff is ultimately responsible for the compilation of the final statewide emissions inventory, which is maintained in an electronic database.

The regulated community and interested stakeholders play a critical role in the review and development of the emissions inventory during the planning and regulatory process. They also participate actively in inventory workshops and in development of data and methodologies that improve the inventory. The ARB staff met often with representatives of industry associations to better understand the emission processes and to use their technical expertise and data to improve the inventory.

Two public workshops were conducted in early April of 1997, one in Sacramento and the other in EL Monte, in order to discuss the implications of SB 2174 on inventory development, and provide detailed descriptions of the data and methodologies used in the new OFFROAD model. The OFFROAD model is used by staff to estimate the emissions inventory for pleasure craft.

In July of 1998, staff published and mailed out a document describing various input factors and the resulting emissions inventory of pleasure craft contained in the OFFROAD model for public comment. Per their request, staff provided electronic copies of all databases to the technical consultants retained by the National Marine Manufacturers Association (NMMA). Staff's response to comments received by various organizations is detailed in Appendix H.

CHAPTER III. EMISSION INVENTORY MODEL STRUCTURE

A. Introduction

The Emissions Inventory for pleasure craft includes total emissions for the entire state, subtotals for each of the 16 air basins and subtotals for each county or portion of a county in each air basin. The data in Table 1 summarize the statewide inventory of reactive organic gases (ROG), carbon monoxide (CO), oxides of nitrogen (NOx), and particulate matter (PM). Collectively, these pollutants are known as "criteria" pollutants.

From the data used to produce the basic annual average emissions inventory, staff prepares other types of inventory products. Some examples are: future year forecasts used to judge attainment prospects, trends to show historical patterns, seasonal inventories for planning purposes, day-specific inventories for use in ambient air quality models, and updated, prior-year inventories used in trend and progress assessments. These other estimates are based on the annual average emission inventory data and additional data needed to produce the specific estimate. Some of the other data sets required include temporal data, growth and control assumptions, spatial data, and historical assumptions.

The inventory category "Other Mobile Sources" is not limited to pleasure craft. Other Mobile Sources include 14 categories of emissions sources such as: small off-road engines (engines less than 25 hp), off-road large spark-ignited engines, off-road recreational vehicles, aircraft, trains, ships and commercial boats. Estimating the emissions from these categories is primarily the responsibility of the ARB, but some categories are estimated by the districts or the United States Environmental Protection Agency (U.S. EPA), such as emissions from aircraft and ships. In this Section, staff presents the structure and algorithms used to revise and improve the emission inventory of pleasure craft using the OFFROAD model.

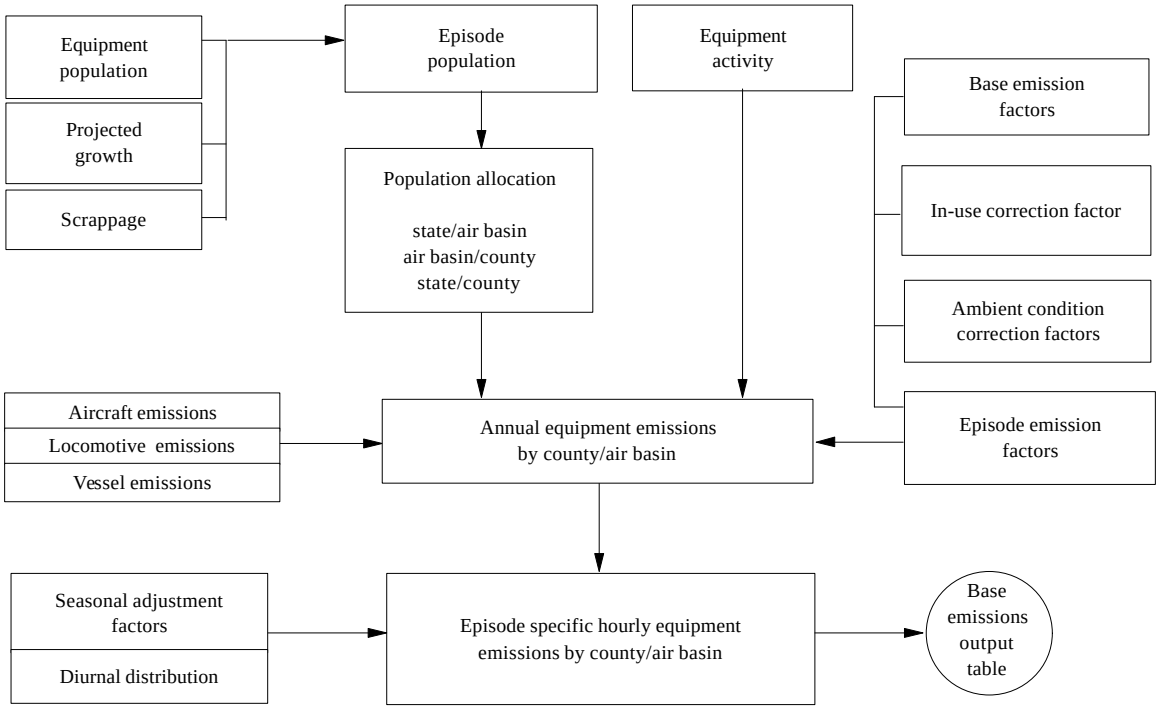
B. Program Structure

The primary emphasis in designing OFFROAD was to provide an overall structure to incorporate the various aspects of off-road source emissions modeling, such as the effects of various adopted and proposed regulations, technology types, and seasonal conditions on emissions. This overall structure is illustrated in Figure 1. Fundamentally, the population, activity, and emission factors are still combined to yield the annual equipment emissions by county, air basin, or state. However, spatial and temporal features have been incorporated, making the new model more accurate in its depiction of emissions.

OFFROAD consists of four main modules: population, activity, emissions, and control factor. The 1990 base year equipment population is adjusted for growth and scrappage, producing model-year specific population distributions for specified calendar years from 1970 through 2020. The statewide population is allocated to each geographic region. The base emission factors are

corrected for in-use and ambient conditions. The annual equipment emissions are adjusted for seasonal and diurnal factors producing the base emissions output.

Figure 1
Flowchart of Overall Program Structure of OFFROAD



The output tables of OFFROAD have a standard layout that displays activity information and emission data. The activity table includes information regarding the population, use hours per day, starts per day, and gallons of fuel consumed per day. The emission estimates are reported for three processes: exhaust, evaporative, and starts. While the output tables aggregate the information by equipment category for the state, the model can also produce more distinct information such as emission estimates of certain equipment type within a county.

C. Methodology

OFFROAD is designed to generate an emission inventory for six pollutants by equipment type, accounting for age and for a given scenario year. The basic equation for OFFROAD is:

$$P_{i,y} = \sum_{i} Pop_{i,v} * EF_{i,v} * Hrs_{i,v}$$

where

P = pollutant (HC, CO, NO_X, PM, CO_2, SO_2)

Pop = equipment population
EF = emission factor
Hrs = annual average use hours
y = scenario year (1970-2020)
I = equipment type
v = vintage (age of equipment)

1) Population Module

This module contains growth factors and scrappage curves that are used to derive an equipment-specific model year population distribution for specified calendar years from 1970 through 2020. The statewide equipment population was obtained through various industry and government agency sources and was divided at the air basin and county level using activity indicators that reflect their usage in those areas.

a) Categories and Equipment Types

There are 95 equipment types aggregated into 14 categories as listed in Table 2. In general, the 14 categories include all equipment types used for a similar purpose or industry. According to the Federal Clean Air Act, emissions from certain equipment types can only be regulated by the U.S. EPA and are, therefore, preempted from State regulation. The equipment types are further divided by fuel, engine type, horsepower group, and preempted or non-preempted status to better characterize emissions, adopted and proposed control strategies, and use. Table 3 shows the fuel type, engine type, and horsepower groups included in the model.

Tables 2 and 3 provide the category and horsepower information for all off-road sources. Those portions of the table shown in bold letters are specific to pleasure craft.

b) Growth and Scrappage

The growth factors are based on socioeconomic indicators such as housing units and manufacturing employment by category, by county, and with respect to the 1990 base year sales. Scrappage is a static function of equipment age and use which varies by engine type and horsepower group. For all equipment types, except lawn and garden equipment and recreational vehicles, the equipment useful life equals the life of the engine represented in years. The number of model years accounted for are twice the equipment useful life. The maximum useful life modeled is 16 years, which translates to 32 model years in a given calendar year. Therefore, the baseline model year distribution is also dependent on the useful life of the equipment. Due to the lack of any other information, the 1990 model year distribution is used for the 1970-1989 calendar years.

Table 2
List of Equipment by Category

a. Lawn and Garden Equipment
1. Trimmers/Edgers/Brush

d. Industrial Equipment (cont)
5. Other material handling

cutters
2. Lawn mowers
3. Leaf blowers/vacuums
4. Rear engine riding mowers
5. Front mowers
6. Chainsaws < 5 HP
7. Shredders < 5 HP
8. Tillers < 5 HP
9. Lawn and garden tractors
10. Wood splitters
11. Snow blowers
12. Chippers/Stump grinders
13. Commercial turf equipment
14. Other lawn and garden equipment

b. Light Commercial Equipment (0-50 HP)
1. Generator sets
2. Pumps
3. Air compressors
4. Gasoline compressors
5. Welding machines
6. Pressure washers

c. Recreational Equipment
1. All Terrain Vehicles (3 & 4 wheel vehicles)
2. Off-road motorcycles
3. Golf carts
4. Specialty vehicles/carts
5. Snowmobiles

d. Industrial Equipment
1. Aerial lifts
2. Forklifts
3. Sweepers
4. Other general industrial equipment
- Abrasive blasting equipment
- Industrial blowers/vacuums
- Marine/industrial winches and hoists
- Multipurpose tool carriers
- Other misc. industrial equipment (catch all)

equipment
- Conveyors
- Other misc. material handling (catch all)
- Industrial tractors

e. Construction and Mining Equipment
1. Asphalt pavers
2. Tampers/Rammers
3. Plate compactors
4. Concrete pavers
5. Rollers
6. Scrapers
7. Paving equipment
8. Surfacing equipment
9. Signal boards
10. Trenchers
11. Bore/Drill rigs
12. Excavators
13. Concrete/Industrial saws
14. Cement and Mortar mixers
15. Cranes
16. Graders
17. Off-Highway trucks
18. Crushers/Processing equipment
19. Rough terrain forklifts
20. Rubber tire loaders
21. Rubber tire dozers
22. Tractor/Loaders/Backhoes
23. Crawler tractors
24. Skid steer loaders
25. Off-Highway tractors
26. Dumpers/Tenders
27. Other construction equipment

f. Agricultural Equipment
1. 2-Wheel tractors
2. Agricultural tractors
3. Agricultural mowers
4. Combines
5. Sprayers
6. Balers
7. Tillers > 5 HP
8. Swathers

Table 2 (continued)

* (Industrial continues next column)

g. Logging Equipment
   1. Chain saws > 5 HP
   2. Shredders > 5 HP
   3. Log skidders
   4. Fellers/Bunchers

h. Airport Ground Support Equipment
   1. Airplane tow tractors
   2. Baggage/Cargo tow tractors
   3. Ground power units
   4. Start units
   5. Deicing units
   6. Load lifting and handling
   7. Service utility carts
   8. Pressure washers

i. Pleasure Craft
   1. Inboard vessels <250 HP
   2. Outboard vessels
   3. Sterndrive vessels
   4. Sail-auxiliary vessels
   5. Inboard w/jet engines
   6. Personal watercraft
   9. Hydro power units
   10. Other agriculture equipment

j. Commercial and Government Vessels
   1. Commercial inboard boats >250 HP
   2. Commercial in/outboard boats
   3. Commercial tug boats
   4. US Coasts Guard boats
   5. Seagoing vessels
      - Motorships
      - Steamships

k. Transport Refrigeration Units
   1. Small units < 25 HP
   2. Large units > 25 HP

l. Locomotive and Rail Operations
   1. Line haul operations
   2. Yard operations

m. Aircraft: Commercial, Military, and General Aviation
   1. Landing and Takeoff Operations (LTO)

n. Agricultural Aircraft
   1. Aircraft operations below 3,000 ft.

- **The portions of the table shown in bold letters are specific to pleasure craft.**

Table 3
Various Fuels, Engine Types, and Horsepower Groups
Used in the OFFROAD Model

Fuel	Engine Type	Horsepower Groups
Gasoline	2-stroke	0-2, 2-15, 15-25, 25-50, 50-120, 120-175, 175-250, 250-500, 500-750
Gasoline and LPG/CNG	4-stroke	0-5, 5-15, 15-25, 25-50, 50-120, 120-175, 175-250, 250-500, 500-750
Diesel		0-15, 15-25, 25-50, 50-120, 120-175, 175-250, 250-500, 500-750, 750+

2) Activity Module

This module contains information such as annual average use hours, load factor, brake-specific fuel consumption, and starts per year for each equipment type by fuel, engine type, and horsepower group. The activity information reflects seasonal and temporal conditions, as described below.

a) Seasonal and Temporal Parameters

The equipment types from diverse industries such as agriculture, construction, and recreation, are included in the OFFROAD model, and their usage patterns are not identical. These seasonal and temporal influences are resolved by monthly, weekly, and daily use patterns for each type of equipment.

Most of the categories (construction, industrial, light commercial, and airport ground service equipment) have uniform activity throughout the year. Recreational vehicles, lawn and garden, and farm equipment display various seasonal use patterns. Equipment types within a category have the same monthly use pattern except for snowmobiles, snow blowers, chain saws (<=5 HP), and tillers. Although most lawn and garden equipment undergo peak use during the summer, chain saw and tiller use peaks during the winter and spring, respectively. In order to be consistent with the seasonal attributes of reformulated fuels, summertime is defined as May through October while wintertime is considered November through April.

There are three types of weekly use patterns: average, weekday, and weekend. The average, or no peak, use pattern is exhibited by airport ground service and transport refrigeration units. Construction, industrial, and farm display mostly weekday, some Saturday, and less Sunday activity. Instances where weekend use is greater than weekday use would be recreational vehicles and lawn and garden equipment.

The daily activity is distributed into eight 3-hour periods (e.g., 3:00, 6:00, 9:00, etc.). The bulk of the activity occurs between 9 a.m. and 6 p.m., which is the daytime use pattern. Airport ground service equipment is utilized whenever the airport is open, and includes servicing of cargo and regular maintenance. Therefore, the use pattern is primarily during business hours with some off-peak activity. In contrast, transport refrigeration units are operated more evenly throughout the entire day because perishables are shipped at night for morning delivery.

3) Emissions Module

This module contains emission rate equations (emission factors) by model year for HC, CO, NO_X, PM, CO_2, and SO_X emissions. HC emissions are modeled for three types of processes: exhaust, evaporative, and start. The emission factors are a function of new engine emissions expressed in gram per brake horsepower hour (g/bhp-hr), and deterioration rates, expressed as a rate of increase in emissions per useful life.

Since several equipment types use the same types of engines, the exhaust emission factors are

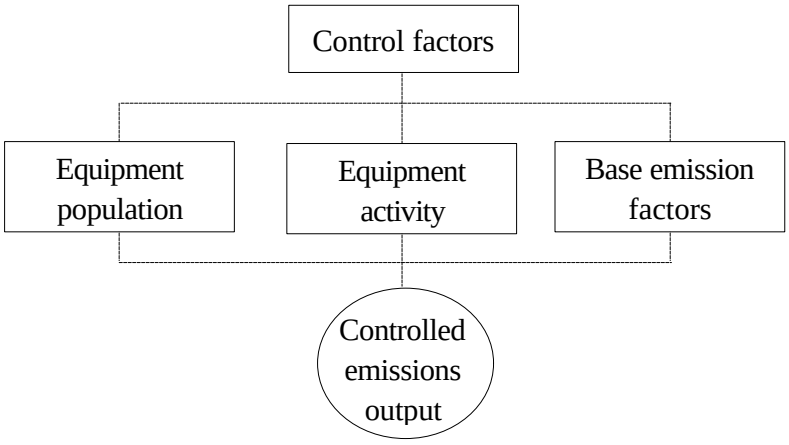
engine-specific. Equipment-specific emission rates are obtained by adjusting the appropriate engine emission rate according to how the equipment is used (duty cycle). The model-year-specific emission rates also reflect the effect of reformulated fuels and stringent emission standards adopted by the Board. Due to the lack of emission data, the deterioration rates are generally based on on-road emissions data[1], with the exception of small off-road engines, which were obtained from emission test results provided by engine manufacturers.

Evaporative emission factors account for refueling, diurnal, hot soak, running, and resting losses. Evaporative emissions are equipment-specific and dependent on fuel systems. Evaporative emissions are only estimated for gasoline equipment since diesel fuel has low volatility and LPG systems are pressure sealed. Due to the lack of data, placeholders are used for hot soak, running, and resting losses. This module also contains correction factors for temperature, reformulated fuels, and volatility. Although no data are currently available, the model is equipped to provide emissions due to start up procedures.

4) Control Factor Module

OFFROAD can also account for regulatory control scenarios as illustrated in Figure 2. The control factor file is a multiplicative adjustment indicated by polluting source, pollutant, beginning year, and ending year. Control factors can be applied to emission rates, activity, and populations. An example of a population control strategy would be to retrofit a particular model year group with an emission control device. Limiting use during peak hours would be an example of an activity control scenario. When this feature is employed, the output consists of both baseline and controlled scenarios.

Figure 2
Controlled Emissions Output



[1] **California Air Resources Board, "Technical Support Document, Derivation of the EMFAC7E Emission and Correction Factors for On-Road Motor Vehicles," July 1990.**

CHAPTER IV. REVISIONS TO THE BASELINE INVENTORY

A. Introduction

The pleasure craft category consists of all recreational boats registered by the California Department of Motor Vehicles (DMV). There are six equipment types in the pleasure craft category. The equipment types are listed in Table 4 by fuel and engine type. The 1990 base year population data is included in the table as well.

Table 4
Equipment Types and Population.

Equipment Type	Fuel/Stroke	1990 Population
Vessels w/Outboard Engines	G2	373,118
Sailboat w/Auxiliary Engines	G2	7,198
Personal Water Craft	G2	67,789
Vessels w/Inboard Engines	G4	61,275
Vessels w/Outboard Engines	G4	19,140
Sailboat w/Auxiliary Engines	G4	5,745
Vessels w/Sterndrive Engines	G4	236,744
Vessels w/Inboard Jet Engines	G4	27,640
Vessels w/Inboard Engines	D	8,524
Sailboats w/Auxiliary Engines	D	11,610

G2 - Gasoline, 2-stroke engine
G4 - Gasoline, 4-stroke engine
D - Diesel engine

B. Population

Methodology
The OFFROAD model contains growth factors and scrappage curves that are used to derive an engine specific model year population distribution for calendar years from 1970 through 2020. The methodology is described in detail in a document entitled, "Documentation of Input Factors for the New Off-Road Mobile Source Emissions Inventory Model," prepared by Energy and Environmental Analysis, Inc. (EEA), dated February 1997.

Sources
The statewide equipment population for pleasure craft was obtained from the DMV statistical records on registered vessels for calendar years 1990 to 1997. Since DMV's statistical records contain information on registered vessels by type of equipment and length and not by engine types, classification and quantification of equipment population by gasoline 2- and 4-stroke engine

cycles or diesel engines was not possible. This split at the statewide level, was determined from the Systems Applications International (SAI) report prepared for the ARB entitled "Development of an Improved Inventory of Emissions from Pleasure Craft in California", dated June 1995. This split was held constant for all calendar years. In addition, DMV's population data did not explicitly specify the personal watercraft (pwc) population, therefore, all boats powered by jet-propulsion (jetboats) in the DMV database under sixteen feet in length were considered to be either two-stroke pwc (less than 12 feet) or two-stroke jet boats. Jet boats greater than 16 feet were considered to be four-stroke inboard jetboats. Further, the registered vessels population obtained from DMV was converted to total engine population using a weighting scheme provided by EEA to the ARB in their February 1997 report. Table 2-13 from the EEA report presents this weighting scheme and is shown in Appendix A of this document.

C. Growth and Scrappage

Methodology

Statewide growth factors were calculated for each equipment type based on DMV population data. Growth factors are the same within each equipment type regardless of engine or fuel type. The statewide growth factors for calendar years (CY) 1990 to 1997 were calculated by normalizing actual calendar year populations to the CY 1990 statewide population. Since county specific data could not be obtained from the DMV in time for this report, a relationship between statewide growth factors and county specific growth factors was determined from growth data included in a report entitled, "A Study to Develop Projected Activity for 'Non-Road Mobile' Categories in California, 1970-2020", prepared by California State University, Fullerton, in October of 1994.

Based on DMV's population estimates, an average of the percentage growth in population between two consecutive calendar years was used to estimate the future (1997+) population of each equipment type as shown in Figure 3. The only exception was pwc equipment which experienced tremendous growth during the early 1990's with the population doubling in less than six years. Since the average percentage growth from year to year would increase the future pwc population to a unrealistic level, staff used their judgment to predict pwc population growth from 1998 through 2020. It was assumed that there will be no significant increase in the pwc population in California until 2002 because of uncertainty of various environmental, noise and usage related restrictions. After 2002, the pwc population was assumed to grow at an average rate based on DMV pwc data from CY 1990 to 1997. This growth was assumed to continue until 2006 at which time the market was assumed to be saturated. For 2006 and beyond, growth was assumed to slow down. Staff used outboard engine population growth as a surrogate for the pwc population growth beyond 2006. These numbers will be updated as actual DMV data is received. The DMV population from 1990 to 1997 is shown in Figure 4. Growth factors from 1990 to 2010 by equipment type are shown in Appendix B.

Scrappage rates and useful life estimates were obtained from data gathered through surveys of engine manufacturers by Power Systems Research (PSR), a market research firm. Scrappage or fleet turnover rate depends on the average useful life of an equipment type. The useful life

Figure 3. Percentage Growth of Each Pleasure Craft Equipment Type

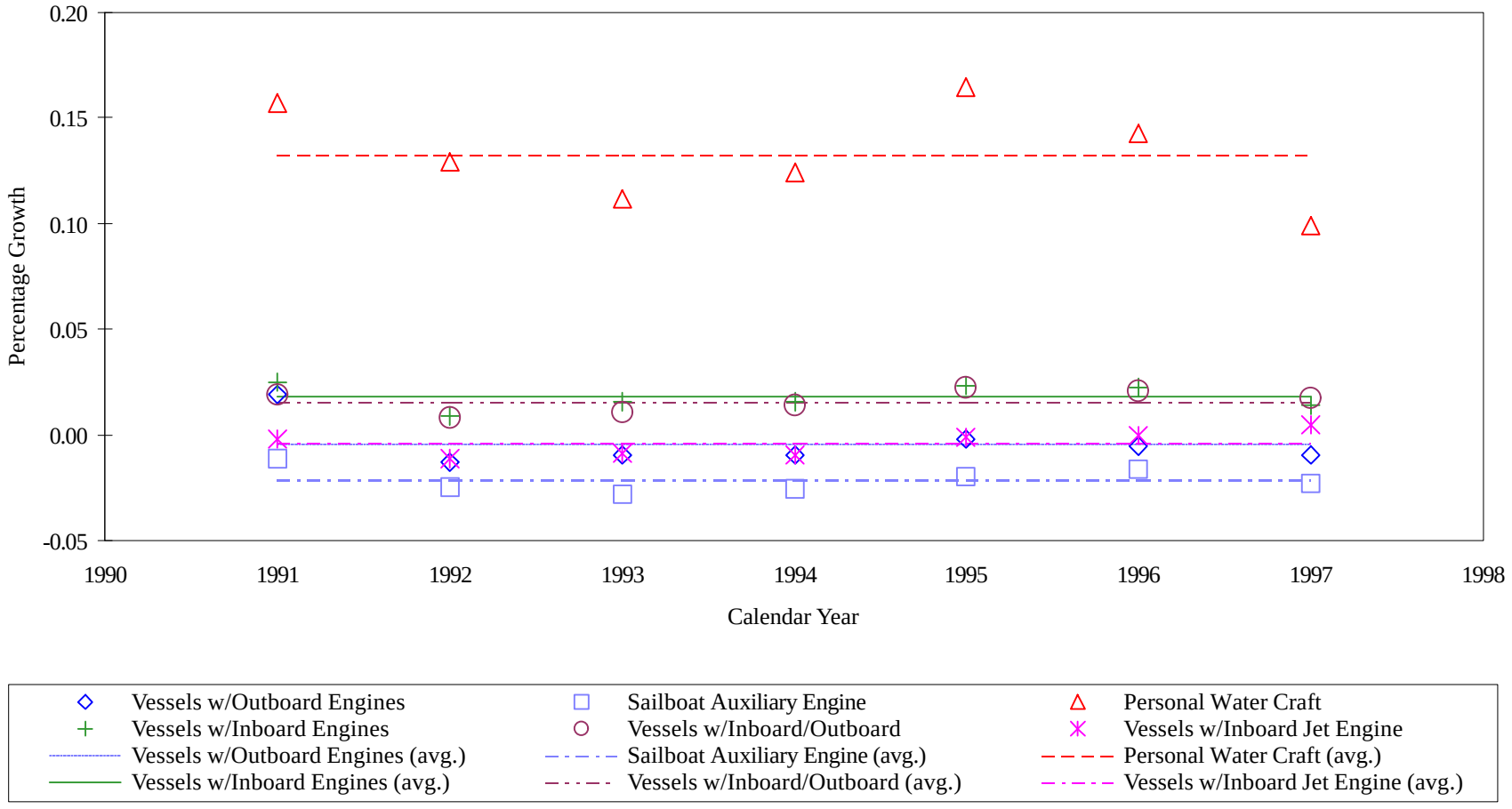
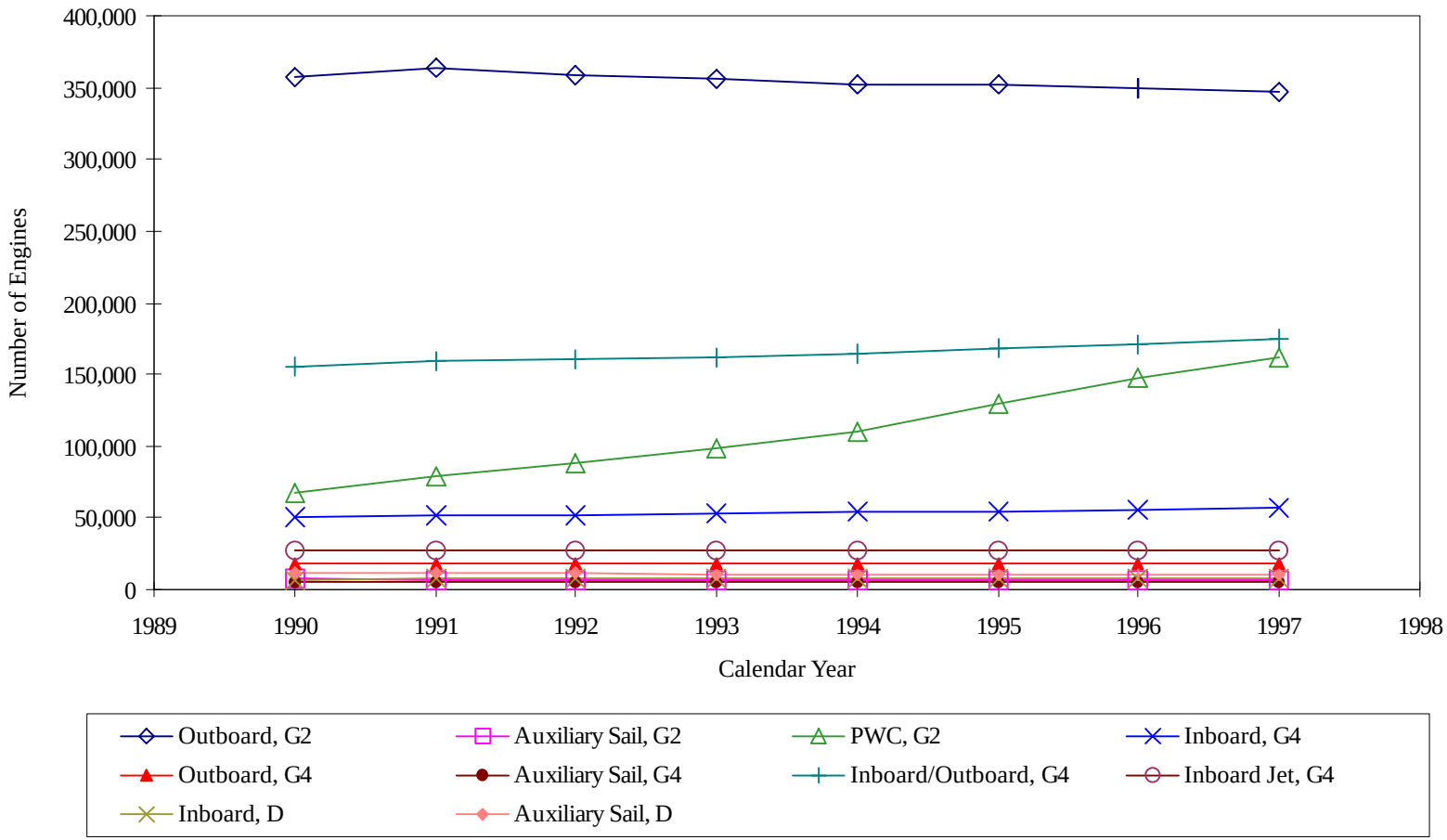


Figure 4. Pleasure Craft Population from DMV Database



describes the point in time when half of the engines sold in a particular year are assumed to be either scrapped or rebuilt. At two times the useful life, all of the engines of that year are assumed to be scrapped. Based on information provided by PSR, the useful life in years is determined by taking the useful life in hours and dividing by the load factor and activity in hours per year. If the useful life is determined to be over sixteen years then sixteen years is used as the useful life. All pleasure craft were determined to have a useful life of sixteen years except pwc which have nine years as their useful life. The useful life of pwc was determined by the National Marine Manufacturers Association. (NMMA) which based its estimate on national pwc registration data by age.

D. Activity

The OFFROAD model has datafiles which contain activity parameters such as usage in hours per year, average maximum horsepower ratings, and load factor by equipment and horsepower group.

Usage

Pleasure craft usage is measured in annual average use hours. Usage data for all pleasure craft equipment was obtained from the SAI report mentioned earlier in this document. In the survey done for this report, boat owners were asked how often they used their pleasure craft engine in a two week period. These surveys were sent out at various times of the year to remove seasonal bias and obtain yearly averages. Alternative source of usage data was available from the PSR database, but staff chose to use the data from the SAI report because it reflects California specific usage.

Staff believes that the usage of pwc decreases as they age. The average usage was determined as follows. First, for the two week survey period, the engine use in hours per boat by age and month of the year is determined by dividing the total sum of engine hours of all the pwc in the same age group and month by the corresponding total number of pwc. The sum of the engine hours per pwc by age over the 12 month period is then divided by 12 to get the average usage per boat by age for a two week period. It is then adjusted from a 2-week basis to a yearly basis by multiplying by 26 weeks. This results in engine use in hours by age of pwc per year. The resulting data was then curve fit to derive the relationship between the age and the usage of the engine. Table 5 shows the usage of personal watercraft using the above methodology. The average usage for all pleasure craft are shown in Table 6.

Load Factor

The load factor (LF) is defined as the fraction of full power typically used by the engine of a specific equipment type. The load factor and the average maximum horsepower ratings for all pleasure craft except for pwcs was obtained from the PSR database. Equipment with sterndrive and inboard jet engines were considered to be in the powerboat category in the PSR database, so they are all assumed to have the same activity.

Table 5
Usage of Personal Watercraft by Age Using SAI report

Age (Years)	No. of Boats	Engine Use (hours/boat/year)	1997 Population Distribution	Population Weighted Usage (hrs/year)
0	10	55.3	0.07525	4.158
1	47	50.9	0.15728	7.998
2	73	46.7	0.16178	7.555
3	69	42.8	0.13759	5.888
4	62	39.1	0.10847	4.245
5	45	35.7	0.09894	3.535
6	42	32.6	0.09593	3.124
7	30	29.6	0.06535	1.937
8	27	27.0	0.03420	0.923
9	26	24.6	0.02280	0.560
10	16	22.4	0.01140	0.255
11	15	20.5	0.00866	0.177
12	8	18.8	0.00730	0.137
13	12	17.4	0.00547	0.095
14	8	16.2	0.00410	0.066
15	23	15.3	0.00274	0.042
16	11	14.6	0.00137	0.020
17	8	14.1	0.00091	0.013
18	8	14.0	0.00046	0.006
Average Usage (hours/year)				**41**

Table 6
Usage of Pleasure Craft in Hours/Year Using the SAI report.

Equipment type		Usage (hrs/year)
Vessels w/Inboard Engines	(gasoline)	93
	(diesel)	88
Vessels w/Outboard Engines		48
Vessels w/Sterndrive Engines		73
Sailboat Auxiliary Engines	(gasoline)	10
	(diesel)	10
Personal Water Craft		41
Vessels w/Inboard Jet Engines		73

Three sources of data was used to assess the load factor as follows:

PSR: - PSR database indicated load factor for pwc to be 0.76. When asked for basis of this estimate PSR was not able to provide supporting information.

NMMA: - NMMA representatives obtained fuel consumption data from a rental fleet owner in Lake Tahoe. They reported fuel consumption to be 3.5 and 4.5 gallons per hour for 85 and 110 rated hp pwc respectively. Based on modal fuel flow data over the marine duty cycle provided by pwc manufacturers to NMMA, NMMA estimated that pwc load factor of 1.0 corresponds to 0.112 gallons per rated hp-hour and pwc load factor of 0.207 corresponds to 0.0298 gallons per rated hp-hr. The gallons per rated hp-hr for rental fleet was determined to be 0.041. Linear interpolation between 1.0 and 0.207 load factor implies load factor for the rental fleet to be 0.315.

ARB/SAI: - Using the SAI data for the fuel usage by age of the pwc, staff estimated population weighted average fuel usage to be 3.35 gallons per hour for the 1993 fleet. The usage weighted average rated hp for the fleet in 1993, during which time the SAI survey for the fuel usage was performed, is calculated to be 46 hp. Fuel usage of 3.35 gallons per hour and average rated hp of 46 implies a 0.073 gallons per rated hp-hr. Using the linear interpolation method used by NMMA, the load factor is determined as 0.62.

ARB: - Due to the uncertainty in load factor estimates, staff chose to revise the load factor to 0.40 which is based upon manufacturers submitted fuel consumption estimates. Staff believes that this represents a conservative estimate of load factor resulting in an inventory which is higher than industry would suggest but lower than staff believes. In the future staff will verify the load factor and update the inventory accordingly. The load factors for pleasure craft are shown in Table 7.

The statewide population was allocated to the air basin and county level using county specific fuel usage data from Table 3-6 in the SAI report. This allocation reflects pleasure craft usage, rather than registration, by air basin and by county. The allocation file used in the model is shown in Appendix C.

Model Year Specific Average Rated Horsepower

The model year (MY) specific average hp rating is assumed to remain constant through time for all equipment types with the exception of pwc. Based on meetings with engine manufacturers, staff has determined that in the case of pwc, the demand has changed from a one-person stand-up model to two- and three-person seated models, and will continue to change with more of the larger models becoming popular. Along with the demand for increase in size, there has also been a demand for increase in power and speed. Due to these reasons, the MY specific average hp for pwc has increased from 45 hp in 1990 to 82 hp in 1997. For these calendar years the average hp values were taken from the PSR database. Staff estimates that the MY specific average hp will increase linearly from 82 hp in 1997 to about 100 hp in 2010. The MY specific average hp is shown in Table 7.

Seasonal and Temporal Parameters

Seasonal and temporal factors are used to adjust for the differences between summer, wintertime, weekend and weekday usage. These factors were obtained from Appendix H in the SAI report and are shown in Appendix D of this document.

Table 7
MY Specific Average Horsepower and Load Factors for Pleasure Craft

Equipment Type		Average hp	Load Factor(%)
Vessels w/Inboard Engines	(gasoline)	164	38
	(diesel)	244	35
Vessels w/Outboard Engines (2-stroke)	< 2 hp	2	32
	2 - 15 hp	6	32
	15 - 25 hp	20	32
	25 - 50 hp	37	32
	50 - 120 hp	79	32
	120 - 175 hp	145	32
	175 - 250 hp	196	32
	250 - 500 hp	274	32
	(4-stroke)	36	32
Vessels w/Sterndrive Engines		164	38
Sailboat Auxiliary Engines	(gasoline)	10	35
	(diesel)	27	32
Personal Water Craft	(1990)	45	40
	(1991)	46	40
	(1992)	48	40
	(1993)	51	40
	(1994)	57	40
	(1995)	66	40
	(1996)	77	40
	(1997)	82	40
	(1998)	83	40
	(1999)	85	40
	(2000)	86	40
	(2001)	88	40
	(2002)	89	40
	(2003)	90	40
	(2004)	92	40
	(2005)	93	40
	(2006)	94	40
	(2007)	96	40
	(2008)	97	40
	(2009)	99	40
	(2010)	100	40
Vessels w/Inboard Jet Engines		164	38

E. Emissions

Hydrocarbon (HC), carbon monoxide (CO), oxides of nitrogen (NOx) , and particulate matter (PM) emission factors for pleasure craft built before US EPA's marine rule was implemented were obtained from the SAI report. These emission factors are based on the 5-mode marine cycle. Exhaust emissions are dependent upon the horsepower and the load factors of the equipment being considered.. Emission factors for pleasure craft are shown in Tables 8a and b.

Table 8a
Emission Factors for Two-stroke Engine in the Pleasure Craft Category (g/bhp-hr).

Engine Size Category (hp)	HC exhaust	CO exhaust	NOx exhaust	PM exhaust
< 2	275	369	0.7	7.1
2 - 15	198	320	1.1	7.1
15 - 25	129	276	1.6	7.1
25 - 50	117	208	1.1	7.1
50 - 120	107	213	1.7	7.1
120 - 175	106	244	1.1	7.1
175 - 250	107	215	1.1	7.1
250 - 500	109	210	1.1	7.1

Table 8b
Emission Factors for Personal Watercraft, Four-stroke Engines, and Diesel Engines in the Pleasure Craft Category (g/bhp-hr).

Equipment type	HC exhaust	CO exhaust	NOx exhaust	PM exhaust
Pwc	144	263	0.84	6.9
4-stroke gasoline engine	9.1	151	5.4	0.07
diesel engine	2.6	4.7	11.3	0.34

The load factor of the marine test cycle, upon which the emission factors in Tables 8a and b are based, is 0.207. Staff believe that emissions data collected with this load factor are appropriate for all equipment types in the pleasure craft category with the exception of pwc where the usage pattern demands more power than is reflected in the marine cycle. Due to the lack of other information, staff proposes to use emission factors based on the marine cycle for emissions calculation purposes.

The rate at which emissions of an engine increases over time is called the deterioration rate. Deterioration rates were determined for pleasure craft with four-stroke engines. These were estimated using uncontrolled on-road vehicle emission deterioration rates. The deterioration rate was calculated by assuming that the useful life of a 1974 model-year on-road passenger vehicle

was 100,000 miles and the total deterioration for the life of that vehicle would be the same as over the useful life of the four-stroke pleasure craft. Deterioration rates are presented in Table 9.

Fuel correction factors were incorporated into the OFFROAD model to account for the changes in the emission rates due to the use of California's Phase 1 Fuel, Cleaner Burning Gasoline, and Clean Diesel Fuel. The fuel correction factors for a gasoline powered equipment and diesel powered equipment were adapted from the on-road, non-catalyst equipped gasoline vehicle and diesel powered vehicle correction factors respectively. Fuel correction factors are multiplicative factors applied to emission rates. Table 10 and 11 show the fuel correction factors for gasoline and diesel fuels respectively.

Table 9
Deterioration Rates of Four-stroke Pleasure Craft in g/bhp-hr[2].

HC	CO	NOx
0.005	0.02906	0.00068

Table 10
Fuel Correction Factors for Gasoline Powered Pleasure Craft

Calendar Year	Summer			Winter		
	HC	CO	NOx	HC	CO	NOx
Pre-1992	1	1	1	1	1	1
1992-1995	0.988	0.994	0.997	0.963	0.895	0.997
1996+	0.921	0.848	1.025	0.921	0.848	1.025

Table 11
Fuel Correction Factors for Diesel Powered Pleasure Craft

Calendar Year	NOx	PM
1993 +	0.9425	0.8012

Incorporating US EPA spark-ignition marine engine rule

The emission standards finalized today for outboards, personal watercraft, and jetboats require a very large reduction in hydrocarbon emissions on a brake specific basis (i.e., g/kw-hr) with only a slight increase in NOx emissions. The standards require increasingly stringent HC control over the course of a nine-year phase-in period beginning in model year 1998. By the end of the phase-in, each manufacturer must meet an HC+NOx emission standard on a corporate average basis that represents a 75 percent reduction in HC compared to unregulated levels. EPA's administrative program requirements are designed to ensure that the targeted reductions actually occur by making manufacturers responsible for testing engines, reporting the results to EPA, and demonstrating compliance with the emission standards. The regulation

includes a corporate average standard, a nine-year phase-in, and a HC+NOx emission standard. It does not include a carbon monoxide standard. (US EPA, October 1996)

The HC+NOx emission standard is determined by an equation shown in Appendix E of this document. In order to reflect the US EPA's rule in California's pleasure craft baseline inventory, staff replaced the uncontrolled 1998+ emission rates with US EPA's standards based on the equation adopted in US EPA's rule. Since the US EPA has a combined HC+NOx standard, staff realized that the HC to NOx ratio should be different than the HC to NOx ratio for uncontrolled engines. The only data available to staff to make any adjustment was the US EPA's 1998 certification data where due to US EPA's trading and banking rule manufacturers had certified engines ranging from 6.68g/bhp-hr to 599.39 g/bhp-hr emissions level. Staff compared each calendar year's emission standard against similar certification test data to adjust the HC to NOx ratio. This methodology was used for each hp group of the pleasure craft category. The US EPA's emission standard based emission rates reflected in the emission inventory for 2010 are shown in Appendix F. Because the number of four-stroke engines being introduced to meet the US EPA rule is unknown, no deterioration was assumed for 1998+ model year emissions from outboard engines or pwc.

Tables 12 and 13 show the statewide population, usage and uncontrolled emission estimates in tons/day for CY 1990 and 2010, respectively. Emission estimates for CY 2010 which reflect US EPA's regulation for spark-ignition marine engines are shown in Table 14.

Table 12
Statewide Exhaust Emissions in tons/day for Calendar Year 1990.

Equipment Type	Fuel/ Cycle	Population	Usage (hrs/yr)	ROG	CO	NOx	PM
Vessels w/Outboard Engines	G2	373,118	48	66.71	133.17	0.745	4.012
Sailboat w/Auxiliary Engines	G2	7,198	10	0.15	0.27	0.001	0.008
Personal Water Craft	G2	67,789	41	17.74	32.70	0.104	0.858
Total	G2	448,105		84.60	166.14	0.850	4.878
Vessels w/Inboard Engines	G4	61,275	93	13.41	207.79	6.454	0.075
Vessels w/Outboard Engines	G4	19,140	48	0.34	5.77	0.183	0.002
Sailboat w/Auxiliary Engines	G4	5,745	10	0.01	0.10	0.003	0.000
Vessels w/Sterndrive Engines	G4	236,744	73	37.86	611.16	19.167	0.228
Vessels w/Inboard Jet Engines	G4	27,640	73	4.42	71.35	5.238	0.027
Total	G4	350,544		56.03	896.17	28.045	0.332
Vessels w/Inboard Engines	D	8,524	88	0.40	0.96	2.310	0.070
Sailboats w/Auxiliary Engines	D	11,610	10	0.01	0.01	0.034	0.001
Total	D	20,134		0.41	0.97	2.344	0.071
GRAND TOTAL		818,783		141.04	1063.28	31.239	5.281

Table 13
Statewide Uncontrolled Exhaust Emissions in tons/day for Calendar Year 2010.

Equipment Type	Fuel/ Cycle	Population	Usage (hrs/yr)	ROG	CO	NOx	PM
Vessels w/Outboard Engines	G2	348,606	48	58.34	109.02	0.708	3.748
Sailboat w/Auxiliary Engines	G2	4,780	10	0.09	0.16	0.001	0.005
Personal Water Craft	G2	293,485	41	161.29	273.65	1.053	8.466
Total	G2	646,871		219.72	382.83	1.762	12.219
Vessels w/Inboard Engines	G4	88,699	93	17.47	252.51	9.510	0.109
Vessels w/Outboard Engines	G4	17,805	48	0.29	4.56	0.175	0.002
Sailboat w/Auxiliary Engines	G4	3,799	10	0.00	0.07	0.002	0.000
Vessels w/Sterndrive Engines	G4	236,743	73	34.87	518.26	19.646	0.228
Vessels w/Inboard Jet Engines	G4	25,925	73	3.84	56.89	2.155	0.025
Total	G4	372,971		56.47	832.29	31.488	0.364
Vessels w/Inboard Engines	D	12,237	88	0.58	1.38	3.286	0.097
Sailboats w/Auxiliary Engines	D	7,619	10	0.00	0.01	0.021	0.001
Total	D	19,856		0.58	1.39	3.307	0.098
GRAND TOTAL		1,039,698		276.77	1216.51	36.557	12.681

Table 14
Statewide Exhaust Emissions in tons/day for Calendar Year 2010 with US EPA Regulation for Spark-ignition Marine Engines.

Equipment Type	Fuel/ Cycle	Population	Usage (hrs/yr)	ROG	CO	NOx	PM
Vessels w/Outboard Engines	G2/G4	348,606	48	38.31	71.33	2.231	3.748
Sailboat w/Auxiliary Engines	G2/G4	4,780	10	0.06	0.11	0.003	0.005
Personal Water Craft	G2/G4	293,485	41	45.19	83.11	8.290	8.466
Total	G2/G4	646,871		83.56	154.55	10.524	12.219
Vessels w/Inboard Engines	G4	88,699	93	17.47	252.51	9.51	0.109
Vessels w/Outboard Engines	G4	17,805	48	0.29	4.56	0.175	0.002
Sailboat w/Auxiliary Engines	G4	3,799	10	0.00	0.07	0.002	0.000
Vessels w/Sterndrive Engines	G4	236,743	73	34.87	518.26	19.646	0.228
Vessels w/Inboard Jet Engines	G4	25,925	73	3.84	56.89	2.155	0.025
Total	G4	372,971		56.47	832.29	31.487	0.364
Vessels w/Inboard Engines	D	12,237	88	0.58	1.38	3.286	0.097
Sailboats w/Auxiliary Engines	D	7,619	10	0.00	0.01	0.021	0.001
Total	D	19,856		0.58	1.39	3.307	0.098
GRAND TOTAL		1,039,698		140.61	988.23	45.319	12.681

The increase in total NOx emissions compared to uncontrolled 2010 level is due to the fact that emission rates reflecting US EPA's rule assume that the majority of the 2-stroke technology will shift to cleaner technology such as direct injection, Ficht, or 4-stroke technology.

Chapter V. Comparison with SIP Numbers

Table 15 contains the tons per day estimate from the 1994 State Implementation Plan (SIP) for the State of California for CY 1990. Compared to the 1990 ROG+NOx tpd inventory, the proposed inventory is 19% higher than the SIP inventory. The SIP inventory is based on a study conducted by KVB, Inc. entitled "Inventory of Emissions from Boating Sources in California" dated 1980. The methodology used to calculate emissions estimates for pleasure craft for the SIP inventory is different than the methodology proposed in this document. The main differences are outlined below:

1. In the SIP, the activity of boats was estimated in terms of fuel consumption by types of waterways which are lakes, rivers, delta areas and coastal areas . In the current methodology, activity is estimated in hours per year usage by boat type which are outboards, pwc, sailboats, inboards etc. In addition the current methodology utilized DMV registered boat population, load factor and average rated hp to calculate emissions inventory for pleasure craft.

2. In SIP methodology, emissions factors in pounds per gallon by waterways are used compared to current methodology where emissions factors in grams per horsepower-hour are utilized. Appendix G show emission factors used for SIP inventory.

Table 15
Statewide Exhaust Emissions Inventory of Pleasure Craft for CY 1990 Used for the SIP.

Equipment Type	Fuel Type	ROG emissions	NOx emissions
Recreational Boat	Gasoline	122.46	16.03
Recreational Boat	Diesel	1.61	4.57
Recreational Boat	Total	124.07	20.60

CHAPTER VI. SUMMARY AND CONCLUSIONS

This Board item marks the third in a series of presentations seeking approval of the off-road inventory. The finalization of the pleasure craft inventory is tied to pending regulatory action regarding this portion of the fleet with the understanding that estimates of effectiveness and cost depend heavily upon the accuracy of the inventory estimates.

The pleasure craft inventory estimates presented in this report were subjected to extensive public review and technical scrutiny. All issues regarding the accuracy of the inventory were addressed. It is believed that this is the most accurate estimate of emissions from this class of engines available.

Staff recommends the approval of the statewide, 1990 emissions inventory for pleasure craft as well as the projections to future years.

REFERENCES

1. Air Resources Board, Development of an Improved Inventory of Emissions from Pleasure Craft in California, June 1995

2. Air Resources Board, Documentation of Input Factors for the New Off-Road Mobile Source Emissions Inventory Mode, February 1997.

3. United States, Environmental Protection Agency, Control of Air Pollution Final Rule for New Gasoline Spark-Ignition marine Engines; Exemptions for New Nonroad Compression-Ignition Engines at or Above 37 Kilowatts and New Nonroad Spark-Ignition Engines at or Below 19 Kilowatts, Title 40, Code of Federal Regulations Parts 89, 90 and 91, October 4, 1996.