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GUIDANCE FOR ESTIMATING LAWN AND GARDEN EQUIPMENT ACTIVITY LEVELS

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GUIDANCE FOR ESTIMATING LAWN AND GARDEN EQUIPMENT ACTIVITY LEVELS

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INTRODUCTION AND SUMMARY

The objective of this study was to develop methodological guidelines to improve the accuracy of county-level activity estimates from lawn and garden equipment. This report documents the guidelines that were developed and includes detailed descriptions of the relevant background material and the step-by-step methodologies for understanding and implementing these guidelines.

This study, sponsored by the Emission Inventory Improvement Program (EIIP), is just one of a continuing series of studies with the common goal of establishing improved emission inventory modeling guidance to assist state and local agencies. The EIIP is a joint partnership between the U.S. EPA and STAPPA/ALAPCO. The products of the EIIP are intended to supplement existing EPA emission inventory preparatory guidance by providing additional specifics such as clarification of individual procedures, evaluating options available, and providing recommended or improved approaches in key areas. This project, with the specific directive to improve guidance for lawn and garden activity estimation, was undertaken because of the importance of this source category to air quality in several metropolitan regions and because current methods do not accurately reflect the signficant impacts of local activity variation. As such, current activity estimates for any given location are subject to significant uncertainty.

Before presenting the results of this study, it is important to clearly identify exactly which modeling parameters collectively define *activity* from this source category and the terminology used in this report to identify them. For the lawn and garden source category, the *total activity* of equipment usage (in units of hours) is calculated by multiplying the equipment *population* by the *activity rate* where the activity rate refers to the in-use hours of activity per piece of equipment over a specified time interval (e.g., annual activity rate would be reported as in-use hours per unit per year). In order to assess total activity for any time period (e.g., annual, seasonal, episodic), *temporal variation* needs to be identified. Temporal variation defines the month-to-month (or seasonal), day-of-week, and hourly activity profiles. Lastly, *equipment characteristics* data, containing equipment details such as engine type and power rating, are generally identified as these are important to fully use the activity data developed. In summary, the guidelines developed in this study provide the methodologies to improve the estimation of equipment population, equipment characteristics, activity rate, and temporal variation data.

The first task of this study was to complete a review of current data and methodologies including existing EPA guidelines, regulatory support documents and other relevant studies. Based on the review, we identified three key components used to estimate equipment activity that were in the greatest need of review and revision. Improving these specific components would net the

greatest improvement in estimated activity, and therefore became the focus of the methodologies that were developed. The identified areas of concern were:

1. Accuracy of a top-down[1] approach to identify county-level population - Which types of equipment are owned and used locally can vary tremendously from location to location depending on the predominant landscape. The local landscape, in turn, depends on several local and regional factors.[2] Current top down methods result in the uniform distribution of individual equipment types in every county nationally, thus not properly accounting for local variation.

2. Averaging commercial and private usage - Separating lawn and garden activity into the components of private and commercial usage is necessary to properly model the different characteristics of each. The magnitude of the activity, seasonal variation of the activity, and the types of equipment typically used are all significantly different between commercial and private usage. The activity estimates for these two types of usage need to be handled distinctly throughout the inventory process to eliminate the significant error created by averaging parameters.

3. Lack of temporal variation data - Sources of data defining monthly, day-of-week and hourly activity patterns are almost non-existent. The limited data available (and thus what is currently used) were developed from private usage data but are applied to the total source category (commercial and private usage combined). Methods need to properly account for temporal variation of commercial usage especially since data indicate that commercial usage contribute well over half of the activity. Also, local data are highly preferred as local variation of activity is important.

Once these areas were identified, the process of developing the modeling guidelines was begun. One factor played the primary role in shaping the methodologies contained in this report that top-down methods cannot reliably estimate county-level activity from lawn and garden equipment. This means that the most effective means to address each area of concern is to estimate local activity directly from sampling local sources. Therefore, our recommended approach is to design and conduct a survey of local activity.

Even though completing a survey is the recommended approach, it may be prohibitively expensive for some air quality planning agencies. For this reason, an alternative approach was also

[1] Top-down refers to the specific approach by which national or state level data are distributed to smaller regions (e.g., counties) using a regression or an allocation surrogate.

[2] Important factors affecting local equipment usage include climate, seasonal temperature, land-use, population density, altitude, rainfall, typical lot size, population demographics, and availability of water in more arid regions.

developed. The alternative approach provides the methodology to best improve activity estimates when limited to using existing data and resources. The alternative approach essentially provides the methods by which the top - down approach can be improved by properly seperating and identifying commercial and private usage. This approach does not address all of the areas of concern; however, it represents a useful tool, and it can quickly provide improved activity estimates at the county level.

Section 2 of this report presents the Technical Background summarizing the important consideration and issues that factored into the development of the guidelines. Section 3 contains the detailed Methodologies and describes how to implement the recommended and alternative approaches.

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2
TECHNICAL BACKGROUND

In this section, we present the background information important to understanding the methodologies that were developed in this study. The topics discussed here include an overview of the lawn and garden source category, EPA's current and anticipated emission inventory preparatory guidelines, other sources of data and information, and uncertainties in the current methods.

THE LAWN AND GARDEN SOURCE CATEGORY

The lawn and garden equipment source category encompasses the wide variety of equipment used by commercial lawn care service providers and by private homeowners. The equipment types this category are shown in Table 2-1. In combination, emissions from these equipment types are a significant source of volatile organic compound (VOC) emissions in most metropolitan regions. According to the U.S. EPA's Nonroad Engine and Vehicle Emission Study (NEVES) (EPA, 1991), lawn and garden equipment is the largest nonroad source category of summer season VOC emissions for 21 of the 24 Metropolitan Statistical Areas (MSAs) examined. Overall, the NEVES data showed that lawn and garden equipment typically accounted for 40 to 50 percent of the nonroad VOC inventory, or about 4 to 6 percent of the total anthropogenic VOC inventory. To a lesser extent, lawn and garden equipment usage also contributes to ambient carbon monoxide (CO), particulate matter (PM) and nitrogen oxides (NO_X) emissions.

Table 2-1
Equipment types included in the lawn and garden source category

Lawn Mowers (walk behind)	Front Riding Mowers
Rotary Tillers < 5 HP	Shredders < 5 HP
Chain Saws < 4 HP	Lawn & Garden Tractors
Trimmers/Edgers/Brush Cutters	Chippers/Stump Grinders
Leafblowers/Vacuums	Commercial Turf Equipment
Snowblowers	Other Misc. Lawn & Garden Equipment
Rear Engine Riding Mowers	

Figure 2-1 presents an example VOC emission inventory showing percent contribution of the lawn and garden source category as well as the other major source categories. These data, representing a 1993 summer season inventory for the four-county Dallas-Ft. Worth non-

attainment region, indicate a lawn and garden contribution of 8 percent.[1] This contribution is significant enough that the magnitude of the activity data, as well as when that activity is assumed to occur, should be verified for accuracy to local conditions. In this inventory, emissions from the lawn and garden category are greater than emissions from any other nonroad source, and are also greater than the point source emissions.

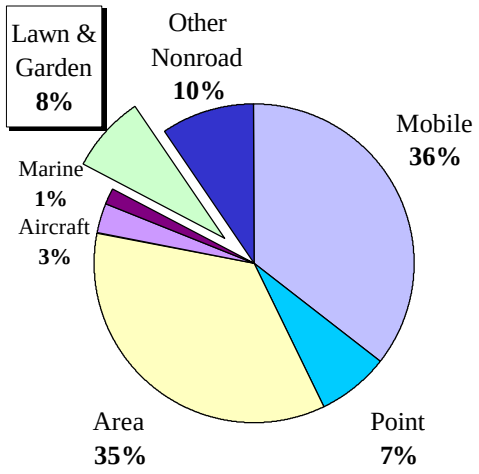

Figure 2-1 Example of a summer season VOC emission inventory highlighting the lawn and garden percent contribution (8 percent) and the contributions of the other major source categories (source: OTAG 1993 summer base case, Dallas-Ft. Worth non-attainment region)

As listed in Table 2-1, there are about a dozen individual equipment types included in the lawn and garden source category. Figure 2-2 shows which of these equipment types are significant contributors to the total for the lawn and garden source category as reflected by equipment population and by VOC emissions. The most significant contributor in both population and emissions is lawn mowers, which constitute about one half of the VOC emissions from the lawn and garden source category (four percent of the total VOC inventory). Another noteworthy observation to make from Figure 2-2 is the difference between commercial turf equipment *population* (0.6% - not labeled) and commercial turf equipment *emissions* (15%). This illustrates the tremendous effect of commercial activity rates on the inventory. Commercial equipment

[1] The Dallas-Ft Worth data are provided for illustration only and were arbitrarily selected from the multi-state emissions databases compiled by the Ozone Transport and Assessment Group (OTAG) in support of their regional modeling efforts. These data are not an official regulatory inventory.

activity rates can make a small segment of the population a significant source of activity and emissions.

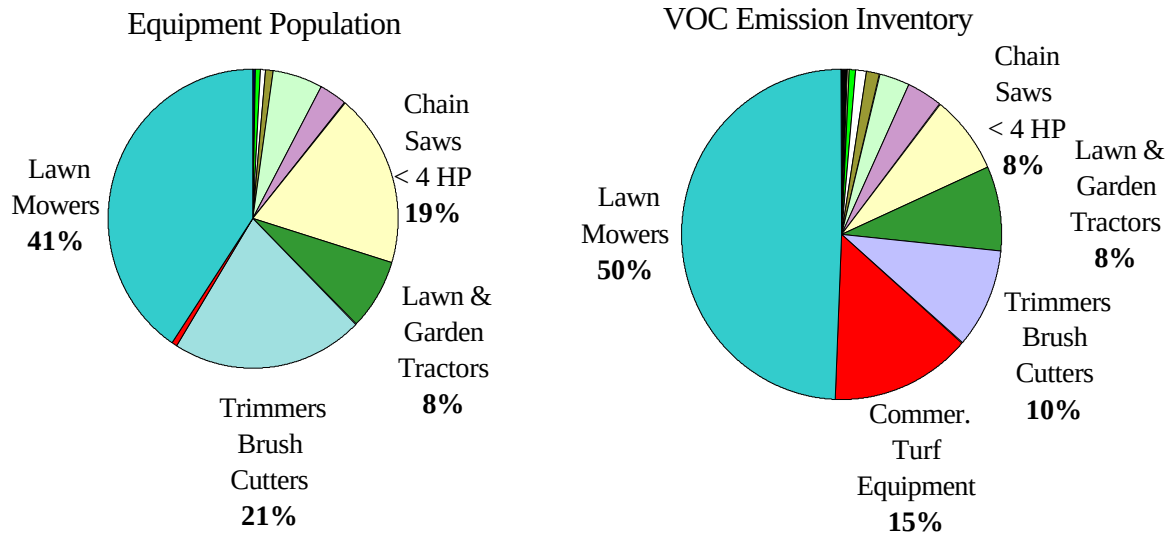

Figure 2-2 Contribution of individual equipment types to the lawn and garden source category total. Proportion of equipment types to the total equipment population (graph on the left) and total VOC emissions (graph on the right) for the 1993 summer inventory for Dallas-Ft. Worth shown in Figure 2-1

EMISSION INVENTORY PREPARATORY GUIDELINES

Described below are (1) current EPA inventory modeling guidelines for estimating emissions from nonroad mobile sources, (2) the EPA computer model currently under development that will automate the development of emission inventories from nonroad mobile sources. Once finalized, this model will become the new guidance for regulatory, nonroad emission inventory development. Note that this discussion provides only a brief summary of EPA guidance. Since the methodologies contained in this report are intended to supplement the existing EPA guidance, the reader should possess a good understanding of the guidance noted below before applying the methods from this report.

CURRENT GUIDELINES

EPA's current guidance for preparing nonroad emission inventories is contained in Procedures for Emission Inventory Preparation - Volume IV: Mobile Sources (EPA, 1992b) and the Nonroad Engine and Vehicle Emissions Study or NEVES (EPA, 1991). In late 1992, EPA released an update to the NEVES-based inventories that corrected inventory boundaries and equipment

population in a few specific instances for the 24 non-attainment regions contain in the NEVES and also released inventories for an additional 9 non-attainment regions. The data and methods contained in Volume IV, the NEVES, and the 1992 updated NEVES-based inventories are currently the primary resource for nonroad emissions, activity and population data. These have served as the basis for most nonroad inventories for past several years. In general, nonroad emissions estimates based on the NEVES and Volume IV employ a "top-down" approach in which national or state level data are distributed to smaller regions using a regression or an allocation surrogate. Lawn and garden equipment is one of ten general nonroad source categories, each of which uses the top-down approach.

The NEVES provided two separate 1990 calendar year inventories (labeled as A and B) for each metropolitan area studied. Inventory A was the EPA's best estimate of emissions using a top-down approach to allocate equipment populations to each metropolitan area using state-level equipment population as the starting point. The 1990 state-level population data were acquired by the EPA from Power Systems Research (PSR), a private company that compiles the data annually as a commercial product. PSR provided a general indication that the state-level data were estimated by allocating national estimates; however, the specific methods and assumptions used have not yet been identified.[2] Inventory B, was developed by updating Inventory A with local equipment activity and population data supplied by equipment manufacturers where possible. Only tabulated results are available for Inventory B and the details of the manufacturer data submissions are considered to be confidential business information. The EPA recommends using the average of the A and B inventory, but also permits the use of either Inventory A or B. All three options are currently used by different municipalities.

EPA'S NONROAD EMISSIONS MODEL (UNDER DEVELOPMENT)

The EPA's nonroad mobile source emissions model (named NONROAD) will serve as the next guidance tool for estimating county-level emission inventories for nonroad mobile sources. EPA's current plans are for releasing an official version of the model at the same time that MOBILE6 is released, currently scheduled for August, 1998. The NONROAD model will estimate emissions for at least general nonroad equipment and marine vessels; if resources permit, locomotives and aircraft will also be included. The basic emission calculations of the model are derived from the NEVES and from the California ARB nonroad emissions model (not yet available to the general public). The model will be able to estimate nonroad emissions by state, by nonattainment area, by county, by sub-counties, and for the nation as a whole.

With the anticipated release of NONROAD, the first question that probably comes to forefront of most readers minds is how will the new model affect the guidelines described in this report*?* This

[2] In conjunction with the NONROAD model development, EPA is investigating the assumptions and methods used by PSR to estimate state-level equipment population and will release a report on this effort in early 1998.

study was closely coordinated with the continued development of the NONROAD model and the release of the model will allow the incorporation of locally-derived activity data. The primary function of the NONROAD model will be to automate and thereby simplify the emission inventory process. In its first release, the EPA expects to rely on the 1996 PSR population database and a top-down approach as the default method for estimating county-level activity. In this way, the default approach of NONROAD will be similar to the NEVES methodology. However, the model is designed to use local input data when available. The development of locality-specific data, such as described here, will enhance the model's application in an analogous manner to the use of local data in the EPA's on-road mobile source emissions model (MOBILE).

OTHER DATA SOURCES AND LITERATURE

As part of this work effort, we completed a review of regulatory documentation as well as several recently completed studies on nonroad activity and emissions. Studies examined included recent efforts sponsored by various state agencies and several EPA-sponsored studies providing a continued examination of the nonroad source category. Documentation of this review is provided in Appendix A of this report and is recommended reading for an improved understanding of the data and approaches used to evaluate nonroad source categories.

UNCERTAINTIES IN THE CURRENT METHODS

There are several concerns with current methods and data currently used to estimate activity from lawn and garden equipment. These are detailed in the following text. Of the concerns noted below, one issue involves the accuracy of a top-down approach for modeling this category as used in the NEVES -- the study defining the current methods. As these criticisms are read, note that the remarks do not represent an evaluation of the quality of the NEVES effort (which in fact is quite commendable). These remarks are to present the argument that updates to the current method should consider alternatives to the top-down approach.

ACCURACY OF THE POPULATION APPORTIONMENT METHODS

Unless directly measuring local activity data, the only means for estimating county-level activity is by applying a top-down approach. The accuracy of county-level population estimates derived using a top-down approach can be highly questionable for the lawn and garden source category.[3] The fundamental assumption defining any top-down approach is that the allocation surrogate defines a uniform population and thus this surrogate can be used to distribute equipment population. In the case of lawn and garden equipment allocation, the assumption of the top-down approach is that the average household (the private usage allocation surrogate) in every county in

[3] The top-down approach is least reliable when commercial and private usage are coupled and allocated uniformly.

every portion of a state will use a uniform distribution of equipment types. In addition, if the PSR data that serve as the source of state-level data were also developed in turn from a top-down approach from national data, the final result is that every county in the nation is presumed to be representative of the national average.

For lawn and garden equipment, however, the top-down approach may not be a good method to estimate equipment populations, as the usage of this equipment depends on several local factors including climate, seasonal temperature, space land-use, population density, altitude, rainfall, lot size, population demographics, and availability of water in more arid regions. In the current top-down method, for example, the relative proportion of equipment in Clark County (Las Vegas) Nevada is the same as that of Dade County (Miami) Florida. This approach will lead to potentially large inaccuracies primarily in counties that do not reflect national average conditions.

In the few cases where independent estimates have been completed, the comparison between population estimates for the same geographical boundary have been observed to differ by factors of two and three (e.g., compare California population estimates from Booz, Allen and Hamilton, 1991 and EPA, 1991). Use of the top-down approach represents the greatest source of uncertainty in current estimates of county-level activity.

COMBINING EVALUATION OF COMMERCIAL AND PRIVATE USAGE

Current methods rarely separate lawn and garden equipment population into private and commercial usage. Rather they rely on data representing the average across both to evaluate total lawn and garden population, activity and emissions.[4] However, almost every aspect of commercial and private usage differs, and to correctly assess the emissions, the calculations must be done separately. The activity patterns are different between commercial and private usage. The equipment activity rates are different, and the type of equipment used is different. Private usage occurs more frequently in lower density areas (suburban and rural housing), while commercial usage occurs more frequently in urban areas. Because nearly every aspect of these usages differs, combining these two types of use at any point in the inventory process introduces some amount of error. In addition, because commercial equipment generally has a shorter useful life (due to greater activity rates), the faster rate of equipment turnover means that the new emissions standards will be introduced into the commercial population at a faster rate. To model the effects of the new standards correctly, the two usages need to be evaluated separately.

Overall, commercial usage represents a small fraction of the equipment population but usually represents more than half of the activity and emissions. To date, though, most studies have focused on private usage and very little information is available describing commercial activity. In

[4] The EPA NONROAD model under development will include the capability to model commercial and private usage separately.

general, because of a greater contribution and lack of data, evaluating commercial activity should be given a higher priority when evaluating lawn and garden activity.

To provide an example of the importance of commercial usage, Figure 2-3 summarizes the commercial equipment contribution from a study of California lawn and garden equipment (Booz, Allen & Hamilton, 1991). The commercial component is only 11 percent of the statewide equipment population; however, these 11 percent represent the majority of the total activity (63 percent) and between 70 and 80 percent of the total emissions. The data from this study indicate that commercial equipment is operated, on average, at a rate *14 times greater* than equipment used for private usage. Also noteworthy in these data is the increase in contribution of emissions relative to hours of activity. This increase results from (1) the average commercial equipment has a higher power rating than the average of the same type of equipment used privately, and (2) emission factors in grams per hour are generally proportional to the equipment's power rating.

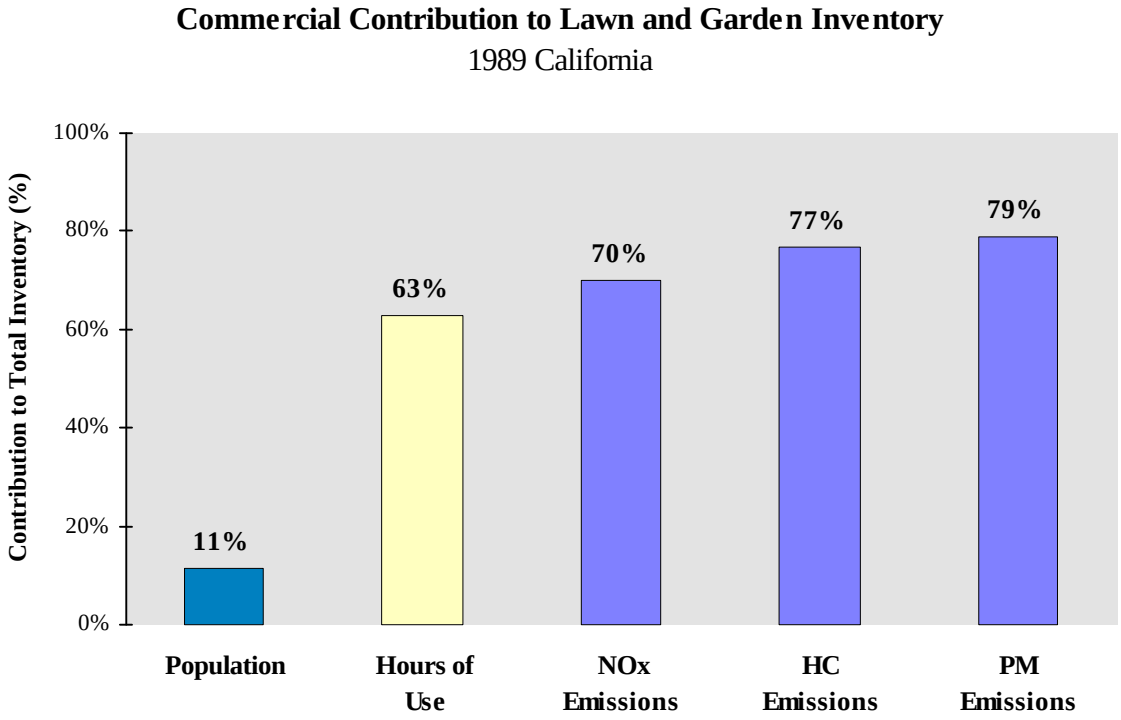

Figure 2-3 Commercial usage contributor as a percentage of total population, hours, and emissions (source: Booz, Allen and Hamilton, 1991).

LACK OF ACTIVITY PROFILE DATA

Activity profile information covering monthly, day-of-week and hourly activity patterns are virtually non-existent. California uses a 1980's residential survey for monthly variation even though more than 70% of the lawn and garden emissions are from commercial usage. Moreover, EPS2, EMS95 and the ARB all use the same day-of-week variation for this category with higher activity on Saturday and Sunday; these assumptions need to be verified as they appear to be based on very little information and may have significant impacts on episodic air quality modeling.

3
METHODOLOGIES

OVERVIEW

Based on the concerns with current methods described in Section 2, the following were defined as the primary objectives of the methodologies to be developed.

- Directly assess the local population.
- Distinguish commercial from private usage in all data collections and inventory calculations.
- Identify local temporal profile and equipment characteristics data.

To provide guidance in meeting these objectives, two separate approaches were developed in the course of this study, a recommended approach and an alternative approach.

- The *recommended approach* is to design and conduct a survey of local activity. This approach was developed as the best means to meet all of the objectives listed above. However, by design, a survey is a labor intensive effort and the resources required to complete this approach may be an important consideration. The survey approach can be implemented completely as described in this section or only in part to focus the evaluation on key local activity parameters.
- The *alternative approach* represents the best means to improve activity estimates if a survey is not feasible. However, this approach effectively only addresses the second objective above -- the separation of commercial and private usage. This approach consists of using available data and methods to improve the top-down method to properly distinguish commercial and private usage. Although continuing to rely on top-down methods, this approach is a quick and effective way to better evaluate the local contribution of private and commercial usage.

Ultimately deciding on which approach best suits the needs of any given location should consider a review of the both methodologies, an estimation of the importance of lawn and garden activity to local air quality, establishing the resources available, and the compatibility of the proposed approaches with existing methods and objectives. Notably, the recommended approach may not be preferred by every area. Two examples where the alternative approach may be more appropriate for a given location include (1) if the contribution of the lawn and garden source category to the local air quality problems is small enough to preclude the usefulness of a survey,

and (2) if resources needed to complete a survey of local activity are better utilized to address other inventory needs. Independent of the approach used, both should be reviewed because the information contained in each are complementary and because in some cases it may be preferable use both approaches in combination by selectively surveying a portion of the local activity.

This remainder of this section provides the detailed methodologies for implementing the guidelines developed in this study. The survey approach (recommended method) is described first followed by the improved top-down approach (alternative method).

RECOMMENDED APPROACH: A SURVEY OF LOCAL ACTIVITY

This approach involves the preparation and implementation of a survey to properly estimate local activity from both private and commercial usage. While a well-designed and executed survey can provide a wealth of information for estimating lawn and garden activity, this approach is also time-intensive. In addition to obvious effort required to conduct the survey, resources are needed both before and after the survey is executed to ensure an efficient and useful survey design and to properly compile and analyze the final survey results.

The six steps involved in developing and implementing a survey as described in this section are:

- defining the objectives of the survey,
- defining the survey "population,"
- preparing the survey,
- performing a pilot survey,
- conducting the survey, and
- compiling survey results.

These six steps are each described below, following a brief overview of the survey approach.

OVERVIEW

The purpose of the survey is to provide locality-specific values for the key activity parameters used to estimate emission inventories from lawn and garden equipment. The key parameters that should be considered for inclusion in a survey are those that could potentially provide the greatest improvement to the activity estimates of lawn and garden equipment. These are:

- **Population** by type of equipment (e.g., lawn mowers, chain saws, etc.) and by type of usage (private and commercial);

- **Activity rates** (i.e., hours of use) by type of equipment and usage;

- **Temporal profiles** by type of equipment and usage describing monthly or seasonal variation, day-of-week variation and hourly variation; and

- **Equipment characteristics** by type of equipment and usage describing engine type (e.g., gasoline 2-stroke, gasoline 4-stroke, diesel, electric), rated power, equipment age, and anticipated remaining useful life.

In designing a survey for a specific location, which of these parameters to include and the level of detail required should be established when defining the objectives of the survey -- the first step discussed below.

While the sequence of steps to follow for surveying lawn and garden equipment activity will be the same for commercial and private usage, there are some noteworthy differences that will require specialization of the survey depending on the type of usage. For instance, the *population*[1] to be sampled will differ for the two usages. This will affect the survey design and how the survey results are evaluated. In addition, there are important differences between usage types, such as equipment types preferred, equipment characteristics, and temporal variation, that should be understood in the design phase of the survey.

It should be emphasized that developing and conducting a survey requires specific statistical skills and understanding. While there are a wealth of references available with detailed information on conducting sample surveys (e.g., Cochran, 1977); however, in any survey effort, *it is critical to work with a statistician from the early planning stages*. A professional statistician can assist in designing and conducting the survey to maximize the amount of information obtained given the project resources.

DEFINING THE OBJECTIVES OF THE SURVEY

The first step in any survey activity is to define the objectives of the survey. In defining the objectives, questions such as the following should be addressed:

- Do you want the survey to provide population estimates for all lawn and garden equipment types or just a subset with the highest emissions contribution? What is the estimated activity and/or emissions for each equipment type? What is the uncertainty of the estimated activity levels?

- Do you want the survey to assess activity from both private and commercial usage, or just one? What is the estimated proportion of private and commercial

[1] The *population* is a specific term referring to the reference group from which the survey is being taken. The definition and role of the population are discussed in greater detail in the subsequent text.

equipment populations? What is the proportion of their activity? Which usage has the greatest uncertainty?

- Do you want the survey to provide activity variation information? What are the time periods of interest to the emission inventory development (annual, seasonal, and/or episodic)? How important are month of year, day of week, and hour of day activity variation to local air quality concerns?

- Do you want the survey to evaluate the individual equipment characteristics of the local population (e.g., engine type, power rating, and age)? Which characteristics are the most important to emission inventory estimation?

- Do you want to develop survey results that can be used to provide future-year activity level predictions without having to perform additional surveys?

While obtaining detailed information from a survey will improve the quality of the consequent emission inventory, there is of course a cost associated with obtaining each piece of information. Obviously asking more questions in the survey will require more time, which is probably the largest cost of performing surveys. Ideally, the scope of a survey would encompass each of the desired objectives. If budgetary or time constraints require a reduction in scope, the proposed objectives should be prioritized and reductions can be made by considering which parameters or sources contribute the least to the overall total and/or have a minimal amount of uncertainty. For example gathering data such as the maximum power rating or age of the equipment may provide valuable input into the emission inventory process, but these data may not vary widely from location to location, and in this, the national-average estimates already available may suffice.

DEFINING THE SURVEY "POPULATION"

Survey researchers use the term "population" to refer to that which is being sampled from. For example, the population of lawnmowers (i.e., the number of lawnmowers in use in a given geographic area) is estimated from the "population" of homes (i.e., the total number of homes in the same geographic area). Defining and estimating the size of this "population" is very important because it is used to scale up activity and other data estimates derived from the survey. The word population used in this manner should not be confused the same word used in the context of estimating equipment populations. To keep the difference clear, quotations will be used where "population" refers to that from which we are sampling, and population (without quotation marks) will be used to refer to equipment population.

One of most important factors affecting the accuracy of the survey ultimately conducted is defining the appropriate "population" to include all significant users of the equipment to be surveyed. This in turn requires that the definition of *private* and *commercial* usage is clearly understood by all participants in the study. Private usage refers to the operation of privately owned equipment by individual(s) in non-employment situation. Commercial usage refers to the

application of equipment as part of one's occupational responsibilities (e.g., maintenance personnel and landscape service providers). Private usage is almost exclusively confined to residential households; however, not all residential usage should be classified as private as many residences rely on professionals for regular upkeep or for assistance with larger projects. Commercial usage occurs in areas such as multi-unit residential, commercial, urban recreational, light industrial and institutional areas. Suggestions for identifying the survey "population" are discussed first for private and then for commercial usage.

The criteria for classifying of all significant sources of activity as either commercial and private usage should be set at the onset of any local study. These criteria should specifically address the ambiguously classified use of privately-owned equipment used in a part-time employment capacity as a minor source of income (relative to the household income). For example, a high school student may use the family lawnmower to maintain a fixed number of neighborhood lawns (anywhere from one lawn to more than a dozen) as a source of spending money. We suggest classifying this type of activity as private usage because (1) the "population" defining private usage and this activity are the same (e.g., privately owned homes), and (2) because the primary resources to define the commercial "population" do not include this activity resulting in its likely omission if classified as commercial.

The guidelines for defining the proper "population" for surveying private and commercial usage are discussed separately in the following as the "populations" and approaches will differ for each.

PRIVATE USAGE

For private lawn and garden equipment usage, there is one clear choice for the survey "population" that will likely be used in most cases - the number of households. Detailed housing count data can be obtained easily , and are presumably readily available to most readers of this document as these data are commonly used in emission inventory development. Comprehensive housing data can be obtained from the U.S. Census publications and census data can be ordered through regional U.S. Government Printing Offices (GPO), or can be obtained electronically from the U.S. Census Web site at:

http://www.census.gov

U.S. Census data include housing counts resolved to the census track level; and various census publications summarizing the data by location or county.

In any survey, the "population" should be identified as specifically as possible to minimize unnecessary sampling when conducting the survey. With respect to housing data, the Census distinguishes housing into the following seven groups:

- 1 unit - detached,
- 1 unit - attached (to neighboring structure on at least one side),

- 2-4 units,
- 4-49 units,
- 50 or more units,
- mobile home or trailer, and
- condominium or cooperative.

Of these, the "population" represented by single-unit housing (first two types shown above) probably covers the vast majority of private usage of lawn and garden equipment. However, there may be areas in which this is not the case. In some areas, for instance, there may be a significant number of duplexes, where the owner lives on one floor (or one half) and a tenant on the other. In such areas, it may be worthwhile to include the category of 2-4 units in the housing that defines the "population."

Once the "population" is established, it is very important to (1) maintain a consistent definition of "population" throughout the survey process, and (2) keep separate records of important groups within the "population" (e.g., duplexes and single-unit detached) which may exhibit significantly different usage characteristics. If relying on U.S. Census data to define the "population," the U.S. Census definitions of the seven housing groups should be followed when conducting the survey so as to correctly identify the "population" being sampled. These definitions are included in the appendices of most U.S. Census housing reports and can also be found at the census Web site noted above.

COMMERCIAL USAGE

For commercial lawn and garden equipment, multiple resources are available to assist in identifying the "population." In a given application, more than one will probably be necessary to properly identify the entire local "population." We recommend examining the following four types of establishments to completely identify the commercial "population:"

- landscape and horticultural service providers,
- establishments that have their own equipment and staff,
- equipment rental companies, and
- general building maintenance providers.

Of these, the first group certainly should be included in any commercial survey and will be the primary source of activity. The remaining three need to be assessed for importance to local activity and will most likely be included in the commercial survey to the extent that each contributes to the commercial activity. Defining the "population" for each of the four is discussed individually.

Landscape and Horticultural Services. The federal government's Standard Industrial Classification (SIC) code of 0780, *Landscape and Horticultural Services*, identifies the majority of commercial activity from lawn and garden equipment and encompasses the landscape and

gardening service industry.[2] SIC 0780 is a 3-digit classification (ending zero's indicate a more general classification) that can be further separated into three 4-digit SIC codes of

- 0781, *Landscape Counseling and Planning*,
- 0782, *Lawn and Garden Services*, and
- 0783, *Shrub and Tree Services*.

All three 4-digit SIC classifications are potentially important to the a local survey as specific equipment are favored by each.[3]

The most widely available and reliable resource for identifying the commercial "population" is the U.S. Census publication County Business Patterns (CBP). CBP is produced annually for each state and data are reported by 2, 3, and sometimes 4-digit SIC codes. In this case, data are reported only for SIC 0780. CBP data tabulate the number of establishments, employees and payroll grouped by the size of the business defined by the number of employees. CBP does not provide individual names and addresses of businesses, so in order to ultimately conduct a survey of this "population," names, addresses and phone numbers for the subset of businesses to be contacted in the actual survey must be also obtained.

Information on obtaining both paper and electronic copies of County Business Patterns may be found on the U.S. Census Web site and by calling any regional U.S. GPO. The latest version of CBP can be viewed and printed at the Web site free of charge. The complete national CBP database available on CD-ROM at a cost of $100 or $150 for two years of data covering every county and state. Bound reports including the data of one state can be ordered at a typical cost of $10 (cost depends on the number of counties in the state).

An example excerpt from CBP is provide in Figure 3-1 for San Diego County, California in 1994 (US Census Bureau, 1996). In this example, the county employment of SIC code 0780 is 5,628 employees from 738 total establishments. Note that the data tabulating establishments are stratified by employment size (useful in designing an efficient survey) and most establishments are in the smallest category -- employing 1 to 4 people (505 of 738, or 68 percent).

[2] SIC codes are a standardized business classification scheme widely used by government and business as a common means for identifying establishments or indexing business data.

[3] For instance, commercial turf equipment is used mostly by landscape architects and contractors (SIC 07810), lawnmowers would tend to concentrate in SIC 0782 businesses, and stump grinders are used primarily by tree services (SIC 0783).

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Table 2. **Counties—Employees, Payroll, and Establishments, by Industry: 1994**—Con.

[Excludes most government employees, railroad employees, and self-employed persons. Size class 1 to 4 includes establishments having payroll but no employees during mid-March pay period. (D) denotes figures withheld to avoid disclosing data for individual companies; the data are included in broader industry totals. For explanation of terms, statement on reliability, and comparability with other data, see introductory text]

SIC code	Industry	Number of employees for week including March 12	Payroll ($1,000)		Total number of establishments	Number of establishments by employment-size class								
			First quarter	Annual		1 to 4	5 to 9	10 to 19	20 to 49	50 to 99	100 to 249	250 to 499	500 to 999	1,000 or more
	SAN DIEGO													
	Total	**816,049**	**4,874,899**	**20,695,962**	**60,050**	**33,456**	**11,698**	**7,297**	**4,749**	**1,614**	**937**	**186**	**67**	**46**
	Agricultural services, forestry, and fishing	**8,180**	**30,633**	**145,008**	**1,170**	**751**	**229**	**114**	**48**	**19**	**9**	–	–	–
07	Agricultural services	7,969	28,326	132,543	1,121	718	218	110	47	19	9	–	–	–
072	Crop services	229	672	3,551	13	7	1	3	1	–	1	–	–	–
074	Veterinary services	1,520	6,002	26,700	225	94	86	37	7	1	–	–	–	–
075	Animal services, except veterinary	384	1,017	4,645	121	95	18	7	–	1	–	–	–	–
076	Farm labor and management services	172	395	1,378	16	12	2	–	1	–	1	–	–	–
078	Landscape and horticultural services	5,628	19,960	94,862	738	505	110	61	38	17	7	–	–	–
09	Fishing, hunting, and trapping	(C)	(D)	(D)	46	31	10	4	1	–	–	–	–	–
	Mining	**449**	**3,495**	**14,762**	**42**	**17**	**9**	**8**	**7**	**1**	–	–	–	–
14	Nonmetallic minerals, except fuels	279	2,237	9,727	24	7	8	5	3	1	–	–	–	–
144	Sand and gravel	199	1,501	6,515	18	6	7	2	2	1	–	–	–	–
	Construction	**42,000**	**260,690**	**1,174,779**	**4,916**	**3,030**	**875**	**515**	**361**	**89**	**43**	**2**	**1**	–

Figure 3-1 Excerpt from County Business Patterns, 1994 California (US Census Bureau, 1996) illustrating the business data reported SIC code for every county. SIC codes shown here do not include trailing zeros (i.e., 078 is SIC code 0780) and represent just a small sample of the total number of SICs tabulated.

One possible complication to using SIC 0780 data from the CBP as the only means to identify the "population" is the CBP purports to generally exclude "most" self-employed individuals (see Figure 3-1). Whether this is significant for SIC 0780 in any given county should be determined on a case-by-case basis as this will depend on the nature of the local lawn and garden service industry.

To assess the impact of self-employed individuals, alternative sources of business data known to include these businesses should be reviewed and compared. For this evaluation, it may suffice to examine just a portion of the local region of interest (e.g., one county) to ascertain if the CBP data are adequate. Alternative sources of data are (most include names, addresses and phone numbers):

- *Yellow Pages* (also available online)
- Government agency files (e.g., labor or tax departments)
- The Professional Lawn Care Association of America (PLCAA)
- Commercially available lists of businesses
- National Business Lists (a firm that specializes in compiling lists of firms)
- Nationwide Directory of Businesses (from American Business Directories)
- Dun's National Business Lists

- American Business Information, Inc.[4]

Note that there may be a non-trivial cost to acquire business listings. Once obtained, each source should be reviewed and compared to determine which one or which combination of resources identifies the complete "population." If multiple sources are required to identify the entire "population," it may be useful to maintain the distinction of sub-population according to their inclusion in each reference examined as this may identify unique groups within the "population." For example, businesses listed only in the *Yellow Pages* but not in the commercial business listings might exhibit distinctly different activity characteristics than the remaining "population."

Establishments That Provide Their Own Maintenance. In some specific instances, an establishment whose primary function is unrelated to lawn and garden services (i.e., SIC code not equal to 0780) will employ the staff responsible for the establishment's lawn and landscaping needs. Although infrequent, the hiring of dedicated staff is generally a viable option only for those establishments that have a significant amount of activity. Thus, the impact may be important and such establishments should be accounted for in the survey. The types of establishments where this may occur locally include:

- golf courses, country clubs, and cemeteries;
- universities, military bases and other large institutions;
- public parks, recreational areas, amusement parks and stadiums;
- state departments of transportation (roadway landscaping and clearing); and
- utility companies (maintenance of transmission wires).

Because these are such diverse establishments and because many have the potential to have a large impact on the local activity estimates, each instance should be considered, and ideally, the total cases will represent a small enough number of sources that each can be contacted individually (note that local departments of parks and recreation may provide data for several facilities). If contacting each is not feasible, (1) use judgement to rank sites according greatest usage potential (noting that lawns, especially when used for recreational activities, require the greatest amount of maintenance), and contact only those with the greatest potential and/or (2) multiple occurrences of the same type of establishment (e.g., golf courses, cemeteries) can be evaluated by contacting a sample of the total.[5]

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[4] This is an online service that is both comprehensive and easy to use -- but for a fee. Information can be found at: **http://www.lookupusa.com:800/cgi-bin/track/LIS/142670381622394/lookupusa/company/wiabi.htm**. The CD-ROM containing all the needed business information for every SIC code costs just under $1,000. Alternatively, data can be electronically downloaded for $0.50 a business. If downloading several counties, the cost quickly approaches that of purchasing the CD.

[5] To provide a sense of the size of the landscape and gardening maintenance staff that might be employed in these cases, we easily identified two examples. The first example is the University of Southern California (USC), a private institution of about 28,000 students situated near downtown Los Angeles. USC employs a grounds-keeping crew of 42 employees. The second example is Golden Gate Park, the largest park in San Francisco covering over 1,000 acres. This park

Equipment Rental Companies. Equipment rental companies can provide all types of lawn and garden equipment, though there is a higher demand for renting the more powerful, less-frequently used equipment such as stump grinders -- as these are less likely to be owned. Rentals are most commonly used by other businesses (e.g., landscape contractors), but renting equipment for private usage occurs too. These establishments can be important due to the high activity rates and due to the tendency towards higher powered equipment. In this case, the *Yellow Pages* can provide a complete listing and direct resource to identify and later survey this "population." Companies are listed under the heading "Contractors' Equipment and Supplies - Renting."[6]

Building Maintenance Services. Lastly, another business segment that may not be properly accounted for yet is building or property maintenance entities that include staff responsible for grounds and landscaping maintenance. Notably, most property maintenance service providers do not include outdoor services as well, but there may be enough instances of establishments that do to warrant an assessment of activity. These establishments would fall under SIC-7349 and, if significant locally, can be evaluated in a similar manner as SIC-0780 (using CBP and/or a commercial business listing); although, the *Yellow Pages* would also suffice in this case and would require less effort.

PREPARING THE SURVEY

Preparation of the survey involves defining the actual questions to be asked. These are, of course, defined by the objectives of the survey, i.e., the type of data that is to be gathered. In general, the survey that is prepared should be subject to a final review for soundness from both an emission inventory and statistical perspective. This review should verify that correct and consistent data specifications and parameter definitions are used throughout. This is important to ensure consistency between the proposed survey and the emission inventory procedures into which the survey data will be incorporated.

Of primary importance to the survey preparation is the selection of clear and efficient wording. The wording of questions must be considered carefully so as not to provide misleading answers. For example, to derive information on activity levels for private usage of lawnmower, one could ask on a survey the following series of questions:

(1) Do you or someone in your household use an engine-powered lawnmower to care for your lawn?

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alone has a city-employed staff of just under 200 gardeners and grounds keepers responsible for maintenance.

[6] If surveying rental companies, the equipment owner will be at a disadvantage to indicate accurately how long the equipment is typically in-use. In this case, the best approach may be to survey the number of days each equipment is rented. The number of hours in-use per day can be taken from another portion of the commercial survey and used to convert the number of rented days to an activity rate.

(2) Typically, how many times per month do you use your lawnmower?

(3) Typically do you mow your lawn on weekdays or weekends?

(4) How long does it take you to mow the lawn?

The second question is not specific enough if seasonal estimates are what is really of interest. In some areas, lawn mowing occurs year round, but in most areas of the U.S. lawn mowing frequency differs by season. So the question is better posed for each season or for just for the one season of interest. The third question is sufficient if estimates are desired for weekdays vs weekends. However, if day of week estimates are desired, the question obviously needs to be worded differently, such as "Typically, what day of week do you mow your lawn."

The fourth question as posed could lead to overestimating lawn mowing activity if survey respondents consider the actual time that they spend taking care of the lawn, including, e.g., raking clippings or using an edge trimmer. Instead, the more accurate and direct question "How long does your lawnmower run when you mow the lawn?" should be asked.

Survey forms for commercial lawn and garden equipment usage will be more complicated, because the way the questions are worded may need to be dictated by the size of the company. For example, for a one-person commercial operation, the questions will be fairly similar to the private survey. Using the lawnmower example again, the parallel questions to be asked could be:

(1) Do you use an engine-powered lawnmower to care for lawns as part of your work?

(2) Typically, which days of the week do you do commercial lawn care that includes some lawn mowing?

(3) On a typical day, what is the total amount of time that your lawnmower is in operation?

For larger commercial outfits, these questions need to be modified to derive information on lawnmower activity levels per employee. Again using the lawnmower example, the series of questions could be:

(1) Does your business use one or more engine-powered lawnmowers to care for lawns?

(2) How many engine-powered lawnmowers does your business have in use?

(3) Typically, which days of the week does your business do commercial lawn care that includes some lawn mowing?

(4) On a typical day, what is the total amount that you estimate each lawnmower is in operation?

The total number of hours of lawnmower operation for the business is then the time of operation per day per lawnmower multiplied by the number of lawnmowers. If, of course, seasonal inventories are desired, then the questions must be revised to ask for information for each season or for the one season of interest.

Overall, the examples above illustrate the importance of careful wording. Also, important is to carefully evaluate any additional parameters not directly used to estimate activity but are necessary to correctly analyze the results of the survey. The following are suggestions for specific parameters that should be considered when preparing the survey questions.

- *Ownership* - Establishing ownership of equipment is important. Clearly indicating that only the equipment owned by the residence or business being surveyed are to be included in the response. This will minimizes possible double counting of borrowed or rented equipment and will permit the proper assessment of population and activity rate from the data gathered. For example, consider a survey of a household at which a neighbor routinely mows the lawn for the household. If the household owns a mower and the neighbor uses it, then the activity is to be surveyed; if the neighbor brings his own mower, the activity is not to be surveyed.

- *Types of Activity* - If equipment are owned, then a complete accounting of all types of activity should be included. This includes, for example, direct usage by the survey respondant, estimated usage when borrowed (if relevant) and estimated activity by any other users.

- *Location of Business or Household* - It is important to confirm the location (by recording county or zip code) of the household or business to properly identify county-level activity.

- *Location of Activity* - It is equally important is to assess where the activity occurs since a business's activity may occur over a larger region. Identifying the proportion of activity by county may be a necessary component of the survey depending on local political boundaries and the size of the business.

- *Number of Employees* - Identifying the number of employees will be needed if stratified sampling is desired (this sampling approach is discussed below). The number of employees will also be needed to express commercial data on a per employee basis if it is desired to use local employment data were used for allocation or growth.

- *Method of Propulsion* - It is important not to omit that only engine-powered equipment are to be included in the survey response. For the engine-powered equipment, the minimum characteristic to define is the power or fuel source of the engine (gasoline, diesel, or electric) and preferably gasoline engines should distinguish 2-stroke and 4-stroke as the emission factors are quite different.[7] Including electric power, although presently not a common engine type, is important as these equipment will not have any direct emisisons.

PERFORMING A PILOT SURVEY

In most cases where a survey is to be used to estimate residential and commercial lawn and garden equipment usage, a pilot survey should be performed for three reasons: (1) to provide information for determining the number of homes or businesses to sample, (2) to determine the relative importance of distinct groups within the "population," and (3) to refine survey questions.

The number of homes or businesses to be sampled is determined by resources available (time and dollars) and/or by the desired level of precision. By precision we refer to the uncertainty in the average response, for example, one may wish to be able to estimate the average number of hours of residential lawnmower use per day to within plus or minus 20 percent. Sample size can be calculated for a desired level of precision with an estimate of the variation in survey responses. Most often, the variation in survey responses will not be known ahead of time; a pilot survey, i.e., a small initial survey, can provide an estimate of this. Standard statistical methods can then be used to estimate the number of survey responses required (see, Cochran, 1977). The more precision desired, the greater the number of survey responses required. On the other hand, one can also estimate the precision that can be obtained for a given amount of resources, using the same information on variation in survey responses from the pilot survey. This is one of the most important aspects of conducting a survey where a professional statistician can be of great assistance.

The pilot survey can be a highly useful tool to evaluate the most efficient assignment of the final survey resources between subgroups within the "population" in the instances where multiple groups have been identified. For example, the commercial usage survey may include distinct and different sources for surveying lawn and garden service businesses (classified under SIC 0780) and general building maintenance providers (SIC 7349). In generally, building maintenance would be presumed to be less significant; however, the pilot survey can provide the necessary data from both groups to determine relative importance of each in defining local commercial activity. These data can be used to effectively focus the final survey resources on key group(s) predicted to provide the greatest amount of information. For example, the pilot data could indicate that building maintenance providers need only be surveyed in a diminished capacity (or even eliminated

[7] 2-stroke engines can be identified most easily by determining whether lubricating oil and gasoline are input into the same fuel tank (2-stroke engines) or separate tanks with a dip stick to check the oil level (4-stroke engines).

from the final survey) without significant impact to the overall uncertainty of the local activity estimate from commercial usage.

The pilot survey will also prove to be useful to refine questions that are not well or clearly posed. If survey respondents repeatedly ask for the same clarification, that will indicate the way in which the question should be reworded in the full survey.

CONDUCTING THE SURVEY

Due to the anticipated difference in the defined "populations" to be sampled, the methods for actually conducting the survey will likely differ for private and commercial usage of lawn and garden equipment. However, there are some general principals that should be followed when conducting both surveys. The surveys should be taken from a random, unbiased portion of the local "population." If not predetermined, establishing whether a response fits the definition of the "population" should be the first done so that unnecessary contacts can be expeditiously ended. Also, in tallying the responses, it must be clearly understood by those conducting the survey that a response indicating no activity or equipment ownership is a valid response and must be recorded with the other survey responses.

For estimating residential lawn and garden equipment, telephone or door-to-door surveys may be conducted. Telephone surveys are certainly less expensive because a greater number of homes can be reached in less time, and are probably quite adequate for the purposed described here. While computerized lists may be available in some areas, randomly sampling from a phone book can be easily done. One method would be as follows:

(1) Divide the number of pages in the phone book with residential listings by the number of survey responses needed. Call this number **m**.

(2) Starting from the front of the phone book, count in **m** pages. Dial telephone numbers starting at the top of the page until someone answers who lives in a household that matches the definition of the "population," and who is able to answer the survey questions.

(3) Count in another m pages and again dial telephone numbers starting at the top of the page until a residence is reached for which someone is able to answer the survey questions. Repeat this until coming to the end of the phone book.

Each phone call should begin with an introduction, an explanation of the purpose of the survey and how the results are beneficial to the public, and an estimate of how much time is typically required to answer the questions to be asked.

For commercial outfits, the answers to survey questions will be time-consuming and onerous for business owners to answer, especially if usage information is being sought for all types of lawn

and garden equipment. It is recommended that for commercial outfits, the survey be mailed to them with a letter of introduction explaining the purpose, and explaining that someone will call on a specified date. Alternatives, businesses could be offered the option of mailing or faxing their responses.

Selection of commercial outfits can be done in a similar manner as was done for residential surveying, except that the list from which the sample is derived using commercial listings as described above. The commercial listing is the compilation of one or more resources that were used to define the "population" of commercial lawn and garden care businesses discussed earlier in this section).

Many sources of information on commercial lawn and garden service providers categorize businesses by number of employees. One type of survey sampling approach known as stratified sampling may be applied here to maximize the amount of information gained from a limited number of surveys. In stratified sampling, the commercial lawn and garden outfits are divided into strata, or categories, defined by number of employees or by annual revenues. Random sampling is then done within each category. There will be more businesses in the smallest category, and only a few in the largest category. Depending on resources available, it may be possible to survey all of the business in the largest category, and sample a portion of the businesses in the remaining categories. Here is where the services of a statistician are especially important for determining the optimal number or proportion of businesses in each category to sample.

COMPILING THE SURVEY RESULTS

Once complete, the results of the survey can be collected and compiled into individual values defining locality-specific population and activity rates. In this process, standard statistical techniques should be employed to estimate the quantities of interest and to assess the uncertainty and the significance of the resulting estimates. Overall, the survey should be designed with a thorough understanding of the inventory method to identify the appropriate parameters for evaluation. Thus, the incorporation of survey results into the inventory should be established in the survey design phase.

In compiling the results, the first task is to estimate the equipment population for the specific political or air quality region(s) used in emission inventory process by scaling the survey results. In the simplest type of survey, e.g. A random survey of households, this population is estimated from

1) a summation of the population for each equipment type distinguished in the survey,
2) divided by the total sample size (total number of responses including those documenting no equipment activity or ownership),
3) multiplied by the total "population" contained in the inventory modeling region.

For example, assume that a survey of private usage was compiled and resulted in a total count of 25 chain saws from a sample of 150 homes from "population" of 60,000 homes representing the emission inventory region. The estimated chain saw population (for private usage) for the inventory region is then calculated as

$$\frac{25}{150} \times 60{,}000 = 10{,}000.$$

Each type of equipment should be evaluated individually in the same manner to assess the local equipment population. Calculations for survey methods other than simple random sampling (e.g., if a stratified sample is performed for commercial usage) are more complicated, and the assistance of a professional statistician should be obtained.

Activity rates and equipment characteristics should be estimated normalized to a per equipment basis once the population of each type of equipment has been established. These data should be converted, as necessary, to the format and level of detail expected in the inventory process. Instances in which data from existing methods are used to define parameters not covered by the survey should be normalized as needed so that original distribution of observed in the survey data is not compromised. Sources of alternative data should consider the latest available information that are consistent with the EPA's emission inventory guidelines. Currently there are relatively few sources of available data complete and detailed enough to be useful in this process. However, those that are currently available are described under the alternative approach below, the next section and constitute the basis for what can be assessed if limited to existing data resources.

USE OF SURVEY DATA TO DEVELOP FUTURE YEAR EMISSION INVENTORIES

If designed properly, use of the survey data is not be restricted only to the present time frame. The basic requirement to extend the survey data into future years is to define a significant relationship between equipment population and an easily identifiable growth rate parameter. For example, locally derived growth parameters may already exist as part of the periodic planning efforts of the local regulatory agency or Metropolitan Planning Organization (MPO). Potential means for projecting population estimates into the future year should be considered when defining the "population."

In some cases, the "population" as defined for the private usage survey may be itself a suitable variable for projecting growth. For example, historic and projected housing data are readily available at either the county, metropolitan or state level and are commonly broken down into types (e.g., single-unit housing) based on proposed land-use strategies. Thus for private usage, the growth in the "population" can be directly determined from the housing projection data if equivalent housing definitions are used. Growth equivalency would inherently mean that the proportion of equipment population per "population" assessed in the survey is constant over time.

This is probably a reasonable assumption, especially for shorter periods, but may warrant further review as more data become available.

As a second example, the criteria used to define the "population" may differ from that used to define future year housing predictions. The U.S. Census resources for housing data probably offer the most complete information to reconcile differences between housing definitions. In addition, other federal agencies closely associated with the U.S. Census specialize in the projection of economic and population variables that may also be considered (e.g., the U.S. Department of Commerce, Bureau of Economic Analysis). Annual U.S. Census reports, such as the County and City and Data Book, can provide housing data by type of housing over time. The current edition (1994) is the twelfth year of publication of this book; all twelve editions are available on the Census Web site. The time series data selected should be examined to assess whether or not the trend in housing defined by the "population" is significantly different than other trends in housing for which projection data are available. If relationship exists, then growth in the "population" can be assessed from the relationship defined.

For commercial usage, data needed to project commercial lawn and garden service establishments (or other defined "populations") are likely not maintained at the local agency level. County Business Patterns, as described earlier in this section, is published annually and could provide the time series information needed to evaluate the trend in county-level, SIC 0780 businesses. The current report, for the year 1994, and reports since 1974, are available in various formats depending on the calendar year. The time series data extracted from this resource, or a similar reference, should be evaluated to determine if a statistically significant relationship exists between SIC 0780 businesses data and existing parameters for which historic and projected growth data are already available. Because of the broad applicability of lawn and garden services to almost any portion of a local region, it is reasonable that commercial lawn and garden activity will follow the general growth rate observed for population, housing or total employment. These parameters should offer a useful starting point for this analysis. Note that we are not suggesting the direct use of these parameters as growth surrogates. We are recommending a statistical examination to determine if a relationship exists.

ALTERNATIVE APPROACH: DEFINING COMMERCIAL AND PRIVATE USAGE FROM EXISTING DATA

As an alternative to the recommended survey approach, this approach describes the best means for improving county-level activity estimates while relying on existing data and resources. In brief, this approach is similar to the procedures already in-use, such as those defined by the NEVES, with the important distinction that activity from commercial and private usage are evaluated separately. The most significant improvement in this approach results from the independent allocation of private and commercial usage to the county-level and thereby more accurately reflecting county activity. Because of the importance of the commercial component,

this alternative approach can produce significantly different estimates of total county-level activity than would be assessed using current procedures.[8]

Although much improved by handling commercial activity separately, the alternative approach still must rely on a top-down method to define county-level estimates, and thus, some of the uncertainty in the estimates will remain. This approach, however, is an effective and immediate means to determine improved county-level activity estimates that can be easily implemented. In many instances, this approach will be better suited to the local needs than the recommended approach. Consider the following cases in which the alternative approach might be used:

1. The emissions from the lawn and garden source category are not a significant enough contributor to local air quality problems to warrant a detailed survey of equipment activity, thus the recommended approach is not needed.

2. As an interim or preliminary course of action, applying the alternative approach would provide improved estimates that could assist in the design of the survey by better defining the important sources and could be used until a survey approach could be carried out.

3. Sufficient resources for the conducting a survey were not available (or available resources would be better utilized elsewhere) and use of the alternative approach will suffice.

4. A survey is planned to assess the local commercial component only, and the alternative approach would provide the activity estimates for private usage.

In the following discussion, we describe the following five steps in the approach that are used to define county-level equipment population, activity rates and temporal profiles:

1. Identify the state-level population,
2. Separate commercially and privately used equipment,
3. Allocate population data to the county level,
4. Identify activity rates, and
5. Evaluate total activity and temporal profiles.

The procedures for each of the five steps are described in detail including suggested sources of data as necessary. After describing the last step, we also present an example application illustrating the use of this approach.

[8] Current methods based on the NEVES contain an inherent national average mixture of commercial and private usage that is applied uniformly to every county.

IDENTIFY THE STATE-LEVEL POPULATION

This approach begins with identifying state-level population data. As was described in (Section 2), the state population data developed by Power Systems Research (PSR) form the basis for equipment population estimates in the NEVES and the upcoming NONROAD model. The PSR data offer the most complete accounting of equipment by states currently available and are suggested as the source of state-level population data in this approach too.

We suggest using the PSR data that have been collected for the first release of the NONROAD model, which will use 1996 as the base year for inventory development.[9] For this study, the EPA provided the PSR data from which the 1996 state-level lawn and garden population data, shown in Table 3-1 were extracted. Table 3-1 does not include the populations of snowblowers because: 1) these should be processed separately when allocating state population data to the county level (this step is described later) and 2) a problem exists with current method that PSR uses to allocate the national population of snowblowers to the state level.[10]

For the state(s) of interest to the given application, the total population from Table 3-1 should be assigned to individual equipment and engine types using the population distribution data provided in Tables 3-2 and 3-3, taken from the 1996 PSR database. After the release of NONROAD, the 1996 PSR population data by equipment and engine types for each state could be extracted directly from the model's input files and used as an alternative resource to the data provided in Tables 3-1 through 3-3. Overall, the 1996 population distribution data show that the total source category population is almost equally divided between 2-stroke and 4-stroke gasoline engines, with less than 1 percent of the population using a diesel powered-engine.

[9] Alternatively, the NEVES-based population data could be used in this approach. The 1990 PSR population data are included in the NEVES documentation and are available in electronic form from the EPA.

[10] Snowblowers differ from the rest of lawn and garden equipment in that the county-level allocation of the state population should depend on the amount of snowfall. Currently, the PSR database does not utilize a specialized allocation for snowblowers using the amount of snowfall. In states where the amount of snowfall is small, nonexistent, or limited to one part of the state, this leads to an over-allocation of snowblowers. The EPA Office of Mobile Sources is aware of this problem and is working with PSR to fix this problem to prevent it from adversely affecting the NONROAD emissions model currently under development.

Table 3-1
1996 PSR lawn and garden equipment population data for each state (except snowblowers)

Region	Total Lawn an Garden (Except Snowblowers)	Region	Total Lawn an Garden (Except Snowblowers)
U.S.	114,452,718	Missouri	2,251,162
Alabama	1,800,125	Montana	369,352
Alaska	226,143	Nebraska	819,648
Arizona	2,080,211	Nevada	642,052
Arkansas	1,077,986	N.Hampshire	575,857
California	13,294,900	New Jersey	3,337,818
Colorado	1,692,659	New Mexico	650,387
Connecticut	1,614,139	New York	6,047,369
Delaware	337,928	N. Carolina	3,152,360
D.C.	111,052	N. Dakota	283,747
Florida	8,013,949	Ohio	4,787,320
Georgia	3,194,307	Oklahoma	1,288,321
Hawaii	551,120	Oregon	1,639,416
Idaho	599,911	Pennsylvania	5,263,667
Illinois	4,673,720	Rhode Island	418,514
Indiana	2,505,706	S. Carolina	1,713,844
Iowa	1,431,091	S. Dakota	349,773
Kansas	1,106,846	Tennessee	2,179,311
Kentucky	1,633,452	Texas	8,160,654
Louisiana	1,847,714	Utah	754,997
Maine	592,024	Vermont	315,031
Maryland	2,404,694	Virginia	3,122,726
Mass.	2,654,694	Washington	2,679,636
Michigan	3,665,713	W. Virginia	686,797
Minnesota	1,979,197	Wisconsin	2,303,970
Mississippi	1,033,550	Wyoming	222,458

Table 3-2
1996 PSR distribution of total lawn and garden population estimates into individual equipment and engine types (except for snowblowers)

Equipment Type	Percent of Population by Engine Type			
	Gasoline 2-stroke	Gasoline 4-stroke	Diesel	**All**
Lawn Mowers (walk behind)	2.67665%	30.40446%	**n/a**	**33.1%**
Rotary Tillers < 5 HP	0.07179%	3.49504%	**n/a**	**3.6%**
Chain Saws < 4 HP	20.72578%	**n/a**	**n/a**	**20.7%**
Trimmers/Edgers/Brush Cutters	24.96351%	1.15152%	**n/a**	**26.1%**
Leafblowers/Vacuums	1.98982%	0.61696%	0.00221%	**2.6%**
Rear Engine Riding Mowers	**n/a**	1.74377%	0.00093%	**1.7%**
Front Mowers	**n/a**	0.08553%	0.00021%	**0.1%**
Shredders < 5 HP	0.07199%	0.16072%	**n/a**	**0.2%**
Lawn & Garden Tractors	**n/a**	9.50789%	0.23981%	**9.7%**
Chippers/Stump Grinders	**n/a**	0.02700%	0.03891%	**0.1%**
Commercial Turf Equipment	0.01067%	0.72720%	0.27978%	**1.0%**
Other Lawn & Garden Equipment	0.10975%	0.89744%	0.00067%	**1.0%**
Total Lawn & Garden (Except Snowblowers)	**50.6%**	**48.8%**	**0.6%**	**100%**

Table 3-3
1996 PSR distribution of snowblowers into individual engine types

Equipment Type	Population by Engine Type			
	Gasoline 2-stroke	Gasoline 4-stroke	Diesel	**All**
Snowblowers	27.24508%	72.74732%	0.00760%	**100%**

SEPARATE COMMERCIALLY AND PRIVATELY USED EQUIPMENT

In this step, the state-level equipment population data are separated into the components representing private and commercial usage. Correctly separating the population is very important to the overall accuracy of this approach due to larger impact of commercial usage. For this reason, an effort should be made before proceeding with this step to identify and consider all current sources of population data defining commercial and private usage.

In this effort, two sources of data were found that included the equipment and engine types needed to address the entire lawn and garden category: the EPA's NEVES report (EPA, 1991) and the 1991 Booz, Allen and Hamilton (BAH) study completed for the California ARB (Booz, Allen and Hamilton, 1991). The data from these two references are summarized in Table 3-4. For both, data were assessed for gasoline-powered engines only. In the course of this work, no data were identified explicitly classifying diesel powered equipment into private or commercial usage; however, it is reasonable to assume that all diesel-powered equipment are used commercially.

Table 3-4
Percent of gasoline-powered population estimated to be commercially used

Equipment Type	Booz, Allen and Hamilton, 1991		EPA, 1991	
Equipment Typ	2-stroke	4-stroke	2-stroke	4-stroke
Lawn Mowers (walk behind)	4.7%	10%	4.7%	10%
Rotary Tillers < 5 HP	32%	32%	32%	32%
Chain Saws < 4 HP	8%	n/a	4.3%	n/a
Trimmers/Edgers/Brush Cutters	10%	21%	6.5%	6.5%
Leafblowers/Vacuums	10%	25%	6.4%	6.4%
Snowblowers	10%	10%	10%	10%
Rear Engine Riding Mowers	n/a	3%	n/a	0%*
Front Mowers	n/a	3%	n/a	0%*
Shredders < 5 HP	36%	36%	36%	36%
Lawn & Garden Tractors	n/a	10%	n/a	10%
Chippers/Stump Grinders	n/a	36%	n/a	**
Commercial Turf Equipment	100%	100%	100%	100%
Other Lawn & Garden Equipment	56%	56%	56%	56%

* No data obtained and assumed to be zero percent.

** Could not determine the value from the documentation of the NEVES. Expectation would be that most if not all are commercially owned (value form BAH Study seems too low).

Overall, the percent of the population assigned to the commercial usage is generally similar in both studies. For the NEVES data, it should be noted that (1) the values of Table 3-4 had to be back calculated from the documentation and were not explicitly defined in the report; (2) in the absence of data, front and rear riding mowers were assumed to have no commercial component; and (3) the commercial component of chippers and stump grinders could not be calculated from the information provided in the documentation. The data from Table 3-4 (or from another source) should be applied to separate the equipment population by usage type. In short, if using the data provided, the usage-specific populations can be calculated from the state population (Table 3-1) multiplied by the equipment distribution (Table 3-2 and/or Table 3-3) and multiplied by the commercial and private usage distribution (Table 3-4).

ALLOCATE POPULATION DATA TO THE COUNTY LEVEL

The purpose of this step is to allocate the state population data to the county level. This should be done by identifying an allocation surrogate for each usage representing equipment activity for which the state and county-level data are known. The surrogates recommended for commercial and private usage are SIC-0780 employment and single-unit housing, respectively. These data can be readily found for every state and county in two U.S. Census annuals, County Business Patterns (CBP) and City and County Data Book (see the recommended approach for additional information).

In assessing the percent of the state population existing in each county, the following equation should be used

$$\%\ Population_{Usage,\ County} = 100 \times \frac{Surrogate_{Usage,\ County}}{Surrogate_{Usage,\ State}}$$

where this index *Usage* signifies either commercial or private indicating that the surrogate data and the equation are dependent upon the usage type. To illustrate the use of this equation, if , for example, SIC-0780 employment was the allocation surrogate for commercial population and the county employment was found to be 2,000 out of 10,000 state employees, the application of this equation means that 20 percent of the state-level commercial population would be assigned to this county.

IDENTIFY ACTIVITY RATES

Activity rates are defined in this document as the equipment's in-use activity per population for a specified interval (e.g., annual activity rate of commercial lawnmowers could be 300 hours per year per unit). The activity rates are much greater for commercial activity than for private activity and it is very important to correctly identify the equipment activity rates for each usage type to properly assess total activity.

Table 3-5 presents activity rate data from two resources. The 1991 BAH study provided the most complete set of data for gasoline engines and the NEVES data are used for diesel engines. Note that the NEVES diesel activity rates in Table 3-5 are values reported for the *Pacific* region. to correspond with the BAH data which are representative of California. Activity rates in other areas of the country may differ depending on the region. In combination, these two resources in Table 3-5 can be considered directly applicable to the Pacific area. To assess annual activity rates elsewhere, we recommend using the NEVES background report *Methodology to estimate Nonroad Equipment Populations by Nonattainment Area* (Energy and Environmental Analysis, 1991). More specifically, Table 5-3 of this report contains annual activity by region of the country that can be used to scale the data of Table 3-5 to represent activity rates of other regions. We caution using the absolute activity rate data directly from Table 5-3 of the EEA report because the data in this table do not match the example calculations provided in the NEVES report, making it difficult to ascertain whether values include or exclude commercial activity for some equipment types.

Table 3-5
Annual activity rate data (hours per year per unit) by engine type and usage type

Equipment Type	Booz, Allen and Hamilton, 1991				EPA, 1991
	Gasoline (2-stroke)		Gasoline (4-stroke)		Diesel
Equipment Type	Commercial	Private	Commercial	Private	All
Lawnmowers (Walk Behind)	320	20	320	20	n/a
Rotary Tillers < 5 HP	72	18	72	18	n/a
Chain Saws < 4 HP	405	7	n/a	n/a	n/a
Trimmers, Edgers, Brush Cutters	170	10	190	10	n/a
Leafblowers, Vacuums	275	10	190	10	190
Snowblowers	60	10	60	10	72
Rear Engine Riding Mowers	n/a	n/a	380	38	48
Front Mowers	n/a	n/a	380	38	n/a
Shredders < 5 HP	190	16.5	190	16.5	n/a
Lawn & Garden Tractors	n/a	n/a	180	56	317
Chippers/stump Grinders	n/a	n/a	190	16.5	516
Commercial Turf Equipment	800	n/a	800	n/a	1239
Other Lawn & Garden Equip.	96	5	96	5	197

EVALUATE TOTAL ACTIVITY AND TEMPORAL PROFILES

In this step, estimation of total activity and/or temporal profiles that may be needed in a given application is performed. Total activity generally does not need to be explicitly estimated in the inventory process and, in general, the population data and the activity rates should be compatible with the current inventory methods and can be directly used.

There may be some instances where total activity needs to be defined or tabulated. In these cases, the data for each usage should be compiled and the following equation can be used to estimate total activity.

$$Activity_{total,usage,county} = \sum_{engine=1}^{3} \sum_{equip=1}^{12} ActivityRate_{usage,equipment,engine} \times Population_{usage,county,engine,equip}$$

In this equation, the county total activity by usage type will be assessed from the summation over the three engine and twelve equipment types.

Temporal profiles may be needed for inventory processing, conversion to episodic conditions, or for estimating the hourly activity profile. Since the activity data are completely separate for commercial and private usage, the temporal profile data should also represent both usages separately. At the time of this publication, there was only once source of data providing both commercial and private temporal profiles (Causley, et. al., 1996). This study, completed for the Texas Natural Resource Conservation Commission (TNRCC), surveyed a small number of individuals and businesses and estimated the temporal profiles for lawnmowers (these were the only equipment type included). The temporal profile data for this project as well as some other resources are included in the literature review in Appendix A.

EXAMPLE CALCULATIONS

We present here an example application of the alternative approach to assist in understanding each of the steps described in this approach. In this case, we will examine the Dallas-Ft. Worth nonattainment region using the modified top-down approach to assess commercial and private activity separately for the counties of Collin, Dallas, Denton and Tarrant.

Table 3-6 summarizes the all of the data and assumptions that will be incorporated into this example application. The first step will be to distribute the population estimate for Texas into equipment, engines and usage. Note that the state level population shown in Table 3-6 is the total without snowblowers and we are assuming that the snowblower population is insignificant.

The application of distribution shown in Table 3-2 with the state of Texas population data is presented in Table 3-7. Tables 3-8 and 3-9 present the results of the distribution of Table 3-7

Table 3-6
Parameters and data used in example application

Parameter	Reference, Value or Assumption
State Population	8,160,654 (Table 3-1)
Population Distribution	Apply data from Tables 3-2, 3-4 (BAH data were used in this example).
County Allocation	City and County Data Book, 1994 ***Fraction single unit * total housing:*** Texas 0.657 * 7,008,999 Collin 0.713 * 103,827 Dallas 0.565 * 795,513 Denton 0.608 * 112,263 Tarrant 0.647 * 491,152 County Business Patterns 1994 ***0780 Employment:*** Texas 21,248 Collin 722 Dallas 3,408 Denton 510 Tarrant 1,377
Activity Rates	Apply data from Table 3-5

Table 3-7
Texas population by equipment and engine for the example application

	Gasoline (2-stroke)	Gasoline (4-stroke)	Diesel
Lawn Mowers (walk behind)	218,432	2,481,202	0
Rotary Tillers < 5 HP	5,859	285,218	0
Chain Saws < 4 HP	1,691,359	0	0
Trimmers/Edgers/Brush Cutters	2,037,186	93,972	0
Leafblowers/Vacuums	162,382	50,348	180
Rear Engine Riding Mowers	0	142,303	76
Front Mowers	0	6,979	17
Shredders < 5 HP	5,875	13,116	0
Lawn & Garden Tractors	0	775,906	19,570
Chippers/Stump Grinders	0	2,203	3,175
Commercial Turf Equipment	871	59,345	22,832
Other Lawn & Garden Equipment	8,957	73,237	55

Table 3-8
Texas commercial usage population for the example application

	Gasoline (2-stroke)	Gasoline (4-stroke)	Diesel
Lawn Mowers (walk behind)	10,266	248,120	
Rotary Tillers < 5 HP	1,875	91,270	
Chain Saws < 4 HP	135,309		
Trimmers/Edgers/Brush Cutters	203,719	19,734	
Leafblowers/Vacuums	16,238	12,587	180
Rear Engine Riding Mowers		4,269	76
Front Mowers		209	17
Shredders < 5 HP	2,115	4,722	
Lawn & Garden Tractors		77,591	19,570
Chippers/Stump Grinders		793	3,175
Commercial Turf Equipment	871	59,345	22,832
Other Lawn & Garden Equipment	5,016	41,013	55

Table 3-9
Texas private usage population for the example application

	Gasoline (2-stroke)	Gasoline (4-stroke)	Diesel
Lawn Mowers (walk behind)	208,166	2,233,082	
Rotary Tillers < 5 HP	3,984	193,948	
Chain Saws < 4 HP	1,556,050		
Trimmers/Edgers/Brush Cutters	1,833,467	74,238	
Leafblowers/Vacuums	146,144	37,761	
Rear Engine Riding Mowers		138,034	
Front Mowers		6,770	
Shredders < 5 HP	3,760	8,394	
Lawn & Garden Tractors		698,315	
Chippers/Stump Grinders		1,410	
Commercial Turf Equipment			
Other Lawn & Garden Equipment	3,941	32,224	

into commercial and private usage populations using the data of Table 3-4. In this instance, we used the BAH data from Table 3-4. The distribution of equipment that make up the commercial and private usage populations from Tables 3-8 and 3-9 are shown in Figure 3-2. In total, the commercial population make up 12 percent of the state-level equipment population in this example.

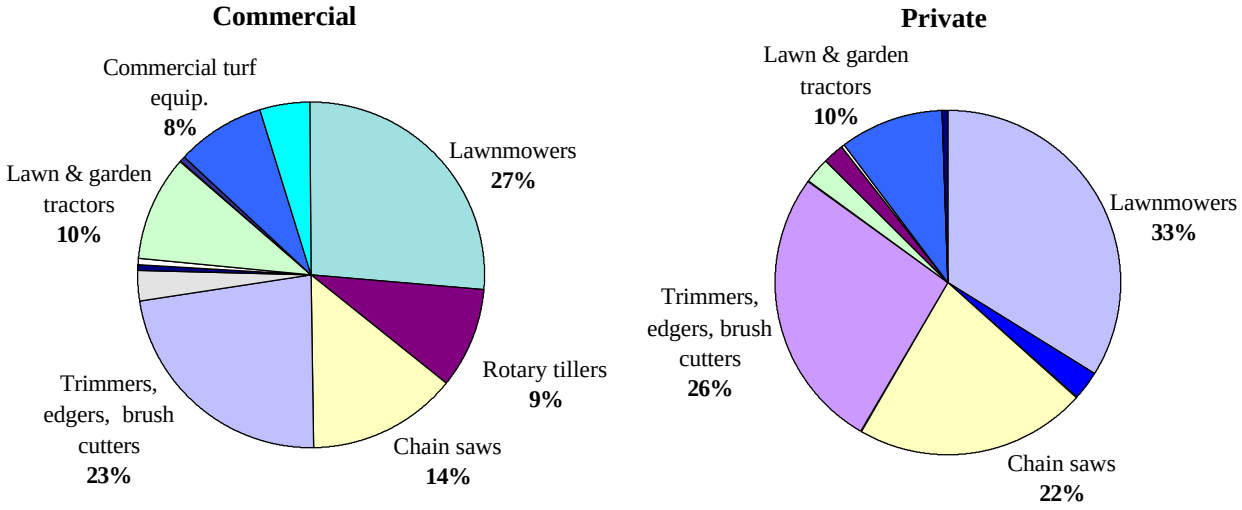

Figure 3-2
Distribution of private and commercial usage populations
by equipment type from the example application

The next step is to use the allocation data of Table 3-6 to estimate the county-level portions of the Texas data. The percent of the state private and commercial usage assigned to each county (calculated from the data of Table 3-6) are shown in the first two columns of Table 3-10. The allocation data for these four counties show that the distribution of commercial and private usage varies from county to county. In this nonattainment region, the counties of Dallas, Collin and Denton are allocated significantly greater proportions of statewide commercial usage than private usage. Commercial allocation in Tarrant County, on the other hand, is less than that for private usage.

Once the allocation data are identified, the assessment of county-level population simply requires the multiplication of the state population by the county allocation factor such as shown in the first two columns of Table 3-10. In this manner, we estimated the commercial and private usage populations for each county.

Table 3-10
Allocation data, commercial population and activity estimates, and total activity for the example application

County	Allocation of State Private Usage (%)	Allocation of State Commercial Usage (%)	Commercial Population (%)	Commercial Activity (%)	Total Activity (hours)
Collin	1.6%	3.4%	22%	85%	10,711,469
Dallas	9.8%	16.0%	18%	82%	52,629,744
Denton	1.5%	2.4%	18%	81%	7,923,831
Tarrant	6.9%	6.5%	11%	72%	24,238,197

County-level activity was then calculated from the county-level population multiplied by the activity rate data provided in Table 3-5. The results of these calculations are summarized in Table 3-10. Included in this table is the percent of the total equipment population commercially owned. The range of 11 to 22 percent shows that the county variability is significant. With respect to activity contributions, the commercial component produces between 72 and 85 percent of the activity. The importance of commercial activity is clearly demonstrated in this example.

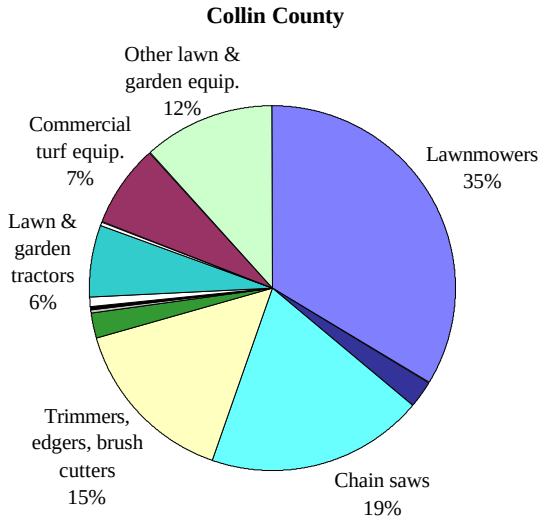

Figure 3-3. Proportion of activity by equipment type in Collin County estimated in the example application

As a final summary, the relative activity data for Collin County by equipment type are shown in Figure 3-3. These data show that lawnmowers and chain saws are the largest sources of activity in this county. It is also interesting to compare these data with those included in the technical background (Figures 2-2 and 2-3).[11]

[11]Note that in this comparison, the data shown in this example are not adjusted seasonally, whereas the data in the background section were.

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4
REFERENCES

Booz, Allen & Hamilton. 1991. *Technical Support Document for California Exhaust Emission Standards and Test Procedures for 1994 and Subsequent Model Year Utility Lawn and Garden Equipment Engines*. Attachment C of CARB mail-out #92-02. Prepared for the California Air Resources Board.

CARB. 1995. *Emission Inventory Procedure Manual, Volume III: Methods for Assessing Area Source Emissions.* Prepared by the California Air Resources Board.

Causley, M.C., C.K. Steiner, L. Gardner, J.P. Cohen, and G. Yarwood. 1995. *Bottoms-Up Emission Inventory Development for Selected Source Categories in the Houston/Galveston and Beaumont/Port Arthur Areas*. Final Report. Prepared for the Texas Natural Resource Conservation Commission. SYSAPP95-94/120.

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Jack Faucett Associates. 1992. *Small Nonroad Engine and Equipment Industry Study*. Final Report. Prepared for U.S. Environmental Protection Agency. 420/R-93-002.

Puri Ph.D., A.K. and R.A. Kleinhenz. 1994. *A Study to Develop Projected Activity for Non-Road Mobile Categories in California*. Final Report. Prepared for the California Air Resources Board. Contract No. 92-732.

Sierra Research, Inc.. 1993. *Evaluation of Methodologies to Estimate Nonroad Mobile Source Usage.* Prepared for the U.S. Environmental Protection Agency. 420/R-93-003.

US Census Bureau. 1996. *County Business Patterns 1994.* Prepared by the U.S. Department of Commerce.

APPENDIX A
LITERATURE REVIEW

LITERATURE REVIEW

The following documents which pertain to estimates of lawn and garden equipment activity levels were reviewed:

1. *Methodology To Estimate Nonroad Equipment Populations By Nonattainment Area,* (Energy and Environmental Analysis. 1991).

2. *Nonroad Engine and Vehicle Emissions Study* (NEVES), (EPA Office of Mobile Sources. 1991).

3. *Procedures for Emission Inventory Preparation, Volume IV: Mobile Sources.* (EPA. 1992b).

4. *Regulatory Impact Analysis and Regulatory Support Document: Control of Air Pollution; Emission Standards for New Nonroad Spark Ignition Engines (less than 19 KW),* (EPA. 1995).

5. *Technical Support Document for California Exhaust Emission Standards and Test Procedures for 1994 and Subsequent Model Year Utility Lawn and Garden Equipment Engines,* (Booz, Allen & Hamilton. 1991).

6. *Small Nonroad Engine and Equipment Industry Study,* (Jack Faucett Associates. 1992).

7. *Evaluation of Methodologies to Estimate Nonroad Mobile Source Usage,* (Sierra Research, Inc.. 1993).

8. *A Study to Develop Projected Activity for Non-Road Mobile Categories in California,* (Puri Ph.D., A.K. and R.A. Kleinhenz. 1994).

9. *Bottoms-Up Emission Inventory Development for Selected Source Categories in the Houston/Galveston and Beaumont/Port Arthur Areas, (*Causley, M.C., C.K. Steiner, L. Gardner, J.P. Cohen, and G. Yarwood. 1995).

10. *User's Guide to the Urban Airshed Model, Volume IV: User's Manual for the Emissions Preprocessor System 2.0, (*EPA. 1992a).

11. *Emission Inventory Procedure Manual, Volume III: Methods for Assessing Area Source Emissions, (*CARB. 1995).

Of these, the first three represent the current EPA emission inventory guidelines and are reviewed together. Subsequently, the remaining eight are discussed individually

EPA EMISSION INVENTORY GUIDELINES

Currently, the EPA's guidance for preparing nonroad mobile source emission inventories is contained in Procedures for Emission Inventory Preparation - Volume IV: Mobile Sources and in Nonroad Engine and Vehicle Emissions Study (NEVES). Additional support information for the NEVES can also be found in Methodology To Estimate Nonroad Equipment Populations By Nonattainment Area. In brief, these guidelines recommend using the NEVES data directly for the 24 metropolitan areas included in the study or by extrapolation for areas not included.

The NEVES was completed in response to a Congressional directive that the EPA quantify the contribution of nonroad sources to air pollution. The NEVES report includes two separate inventories (identified as A and B) for 24 regions for the calendar year of 1990. The original report was later supplemented with data for 9 additional regions. Inventory A was the EPA's best estimate of emissions by metropolitan statistical area (MSA) from state and national level equipment population data (derived from the Power System Research database) using a top-down methodology. Inventory B was developed by augmenting Inventory A with local engine and equipment activity and population data supplied by manufacturers where available. Only emission totals are reported for Inventory B; details of the manufacturer data submissions are not publicly available except for what is included in the documentation. The EPA recommends using the average of the A plus B inventory, but also permits the use of either Inventory A or B. Currently, most metropolitan regions are using the average A/B inventory; however, some regions are using Inventory A because of the ability to reproduce the estimated emissions.

In the NEVES, lawn and garden nonroad populations are defined at the regional level using the combined surrogates of county-level single-family housing units and landscape/horticulture service employees. Although the study assumes a uniform proportion of equipment types and commercial/private usage throughout the U.S., these two surrogates are suitable for separately estimating local populations for private and commercial lawn and garden equipment populations as they are directly related to usage. Thus, regional variation of equipment types is not accounted for (e.g., the fraction of lawn and garden activity associated with the private use of chain saws in the same in New York City as it is in Seattle). Table A-1 shows the 1990 national lawn and garden equipment population data from the NEVES. The distribution of equipment shown in Table 4-1 is that which was used in all nonattainment regions.

Total annual activity of lawn and garden equipment was originally estimated for six regions (Northeast, Southeast, Great Lakes, Southwest, Northwest and West Coast). Two additional regions were later defined. The "Rocky Mountain" region was estimated from the average of the Great Lakes and the Northwest, and the "Mid-Atlantic" region was estimated from the average of the Northeast and Southeast regions. In some cases, the assignment of cities to regions produced questionable results. For example, St. Louis (in the Great Lakes region) is assumed to have less

lawn and garden activity than Denver (in the Rocky Mountains region) even though St. Louis is more temperate (based on the number of heating degree days) and receives more than twice as much precipitation.

For the purposes of seasonal allocation, the nation was divided into three regions based on mean January temperatures of cold (less than 35 ^{o}F), medium (35 to 45 ^{o}F), and warm (more than 45 ^{o}F). For cold, medium and warm regions, the summer season percent of annual activity was assumed to be 50, 40 and 34 percent, respectively. For all three regions, winter season activity was estimated at 6 percent of the annual total.

REGULATORY IMPACT ANALYSIS AND REGULATORY SUPPORT DOCUMENT: CONTROL OF AIR POLLUTION; EMISSION STANDARDS FOR NEW NONROAD SPARK IGNITION ENGINES (LESS THAN 19 KW)

This document represents the EPA's technical support material for new emission standards of nonroad spark ignition (gasoline powered) engines with a rated power at or below 19 kilowatts. Most lawn and garden equipment are covered by these regulations. Notable in this document is that emissions are estimated for commercial and private applications separately. This was done because the relatively high rate of commercial usage results in a relatively quick fleet turnover translating into a greater number of new engines meeting lower emission standards being introduced to the fleet. Thus to accurately assess the regulation, it was important to assess private and commercial usage separately. Useful data and information in this report include historic sales data by application (private or commercial) and equipment, sales projections, attrition data by application and equipment, and annual activity by application equipment. These data represent national average estimates. There are no data reporting regional or seasonal variation.

TECHNICAL SUPPORT DOCUMENT FOR CALIFORNIA EXHAUST EMISSION STANDARDS AND TEST PROCEDURES FOR 1994 AND SUBSEQUENT MODEL YEAR UTILITY LAWN AND GARDEN EQUIPMENT ENGINES

This study was completed in 1990 by Booz, Allen and Hamilton for the California ARB in support of California regulatory development. California lawn and garden equipment activity and emissions were estimated for commercial and private applications separately. The three-step process by which activity levels were estimated consisted of (1) estimate the California percent of national sales, (2) estimate the percent of commercial and consumer sales, (3) estimate commercial and private populations from sales and attrition data.

Useful data and information from this study include seasonal variation of private usage based on survey data (collected in a previous study), proportions of consumer and commercial sales, annual activity by application and equipment type, and equipment attrition. It is also noteworthy to mention that there was considerable variation among data sources sited for information. For example, three separate estimates for private chainsaw usage were sited — 7, 10 and 25.6 hours per year. This demonstrates the uncertainty that exists in these estimates.

SMALL NONROAD ENGINE AND EQUIPMENT INDUSTRY STUDY

This study was completed in 1993 by Jack Faucett Associates to examine the small nonroad engine and equipment industry for the U.S. EPA. It does not contain too much information related to lawn and garden equipment activity. There is some historical national sales data by equipment and fuel type and some discussion of usage by equipment type.

EVALUATION OF METHODOLOGIES TO ESTIMATE NONROAD MOBILE SOURCE USAGE

This study was completed in 1993 by Sierra Research, Inc. for the U.S. EPA to review the NEVES and to recommend potential alternatives. For lawn and garden equipment, the primary criticisms of the NEVES were the coupling of commercial and private applications and the use of the same equipment mix throughout the U.S. As an alternative top-down approach, Sierra suggested allocating equipment and usage based on residential lot size. Moreover, Sierra suggests that a bottoms-up approach would be labor prohibitive, and instead suggested additional surveying of equipment manufacturers. Data needs identified were (1) equipment population and sales by residential and commercial applications, (2) annual activity by application and region, and (3) equipment distributions as a function of lot size.

A STUDY TO DEVELOP PROJECTED ACTIVITY FOR NON-ROAD MOBILE CATEGORIES IN CALIFORNIA

This study was completed in 1994 by the California State University at Fullerton for the California ARB. The purpose was to develop county-level growth surrogates for nonroad sources in California by statistically deriving projection factors based on historical and economic data. For private and commercial lawn and garden usage, the study recommends using housing units and construction valuation, respectively, for the projection of activity. The projection of construction valuation was determined from examining the relationship between historic construction valuation and household growth.

The use of housing units as an indicator of private usage is a reasonable surrogate and is commonly used (some studies use single family housing units instead of total units). However, the use of construction valuation is unique to this study and may be questionable. For example, it follows that increases in construction would result in increased demand for commercial lawn and garden activity; however, if construction valuation increases by 50 percent over a given period,

this would not necessarily translate into a 50 percent increase in commercial lawn and garden activity.

BOTTOMS-UP EMISSION INVENTORY DEVELOPMENT FOR SELECTED SOURCE CATEGORIES IN THE HOUSTON/GALVESTON AND BEAUMONT/PORT ARTHUR AREAS

This study was completed in 1995 by Systems Applications International (SAI) for the Texas Natural Resource Conservation Commission (TNRCC). SAI examined several sources using surveys and other locally derived sources for a bottoms-up estimation of emissions. Included in this study were commercial and residential lawnmowers. Private activity was determined from a telephone survey of homeowners by random selection of residential phone numbers. Commercial activity was determined from surveying business selected from business listings. Concerns with this study include the timing (surveys were completed while the region was experiencing an exceptional flooding event) and question format (e.g., asking how long does it take the operator to mow the lawn instead of how long does the lawnmower run when mowing the lawn).

Useful information from this study includes the survey-derived activity estimates by commercial and private usage as well as monthly, day-of-week, and hourly activity profiles. Tables A-2 and A-3 present the day-of-week and monthly activity distributions, respectively, for private and commercial usage. Although the distribution of activity generally follows expectations, there are some noteworthy observations: (1) Friday has higher private activity than Sunday, (2) a significant amount of commercial usage (20%) occurs over the weekend, and (3) the monthly profile of private usage is strongly affected by the seasons, whereas, commercial usage is nearly constant throughout the year.

USER'S GUIDE TO THE URBAN AIRSHED MODEL, VOLUME IV: USER'S MANUAL FOR THE EMISSIONS PREPROCESSOR SYSTEM 2.0

The Emission Preprocessor System (EPS) to the Urban Airshed Model (UAM) is a widely used tool for emission inventory development for photochemical (ozone) air quality studies. Version 2.0 was developed by SAI in 1992 under the sponsorship of the U.S. EPA. The version of EPS2.0 publicly available includes several modeling default values which are commonly used in inventory development. For lawn and garden activity, EPS2.0 uses the monthly and day-of-week activity profiles shown in Tables A-4 and A-5, respectively. The source of these profiles is not indicated in the model's documentation. Notably, the model uses the same profiles for nonroad lawn and garden activity as it does for construction, agricultural and logging nonroad activity.

EMISSION INVENTORY PROCEDURE MANUAL, VOLUME III: METHODS FOR ASSESSING AREA SOURCE EMISSIONS

This report contains the California ARB's guidelines for area source emission inventory development including lawn and garden equipment. Lawn and garden emissions for the state are based on the 1990 Booz, Allen and Hamilton completed as part of the utility engine regulatory development (described above). Allocation of both commercial and private activity to the county level was completed using the county distribution of single family housing units (SFHUs) with the exception of chain saws. Commercial chain saws were allocated to counties based on board feet of lumber produced and private chain saws were allocated using the number of total SFHUs and SFHUs with wood heating. The documentation describes the activity distribution profiles qualitatively but does not quantify them (e.g., day-of-week "activity is heaviest on weekends for residential and on weekdays for commercial equipment").

Table A-1
1990 National lawn and garden equipment population estimate from the NEVES (EPA, 1991)

Equipment Type	Diesel Powered Population	Gasoline Powered Population	Total Population	Percent Diesel	Percent of Total
Trimmers/Edgers/Brush Cutters	0	18,817,288	18,817,288	0	20
Lawn Mowers	0	35,764,096	35,764,096	0	38
Leaf Blowers/Vacuums	0	2,693,031	2,693,031	0	3
Rear Engine Riding Mowers	4,725	862,015	866,740	1	1
Front Mowers	0	138,685	138,685	0	0
Chain saws < 4 HP	0	16,689,033	16,689,033	0	18
Shredders < 5 HP	0	107,322	107,322	0	0
Tillers < 5 HP	0	4,843,782	4,843,782	0	5
Lawn & Garden Tractors	242,840	6,748,253	6,991,093	3	7
Wood Splitters	79	502,181	502,260	0	1
Snowblowers	0	5,145,850	5,145,850	0	6
Chippers/Stump Grinders	17,087	16,368	33,455	51	0
Commercial Turf Equipment	88,049	480,481	568,530	15	1
Other Equipment	180	396,454	396,634	0	0
Total	352,960	93,204,839	93,557,799	0	100

Table A-2
Day-of-week variation of activity from the TNRCC study of lawnmower usage in the Houston area (Causley et. al., 1995)

	Percent of Weekly Activity	
Day of Week	Commercial	Residential
Monday	16	11
Tuesday	16	10
Wednesday	16	11
Thursday	16	15
Friday	16	16
Saturday	10	24
Sunday	10	14

Table A-3
Monthly variation of activity from the TNRCC study of lawnmower usage in the Houston area (Causley et. al., 1995)

	Percent of Annual Activity	
Month	Commercial	Residential
January	9	2
February	9	2
March	7	11
April	7	11
May	7	11
June	10	13
July	10	13
August	10	13
September	8	8
October	8	7
November	8	7
December	9	2

Table A-4
Default day-of-week activity variation of lawn and garden equipment from EPS2.0 (EPA, 1992a)

Day of Week	Percent of Weekly Activity
Monday	16
Tuesday	16
Wednesday	16
Thursday	16
Friday	16
Saturday	11
Sunday	7

Table A-5
Default monthly activity variation of lawn and garden equipment from EPS2.0 (EPA, 1992a)

Month	Percent of Annual Activity
January	1
February	3
March	4
April	7
May	13
June	13
July	13
August	13
September	13
October	11
November	7
December	1