IMPROVING LOCAL AIR EMISSIONS INVENTORIES FROM NONROAD SOURCES

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26 November 2002

TABLE OF CONTENTS

Page

TABLES

FIGURES

EXECUTIVE SUMMARY

This report outlines past work and presented new approaches to revising nonroad (off-road) emissions estimates for regional areas. The current nonroad emission estimates used by most planning agencies have relied on the NONROAD model for most categories and specific local estimates for aircraft, commercial marine, locomotive, and often airport ground support equipment. The purpose of this report is to describe the available data and methods to generate better local nonroad activity estimates.

The approach used in the NONROAD model and in current estimates for aircraft, commercial marine vessels, and locomotives to estimate and distribute emissions in each equipment category was outlined followed by a description of ideas for improving the overall emission inventory or specific elements or input variables taken from references or suggested in this report. A summary of the proposed approaches is shown in Table ES-1.

Table ES-1. Suggested revised approaches by nonroad category and input estimate.

Nonroad Category\ Input Estimate	Equipment Population	Activity (hours and load)	Spatial Allocation	Temporal Allocation	Category Fuel Consumption
Agriculture	Census estimates; Irrigation pumps counts	Survey; instrumented equipment	Harvested Acreage (by crop type); Irrigated Acreage	Activity by Crop type; Survey	DOE – EIA; State fuel tax info.
Aircraft	Survey airports	Time in mode estimates from databases and survey	By airport LTO by aircraft type	Federal Aviation Administration estimates	Not useful
Constructio n and Mining	Survey	Survey; use current surveys; instrumented equipment	Employee or Payroll; Revenue (reported to be unavailable); Permit data	Survey	DOE – EIA; State fuel tax info.
Industrial / Commercial	Survey	Survey; instrumented equipment	Employee or Payroll; Revenue (reported to be unavailable)	Survey	DOE – EIA; State fuel tax info.
Lawn and Garden	Survey; residential or commercial operators	Survey; residential or commercial operators; instrumented equipment	Land use (lawn or managed area); Employee or Payroll or Revenue (reported to be unavailable) for commercial users	Survey	Survey
Locomotive	Survey or Link level analysis	Survey; Grade crossings	Ton-mile activity; Survey	Survey	DOE – EIA; Survey
Recreational marine	Registration	Survey; instrumented equipment	Revised water surface allocation; Survey	Survey	Survey; historic surveys used in default approach
Shipping (Commercia l marine)	Army Corps and Coast Guard data and fuel tax revenue	---	Army Corps calls and lock data	Army Corps data by waterway	TVA Fuel tax revenue estimates

For each category listed in Table ES-1, a description is provided of the methods currently used to create local emissions inventories, adjustments that have been developed by local agencies, and what methods might be investigated. Excepting spatial allocation methods, the improved estimates would heavily rely on resource intensive survey methods. These survey methods are described in detail, outlining the universe of equipment owner/operators and the recommended structure of the survey.

Table ES-2 lists the practical suggested projects to improve the nonroad emissions inventory. The text of the report outlines a number of other potential projects, but such other suggestions have either not been attempted before or have not been well defined. Each project described in Table ES-2 has been more fully described in the report. For each project, the importance of the project to the emission inventory or our understanding of its effect on air quality is estimated. The possible change to the state or regional inventory is provided, though the actual change to the inventory would depend upon the results of the study. Lastly, the expected cost has been given as an estimate of the number of hours required to complete such a study for each State, because State employees may perform some or all of the work. In some cases, additional resources may need to be purchased (databases or other tools) to complete the study but typically are a fraction of the overall cost of performing the work.

Table ES-2. Proposed practical projects for revising nonroad equipment inventories.

Nonroad Category	Project	Importance	Possible Change	Cost*
Agriculture	Census estimates	Large on a statewide basis	Could be significant (Illinois example in report)	Low
Agriculture	Temporal and Spatial Allocation Using Crop Type Surrogate	Small	Larger temporally than spatially	Low
All	DOE/EIA State fuel tax information – Energy balance check on diesel nonroad activity	Large	Could be significant	Low
All	Finer spatial resolution using local spatial surrogates	Small	Redistribute current inventory	Medium
Aircraft	Aircraft emissions estimates using detailed LTO by airframe for all airports	Small statewide; medium in metro areas	Medium significance	Low
Construction and Mining	Survey	Large	Significant	High
Industrial / Commercial	Survey; risky and not well defined	Medium; large in metro areas	Significant	High
Lawn and Garden	Survey; residential or commercial operators	Large	Medium significance	Medium
Locomotive	Survey of railways	Large	Small; more appropriate estimates of switching activity	Medium
Locomotive	Link level; Grade crossings; risky study	Large	Independent, large, and spatially resolved	High
Recreational marine	Registration data mapped to vessel type	Medium	Small, not spatially resolved	Low
Recreational marine	State phone survey method	Medium	Medium and spatially resolved	Medium
Recreational marine	Spatial allocation method ground truthed with small targeted surveys	Small	Spatially resolved	Low

Nonroad Category	Project	Importance	Possible Change	Cost*
Shipping (Commercial marine)	Port Calls, Army Corps, Coast Guard and TVA fuel use data	Large for metro areas	Spatially resolved; and most cost associated with smaller sources	Medium

* - Cost; Low – 100(s) hours per state; High - 1,000(s) hours per state

1. INTRODUCTION

This report outlines past work and presents new approaches to revising nonroad (off-road) emissions estimates for regional areas. The current nonroad emission estimates used by most planning agencies have relied on the NONROAD model for most categories and specific local estimates for aircraft, commercial marine, locomotive, and often airport ground support equipment. The purpose of this report is to describe the available data and methods to generate better local nonroad activity estimates.

The NONROAD emissions model, currently available in draft form on the NONROAD web page at http://www.epa.gov/otaq/nonrdmdl.htm, describes most types of nonroad equipment. Although the model is in draft form and is still evolving, it has been used to develop the NEI99 (http://www.epa.gov/ttn/chief/net/index.html) nonroad emissions estimates, and EPA has accepted recent SIP modeling efforts using the NONROAD model estimates. At the time of this report, the most recent draft model on the NONROAD web page was the June 2000 version. However, EPA is expected to release a new version of the model with significant revisions in emissions estimates from earlier versions, not before Spring of 2003.

The NONROAD includes both emission factors and default county-level population and activity data, and so is used to estimate emissions for traditional off-road sources such as lawn and garden equipment, pleasure craft, construction equipment, and agricultural equipment. The original model development and technical approach was outlined in a conference paper written by ENVIRON staff (Pollack and Lindhjem, 1997); complete and detailed technical descriptions of all aspects of the model can be found on the EPA NONROAD web page.

The NONROAD model estimates emissions for six exhaust pollutants: hydrocarbons (HC), NO_X, carbon monoxide (CO), carbon dioxide (CO_2), sulfur oxides (SO_X), and PM. The user selects among five different types for reporting HC — as total hydrocarbons (THC), total organic gases (TOG), non-methane organic gases (NMOG), non-methane hydrocarbons (NMHC), or volatile organic compounds (VOC). Particulate matter can be reported as total PM, PM of 10μ or less (PM_{10}), or PM of 2.5μ or less ($PM_{2.5}$). The model also estimates emissions of non-exhaust HC for six modes — hot soak, diurnal, refueling, resting loss, running loss, and crankcase emissions.

The NONROAD model provides emission estimates at the national, state, and county level. County level emissions are determined by allocating the state level estimates with econometric or other activity indicators, such as employees, tilled acreage, and construction valuation. The NONROAD model also provides emission estimates annually or temporally allocated by month or average monthly day of week.

The NONROAD model incorporates the effects of the emission standards through a dynamic age distribution calculation. The national non-road emission standards included in the model are:

- Diesel engines
- Small gasoline engines (handheld and nonhandheld equipment $<$25 hp)

- Recreational marine gasoline engines
- Recreational and commercial marine diesel engines

A recently adopted large spark-ignition (gasoline, LPG, and CNG) engine rule (including those used in recreational vehicles) is expected to be included in the soon-to-be-released version of the NONROAD model. When the current draft was released, these rules were not included in the emissions factors because proposed rules typically are not included until issued as final rules.

The NONROAD model includes more than 80 basic and 260 specific types of nonroad equipment, and further stratifies equipment types by horsepower rating and fuel type, in the following categories:

- airport ground support, such as terminal tractors;
- agricultural equipment, such as tractors, combines, and balers;
- construction equipment, such as graders and back hoes;
- industrial and commercial equipment, such as fork lifts and sweepers;
- recreational vehicles, such as all-terrain vehicles and off-road motorcycles;
- residential and commercial lawn and garden equipment, such as leaf and snow blowers;
- logging equipment, such as shredders and large chain saws;
- recreational marine vessels, such as power boats;
- underground mining equipment; and
- oil field equipment.

The basic equation for estimating emissions in the NONROAD model is as follows:

$$Emissions = (Pop)(Power)(LF)(A)(EF)$$

where

Pop = *Engine Population*
Power = *Average Power (hp)*
LF = *Load Factor (fraction of available power)*
A = *Activity (hrs/yr)*
EF = *Emission Factor (g/hp-hr)*

The national or state engine population is estimated and multiplied by the average power, activity, and emission factors. National average engine power, load factor (the relative fraction of maximum available power that engine use on average), annual activity, and emission factors are estimated and used to calculate the national yearly emissions. (Typical NONROAD estimates of equipment population by power level were derived from Power Systems Research (PSR), a marketing research firm). Equipment population by county is estimated in the model by geographically allocating national engine population through the use of econometric indicators, such as construction valuation. The manner in which the geographic allocation is performed is as follows:

$$(County\ Population)_i\ /(National\ Population)_I = (County\ Indicator)_i\ /(National\ Indicator)_i$$

where" i" is an equipment application like construction or agriculture.

NONROAD activity is temporally allocated using a similar equation as for geographic allocation through the use of monthly, and day of week fractions of yearly activity.

The NONROAD model has default estimates for all variables and factors used in the calculations. All of these estimates are in model input files, and can be changed by the user if data more appropriate to the local area are available. For example, if construction equipment surveys are used to gather local population and activity estimates, these can be input to the model for improved local emissions estimates.

It is helpful to remember that the nonroad activity estimates in NONROAD are a combination of equipment population, rated power of that equipment, hours of use, and average in-use load. These four input values (using the engine efficiency) can be compared with fuel consumption estimates if available, and may be addressed individually or in combination with one another.

For aircraft, commercial marine, and locomotive, national and locally specific activity or fuel consumption data has been used to determine the emissions for these categories.

The improvements addressed in this report include a number of input estimates used in the NONROAD model and addresses aircraft, commercial marine, and locomotive estimates separately. These input variables may be addressed uniquely or in combination with other estimates.

1. Equipment population
2. State-to-county spatial allocation
3. Fuel usage (an activity indicator)
4. Load
5. Hours/day of usage
6. Seasonal and day-of-week variability

The nonroad categories reviewed in this report are listed below by pollutant to which they primarily contribute. Small gasoline engines contributed a greater fraction of the VOC emissions, while large diesel engines are more important to NOx and PM emissions.

<u>VOC Categories</u>
Recreational marine
Lawn and Garden
Aircraft (Commercial, recreational, and military)

<u>NOx and PM Categories</u>
Agricultural equipment
Construction equipment
Industrial\commercial equipment
Locomotives (Switching and Line-haul)
Shipping (Large, barge, dredge, ferries, and commercial fishing)

These categories were mainly chosen for their importance to the urban air quality as shown in Table 1-1 for Illinois State and Table 1-2 for Wisconsin. The 8 chosen categories include more than 95% of the NOx, 85% of the PM2.5, and 60% of the VOC emissions from nonroad equipment. Recreational equipment and logging (for Wisconsin and Michigan especially) represent the next two most important categories omitted in this study, and their activity would typically be associated with rural counties.

Table 1-1. Illinois 1999 annual nonroad emissions (tons/year) (NEI, 1999).

Nonroad Category	VOC	NOx	PM2.5
Agricultural Equipment	8,115	68,123	3,736
Aircraft	1,706	5,040	119
Airport Ground Support Equipment	142	695	75
Commercial Marine	1,253	27,722	2,436
Construction and Mining Equipment	8,193	43,857	4,210
Industrial\Commercial Equipment	12,334	33,480	2,332
Lawn and Garden Equipment	36,083	6,765	1,253
Locomotives	2,418	63,079	1,383
Logging Equipment	109	20	8
Railway Maintenance	67	305	33
Recreational Equipment	18,691	842	246
Recreational Marine	8,366	538	351

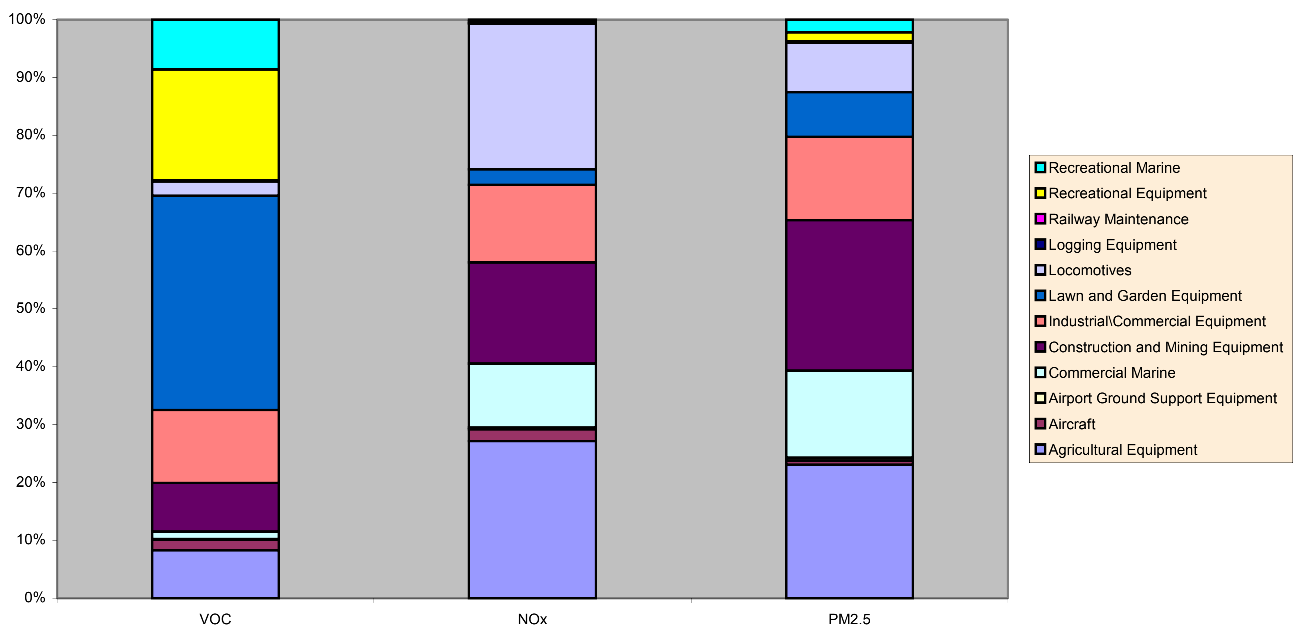

Figure 1-1. Illinois Nonroad Source Emission Inventory (NEI, 1999)

Table 1-2. Wisconsin 1999 annual nonroad emissions (tons/year) (NEI, 1999).

Nonroad Category	VOC	NOx	PM2.5
Agricultural Equipment	3,275	27,551	1,510
Aircraft	402	731	78
Airport Ground Support Equipment	14	71	8
Commercial Marine	352	7,577	701
Construction and Mining Equipment	4,054	21,699	2,081
Industrial\Commercial Equipment	5,303	17,404	1,113
Lawn and Garden Equipment	18,039	2,667	522
Locomotive	888	23,180	508
Logging Equipment	10,663	1,885	743
Railway Maintenance	29	133	15
Recreational Equipment	45,303	1,434	695
Recreational Marine	39,470	2,644	1,704

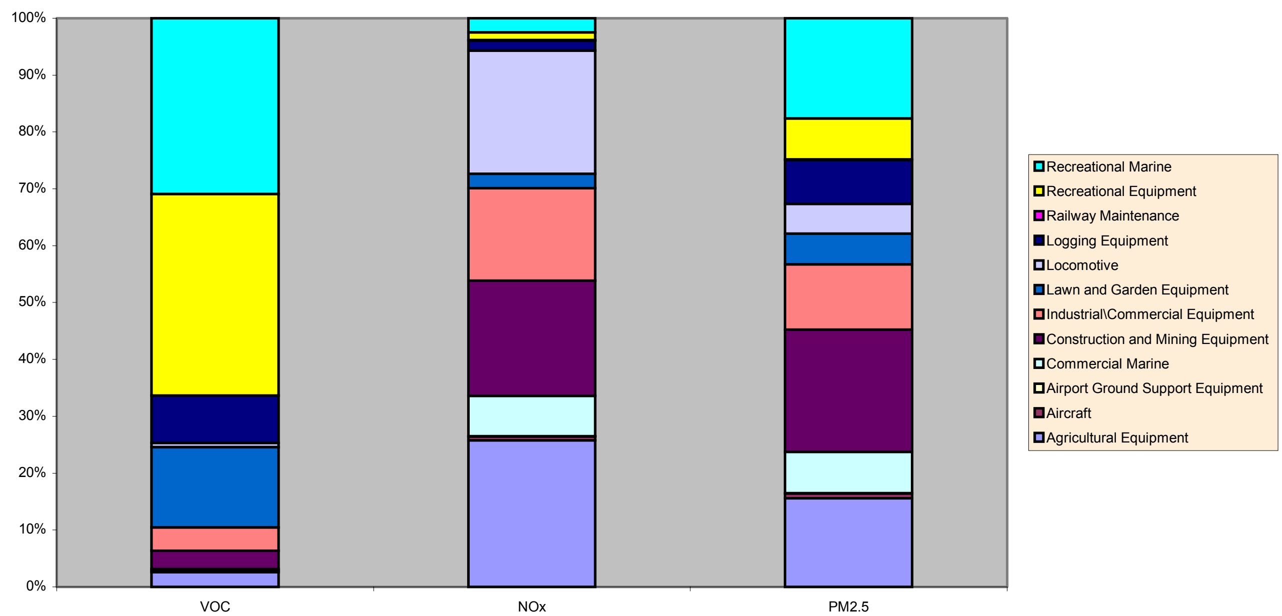

Figure 1-2. Wisconsin Nonroad Source Emission Inventory (NEI, 1999)

The approach used in the NONROAD model and in current estimates for aircraft, commercial marine vessels, and locomotives to estimate and distribute emissions in each equipment category is outlined followed by a description of ideas for improving the overall emission inventory or specific elements or input variables taken from references or suggested in this report. A summary of the proposed approaches is shown in Table 1-3.

Table 1-3. Suggested revised approaches by nonroad category and input estimate.

Nonroad Category\ Input Estimate	Equipment Population	Activity (hours and load)	Spatial Allocation	Temporal Allocation	Category Fuel Consumption
Agriculture	Census estimates; Irrigation pumps counts	Survey; instrumented equipment	Harvested Acreage (by crop type); Irrigated Acreage	Activity by Crop type; Survey	DOE – EIA; State fuel tax info.
Aircraft	Survey airports	Time in mode estimates from databases and survey	By airport LTO by aircraft type	Federal Aviation Administration estimates	Not useful
Construction and Mining	Survey	Survey; use current surveys; instrumented equipment	Employee or Payroll; Revenue (reported to be unavailable); Permit data	Survey	DOE – EIA; State fuel tax info.
Industrial / Commercial	Survey	Survey; instrumented equipment	Employee or Payroll; Revenue (reported to be unavailable)	Survey	DOE – EIA; State fuel tax info.
Lawn and Garden	Survey; residential or commercial operators	Survey; residential or commercial operators; instrumented equipment	Land use (lawn or managed area); Employee or Payroll or Revenue (reported to be unavailable) for commercial users	Survey	Survey
Locomotive	Survey or Link level analysis	Survey; Grade crossings	Ton-mile activity; Survey	Survey	DOE – EIA; Survey
Recreational marine	Registration	Survey; instrumented equipment	Revised water surface allocation; Survey	Survey	Survey; historic surveys used in default approach
Shipping (Commercial marine)	Army Corps and Coast Guard data and fuel tax revenue	---	Army Corps calls and lock data	Army Corps data by waterway	TVA Fuel tax revenue estimates

Only recreational marine equipment is typically registered, so the most important estimates, equipment population, will likely rely on a survey to revise the current information unless the State begins to register such equipment. Likewise activity (hours of use and engine load) would rely on surveys of owner/operators. Activity surveys could include instrumented equipment studies using Portable Activity Monitors (PAM) or Portable Emissions Monitors (PEM), which form the basis for EPA planned improvements in future emissions models (http://www.epa.gov/otaq/ngm.htm). Surveys are difficult to perform and are therefore resource intensive. Also, with surveys there is the concern of biased surveys by contacting unrepresentative owners, and in the case of surveys of equipment population the bias is likely to be low because it is difficult to identify all types of equipment owners.

The purpose of this report was to address state to county allocation primarily, but approaches that utilize more refined spatial allocation surrogates could be addressed as well to improve county level or finer resolution. The current spatial allocation methods of state- or county-level emissions have been accomplished with the aid of spatial surrogate data for each emission source category or groups of source categories. Spatial surrogates are typically based on the proportion of a known region-wide characteristic variable which exists within the region for which the emission estimates are desired, typical counties or modeling domain grid cells (e.g. land use categories, population, socioeconomic data, etc.). The development of an accurate spatially resolved emission inventory at any particular spatial resolution requires surrogate data of comparable resolution. In addition, in the case of land use data, the ability to distinguish between various land cover characteristics is necessary to properly allocate the state- or county-level emission estimates for certain source categories. For off-road mobile source emissions, geospatial data describing transportation networks may be required, particularly for locomotive and commercial marine emission sources. Other desirable features of the underlying surrogate databases are the currentness of the data (i.e., for what year are the data based on and how often are they updated) and the availability and quality of the data. Table 1-4 provides a sample of the types of surrogate indicators commonly used for various area and mobile emission source categories.

Table 1-4. Commonly used surrogate indicators for selected emission source categories.

Source Category	Activity Surrogate	Spatial Surrogate
Lawn & Garden Equipment Residential	Number of Residential Housing units	Urban Residential Housing
Lawn & Garden Commercial	Number of Employees in Landscape/Horticulture Services	Residential Housing, Urban Landscape (Parks, Cemeteries, Golf Courses, etc.)
Construction Equipment	Total dollar Value of Construction	Urban Areas
Agricultural Equipment	Harvested Cropland	Agricultural Lands
Recreational Marine	Modified Water Surface Area	Modified Water Surface Area
On-road Mobile (including Off-road Street Sweepers)	Link-based VMT	Various transportation networks

There are numerous geospatial databases available from a variety of sources that could be used to further improve the spatial allocation of state-level emission estimates to the county-level, and several specific to off-road equipment categories are outlined in the following chapters. These datasets provide for various spatial resolutions and geographic extent and include a wide variety of features such as land use/land cover (LULC) classifications, transportation network line coverages, and polygon and point locations of features such as airports, oil fields and production wells, and urban landscape features among others. In addition, special study datasets are often available from state and local agencies and planning organizations.

The spatial allocation for many emission source categories can be modified by the estimates thought to be associated with the equipment activity or through direct surveys. Historic estimates have often included employees (for construction and mining, industrial\commercial, and commercial lawn and garden categories), but headquarters staff and other similar issues may skew employee data with respect to spatial allocation. Revenue data might be used but the States (Wisconsin and Michigan) responding to our inquiries maintain that such data is unavailable, though the State of Texas was able to obtain just such information from their State Comptroller.

Several Land Use/Land Cover (LULC) databases are available which may provide the detail necessary to improve the spatially allocation of certain emission sources that have traditionally been associated with economic indicators. These source categories include, among others, lawn and garden equipment, construction and mining, and commercial and recreational marine. Selected LULC databases include the USGS 1:100,000 (200meter) scale resolution data (www.epq.gov/ngisgm3/spdata/EPAGIRAS) and the nation-wide spatial surrogate database developed by the EPA (ftp://ftp.epa.gov/EmisInventory/emiss_shp). In the case of construction and mining, the USGS 1:100,000 scale LULC database often provides enough detail to spatially locate strip mines, quarries and gravel pits for the allocation of emissions associated with these activities. This database also distinguishes among the various urban land uses, including residential, commercial, industrial, and transportation/communication/utilities. These data could be used for the spatial allocation of certain construction and industrial/commercial equipment, thus providing improvements for over the traditional population and/or economic indicators. Likewise, these LULC databases typically distinguish among specific agricultural crops and so the allocation of agricultural equipment emissions can be improved by treating them on a crop-specific basis. State and local agricultural agencies may also have access to geospatial databases that can provide this required detail.

Transportation networks, including inland waterways and ports, available from the US Census Bureau in the form of TIGER/Line files (www.census.gov/geo/www/tiger/tigerua/), compatible with most geographic information systems (GIS), can be used for recreational and commercial marine emission source categories. In combination with Army Corps data and local survey information, improvements for these emission sources can be achieved using the detailed spatial data from the TIGER/Line data files. Spatial allocation of locomotive emissions can also take advantage of these databases to further refine locational characteristics of railways, spur lines and railyards. These data also often provide details concerning the urban landscape (e.g. parks, cemeteries, and golf courses, etc.) which can be used for the lawn and garden source categories, both residential and commercial.

Overall nonroad equipment activity (equipment population combined with individual equipment activity) may be estimated or verified through fuel consumption estimates by nonroad category. For instance, diesel fuel consumption has historically been available at the State level from annual surveys by the Department of Energy's Energy Information Administration (DOE-EIA) (http://www.eia.doe.gov/oil_gas/petroleum/info_glance/distillate.html). Kean et al. (2000) have used the DOE-EIA survey results to estimate overall diesel nonroad equipment activity by category. The DOE-EIA categories do not necessarily match the EPA nonroad categories (for instance, DOE-EIA considers mining an industrial activity instead of construction). Also, DOE-EIA may not entirely account for highway diesel fuel use in nonroad equipment, but State fuel tax rebates for highway fuel used in nonroad engines (available according to John Nordlie, Excise Tax Section Chief, State of Wisconsin) may provide a means to account for this use, however not all companies may apply for a tax rebate.

Because highway vehicles are registered and monitored and stationary sources are permitted, other emission sources are considered to be more accurately determined than nonroad activity, and many of the survey approaches suggested in this report (as with all surveys) may be questioned for accuracy. Other options to improve these estimates have been suggested but were not investigated in this report. A registration program for nonroad equipment would produce more accurate information than is commonly available, but is outside the scope of this work. Another option is to explore the financing arrangements of larger equipment and some financial databases may be commercially available, but a large fraction of owners may internally finance their equipment including public entities. Also, not investigated in this report was to investigate the States' tax structure; States (Texas is an example) are known to tax businesses according to their investments (for example equipment ownership) or business assets. These sources of information may provide a means to estimate the equipment ownership.

In the following sections, each of the eight nonroad subject categories addressed in this report is described in more detail outlining available information and approaches to improving the local emissions inventories of nonroad equipment.

2. AGRICULTURAL EQUIPMENT

The agricultural sector consists of the equipment types listed and described below in Table 2-1. By far the most important equipment types are agricultural tractors, primarily powered by diesel engines and accounting for over 80% of the THC, NOx, and PM. The agricultural equipment types are used primarily in agricultural production, yet the usefulness of agricultural tractors also extends to construction, landscaping (e.g. large scale mowing), and general-purpose grounds keeping.

Table 2-1. Equipment types and descriptions for agricultural equipment. (xx refers to '60' for 2-stroke gasoline, '65' for 4-stroke gasoline, '70' for diesel, '67' for LPG, 68 for CNG).

SCC	Equipment Type	Definition
22xx005010	2-Wheel Tractors	Walk-behind 2-wheeled tractors for use in edible produce or other intensive farming
22xx005015	Agricultural Tractors	Large and small agricultural tractors, most prevalent farm equipment type
22xx005020	Combines	Self-propelled combined harvesting and cleaning equipment
22xx005025	Balers	Equipment that bales from loose or windrowed hay or other forage mowed crop
22xx005030	Agricultural Mowers	Equipment for mowing not intended for later baling or harvesting
22xx005035	Sprayers	Small (backpack) and large (self-propelled) powered equipment designed specifically for spraying
22xx005040	Tillers > 6 HP	Primarily small tillers similar to those used in lawn and garden applications intended to be used in edible produce or other intensive farming
22xx005045	Swathers	Equipment designed to cut crops for later baling or harvesting including windrowers
22xx005050	Hydro Power Units	Power engines designed to specifically supply hydraulic power; might be misapplied as agricultural equipment
22xx005055	Other Agricultural Equipment	Other various cultivation equipment types and include harvesters or other special cultivating equipment
22xx005060	Irrigation Sets	Agricultural pumps and pivot wheel irrigation equipment to distribute water to fields or livestock.

The NONROAD model has primarily relied on population and activity estimates provided by PSR. The national estimates have been allocated to the county level using Harvested Cropland provided by the Census. (County estimates are summed by State to estimate state equipment population). Temporal allocations were general estimates of national yearly activity.

Alternative Approaches

Census of Agriculture

The population of equipment used on farms is regularly surveyed in the Census of Agriculture and the data includes estimates of various types of farming equipment broken out in power level groupings and by county. A comparison between the equipment counts for Illinois from the latest 1997 Census of Agriculture (the 2002 Census is due in 2003) and those 1998 estimates in the June 2000 draft-NONROAD model are shown in Table 2-2 and are available for all States.

Table 2-2. Comparison of NASS\Draft-NONROAD Illinois farm machinery populations.

Equipment Type	Illinois – NASS, 1997	Illinois – Draft NONROAD, 1998
Ag. Tractors < 40 hp	49,169	21,607
Ag. Tractors 40 – 99 hp	81,493	61,083
Ag. Tractors > 100 hp	69,039	82,957
Combines	37,502	25,011
Mowers and Swathers	17,647	6,567
Balers	21,432	1,702

The Census of Agriculture only polls farms for equipment ownership, so other owners of agricultural equipment (such as construction firms, landscaping –including golf courses and other grounds keeping–, and municipalities) are not included in these estimates. So while the Census provides equipment population estimates in excess of those in NONROAD, it likely undercounted the in-use population for agricultural tractors.

The Census also provided estimates of the harvested cropland, which can be compared with the figures used by EPA in their county allocation. Though likely both are derived from similar data sources.

An alternative approach to the Census figures for in-use population is to use data on historic sales of agricultural equipment available from either of two sources (NASS (2002) and USDA (2002b). The historic sales information can be combined with the estimates of average life and scrappage to estimate the in-use population. However, the historic sales may need to be available for several decades to include all equipment still operating in the field, and the average life and scrappage estimates would introduce uncertainty.

Temporal allocation may be made through the activity associated with the most prevalent crop types used as shown in Table 2-3 for Illinois and county examples of land cover are also available as in Figure 2-1. Agricultural extension services may be able to provide typical equipment activity during each season for each type of crop and certainly harvesting of the more prevalent crop types would likely fall within a prescribed time frame.

Table 2-3. Illinois major agricultural products (USDA, 2002a).

Crop Type	Production (1000 Bushels)	Acres in Production	Trend
Corn	1,688,550	11,050	Increasing
Soy	459,800	10,450	Increasing
Wheat	52,440	920	Decreasing
Hay	2,670,000 tons	850	Decreasing

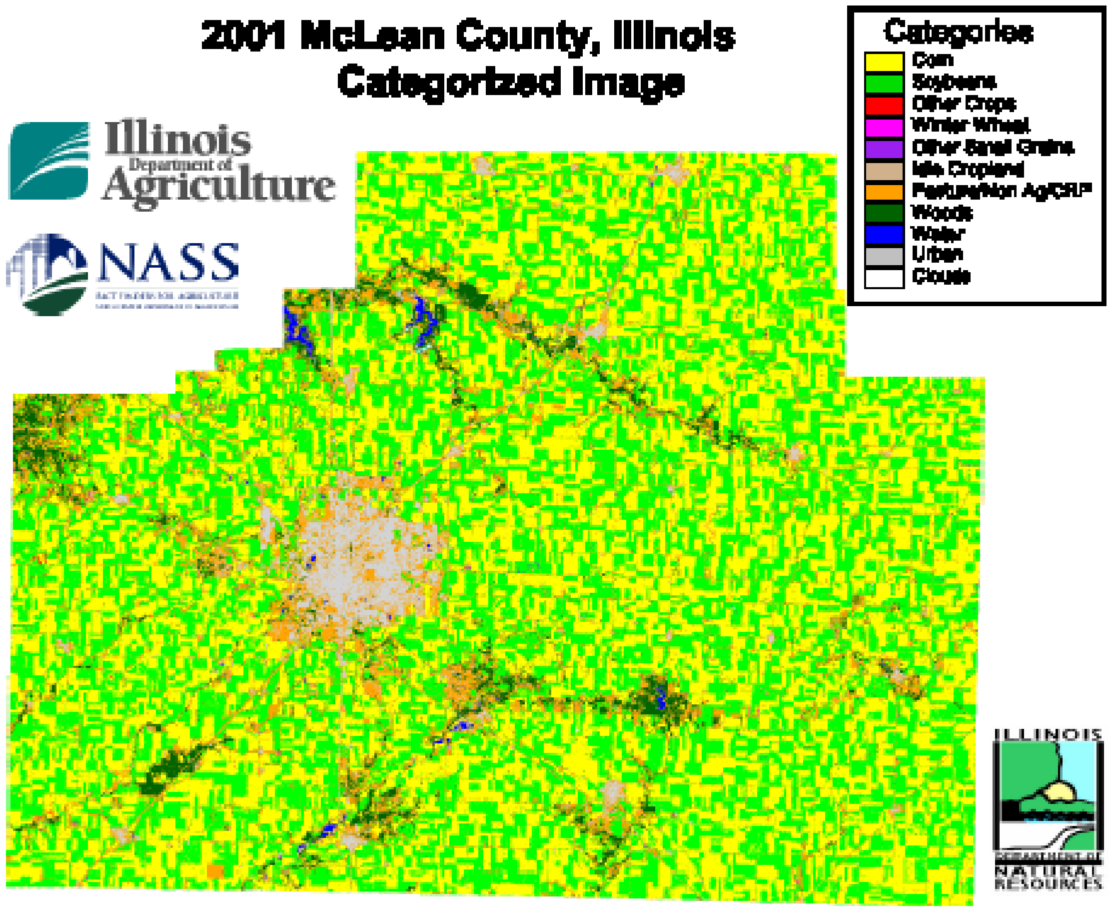

Figure 2-1. Land and crop cover for McLean County, Illinois.

Farm and Ranch Irrigation Survey

For one equipment type, irrigation sets, a specific data source is available (USDA, 2002c) for these equipment types. Irrigation pumps include both the pivot wheeled irrigation systems as well as other types of water pumps. USDA (2002c) provides estimates of in-use population and irrigated acreage allowing for revised in-use populations and\or geographic allocation.

Irrigation pumps are a unique equipment type in that a only fraction of these were considered as mobile sources and included in the NONROAD model with the remainder assumed to be stationary or area sources. Table 2-4 taken from NONROAD documentation (EPA, 1998), indicates the fraction of irrigation sets considered mobile and stationary. Even so, the USDA (2002c) data indicates fewer irrigation pumps, (equaling 2,623), compared with the draft-NONROAD estimate of 3,693 and where the NONROAD estimate includes only engine-powered pumps and not including electric pumps.

Table 2-4. Fraction of semi-stationary nonroad equipment types.

Power Range (Hp)	Percent Mobile Equipment
0 to 25	90
25 to 40	90
40 to 100	70
100 to 175	20
175 to 300	15
300 to 500	10
500+	0

3. AIRCRAFT

Aircraft emissions are comprised of a number of types of aircraft described in Table 3-1 by subcategory. At commercial airports air carrier flights typically are responsible for nearly all of the NOx and most of the VOC; however, piston aircraft, such as most general aviation, often contribute a large fraction or most of the CO. They may also account for significant VOC and PM_{10} emissions, depending upon the airport.

Table 3-1. Aircraft types.

Aircraft Subcategory	Purpose	Engine Type
Air Cargo	Typically included under air carriers	Turbofans
Air Carrier	Scheduled transport >60 seats	Turbofans
Air Commuter	Scheduled transport <60 seats	Turbofans and turboprops
Air Taxis	Unscheduled <60 seats	Turboprops and piston
Military Transport	Self-explanatory	Turbofans and turboprops
Military Combat	Self-explanatory	Turbojets
General Aviation	Miscellaneous non-military, light planes usually	Piston (90-95%), turboprops (3%), turbojets (3%) *

* Statistical Handbook of Aviation

The LADCO region, which includes the states of Illinois, Indiana, Michigan, Ohio, and Wisconsin, contains more than six hundred airfields. These include FAA towered and contracted airports, smaller local general aviation facilities as well as military airbases. While emissions at airports are dealt with in considerable detail within the realm of Environmental Impact Reports and/or Statements (EIR/EIS), they are often treated as point sources within regional emissions inventories. The latter sometimes belies the level of complexity involved in the estimation of aircraft emissions, including their seasonal and temporal allocation. The following discussion summarizes the methodology used to develop the existing aircraft emissions inventories for the LADCO states and suggests alternate approaches to improve specific components of these inventories.

Aircraft emissions currently assumed within the LADCO region are based upon the 1999 National Emissions Inventory (NEI99 v 1.5). According to EPA's documentation (EPA 2001), air carrier emissions were estimated using the latest version of FAA's Emissions and Dispersion Modeling System (EDMS v 4.0) with airframe specific LTO data from *Airport Activity Statistics of Certificated Route Air Carriers* (DOT 2001), an assumed taxi/idle time-in-mode of 26 minutes, and default engine assignments. Where an aircraft was not available in the EDMS database and for foreign carriers, the average of the emission factors for identified aircraft was used. For air taxis, general aviation, and military aircraft activity, the LTO data were taken from the FAA's Air Traffic and Activity Data System (ATADS), which produces total operations at each airport. No airframe details are given (DOT 2001b). EPA fleet average emission factors on a per LTO basis were used.

To identify areas for improvement most effectively, the critical components of the aircraft emissions inventory procedure should be clearly understood. Major factors that affect the magnitude of emission estimates include the number of landing/takeoff cycles (LTOs), the time spent in each of four operating modes (approach, taxi/idle, takeoff, and climbout), and the fleet composition. In addition, the development of modeling emissions inventories relies heavily upon accurate spatial and temporal allocation of the total emissions. While spatial allocation of emissions is fairly straightforward, their seasonal and temporal profiles can be quite involved.

Activity and Fleet Composition

As mentioned above, the current air carrier emissions were derived from detailed FAA activity data. Military bases are not included in this database, and all foreign carriers may not be included. The foreign carriers may be determined by subtracting the domestic carrier operations from the FAA's Terminal Area Forecast (TAF) total at each airport to determine if the foreign carriers had been included; however, these results will not contain aircraft-level details. To determine the fleet composition, the World Jet Inventory can be consulted to derive an average fleet profile for these carriers (JIS 2001). Better still would be contacting the authorities at each airport that has international carrier operations to request carrier-specific LTO data.

Military aircraft operations data are often quite challenging to obtain. In the best scenario, the airbase has contracted a private consultant to develop its emissions inventory, in which case the data are readily available (though not necessarily readily disbursed). In many cases, detailed operational data must be officially requested by the local environmental agency. Emissions from these bases are not trivial, especially if the base serves as a central training facility (such as the Little Rock Air Force Base). Also important in these cases is to identify touch-and-go (T&G) operations, which are characteristic of training facilities and effectively reduce emissions by eliminating taxi/idle times.

Time-in-mode

As noted above, the amount of time spent in each of four basic operating modes, also known as the time-in-mode (TIM), is a critical factor in determining emissions. This is because different levels of thrust are required in each of these modes, resulting in large variations in emission rates. In the case of commercial aircraft, the dominant emitting mode is the taxi/idle mode due to both a higher emission rate and the longest duration. Typically, the emissions from this mode are at least 80% of the total. Another level of complication arises from the fact that different airlines at different airports will have particular taxi/idle TIMs at various times of the year. The Bureau of Transportation Statistics (BTS) maintains a database, which heretofore has been publicly available, that has taxi times by airport by carrier and date. However, these data are available for only about fifty large airports. TIMs for general aviation (GA) and military aircraft are not as readily accessible. For the former, a survey of GA operators at a sample of large and small airfields could yield valuable insight. In the latter case, again the data must be requested for each airbase.

The times-in-mode can also be affected by climate conditions. In particular the mixing height indirectly affects the approach and climbout TIMs since aircraft emissions are counted only if the aircraft is below the mixing height. This depth not only varies during the course of the day (as much as 2000 feet) but also across the seasons (up to about 1000 feet variation). This type of data can be used in conjunction with hourly and seasonal activity profiles to yield more appropriate estimates for each time period. The US EPA maintains a database of mixing heights at http://www.epa.gov/scram001/tt24.htm#mixing. However, these data are not hourly and thus need to be fit to a profile or interpolated using surface meteorological data via software such as PCRAMMET. Alternatively, Rawinsonde data can be used to deduce mixing heights. This route is more cumbersome since software to implement the required algorithms to produce mixing heights is not readily available. Furthermore, these data are collected at relatively fewer stations scattered throughout the US so that airport-specific information may not be available. One final option is to perform meteorological modeling using specialized models such as MM5.

Seasonal and Temporal Allocation

Seasonal variations in aircraft activity are due to several factors including vacationing, holidays and economic incentives. Since ATADS data report monthly LTOs at many large airports, these data are recommended for use to develop seasonal activity profiles. These data can be found at http://www.apo.data.faa.gov/faaatadsall.HTM. Aside from this, the effects of mixing heights should also be considered concurrently when seasonal emissions are estimated.

To establish hourly profiles for aircraft activity, it is oftentimes helpful to identify specific fleets for which operational schedule information is unique and centrally located. One such type of specialized fleet at some airports is that belonging to shipping companies such as FedEx. These fleets typically operate in the night and early morning hours and on set schedules. Data on number and times of departures are usually obtainable by request via the particular airport authority. Commercial air carrier hourly departure data are available for fifty large airports from the FAA's Aviation System Performance Metrics (ASPM) which has access restrictions (http://www.apo.data.faa.gov/faamatsall.HTM). For general aviation, the hours of operation are typically limited by daylight and noise considerations. At some airports, general aviation is restricted to designated runways/fields that have a separate control tower. For these airports, it may possible to request data for the specific tower.

4. CONSTRUCTION AND MINING EQUIPMENT

Construction and mining equipment is typically the dominant category as a source of nonroad emissions in a study area, and is thus the category of most interest for cataloging and improving local regional estimates of activity and emissions. Construction firms also own and use equipment catalogued by EPA under industrial and commercial categories, including such types as aerial lifts, sweepers, generator sets, pumps, compressors, welders, and some agricultural tractors. EPA labels construction and mining equipment as just those types shown in Table 4-1.

Table 4-1. Equipment types and descriptions for construction equipment. (xx refers to '60' for 2-stroke gasoline, '65' for 4-stroke gasoline, '70' for diesel, '67' for LPG, 68 for CNG).

SCC	Equipment Type	Definition
22xx002003	Pavers	Large and small (such as for curbs) primarily self-propelled pavers
22xx002006	Tampers/Rammers	Small 'handheld,' walk-behind, or single person sized equipment for compaction such as for sidewalk or other small area compaction
22xx002009	Plate Compactors	Similar to tamper/rammers with a larger vibrating plate instead of a ram
22xx002015	Rollers	Rollers include smooth and knobby (such as used in landfills and called "compactors" not to be confused with smaller Plate Compacters) self-propelled rollers
22xx002018	Scrapers	Special equipment type that is an off-highway tractor with a mid-frame bucket that lowers to scrape loose material (dirt) into the bucket to carry to another part of the job site to dump; sometimes converted to a water-wagon
22xx002021	Paving Equipment	Various equipment types used to smooth and distributing paving material including vibrators and finishers to support the work of the pavers
22xx002024	Surfacing Equipment	Other various equipment used to supplement paving activity including paving material mixers, surface profilers (road reclaiming chippers), and seal coating equipment not used to distribute paving material as with paving equipment
22xx002027	Signal Boards	Includes both highway boards and light plants used for nighttime lighting
22xx002030	Trenchers	Large and small trenchers typically using a rotating front mounted rotating 'blade' to pull material from trench and distribute it to the side.
22xx002033	Bore/Drill Rigs	Self-explanatory drills or boring rigs of all types that are skid mounted, trailer mounted, or self-propelled; not to be confused with highway trucks with drill attachments running off the highway engine, though truck mounted nonroad engines\equipment exist
22xx002036	Excavators	Single purpose wheeled or tracked excavators (backhoe) distinct of multipurpose tractor/backhoe/loaders
22xx002039	Concrete/Industrial Saws	Handheld and large engine powered saws for stone cutting.
22xx002042	Cement & Mortar Mixers	Small mixers used for small batch mixing
22xx002045	Cranes	Self-propelled typically cable hoists; not to be confused with highway trucks with crane attachments running off the highway engine, though truck mounted nonroad engines\equipment exist
22xx002048	Graders	Called road or motor graders often used to prepare a site, especially a road, for paving. A blade is mid-frame mounted with equipment having a long wheel base
22xx002051	Off-highway Trucks	Large off-highway dump trucks not certified for highway use
22xx002054	Crushing/Proc. Equipment	Various crushing and screening equipment for bulk material
22xx002057	Rough Terrain Forklifts	Rough terrain forklifts (RTF) can be confused with typical forklifts but have larger knobby off-road wheels and can be confused with rubber tire loaders but are specifically designed for handling palettes. RTFs include telescoping lift trucks called telescopic handlers often used in building construction.
22xx002060	Rubber Tire Loaders	Bucket loaders or front-end loaders with a front mounted bucket for scooping though other attachments can be used instead of a bucket
22xx002063	Rubber Tire Dozers	Similar to a rubber-tire loader with a vertically mounted blade instead of a bucket
22xx002066	Tractors/Loaders/ Backhoes	Common and ubiquitous multipurpose equipment type that is most often referred to as a "backhoe" but include the combined functions of loading and a backhoe in one unit. Agricultural tractors with alternative attachments may used for similar purposes
22xx002069	Crawler Tractors	Tracked (not wheeled) loaders and dozers
22xx002072	Skid Steer Loaders	Smaller (able to be 'skid' mounted to transport to job site) loaders which may have alternative attachments than a bucket for loading
22xx002075	Off-Highway Tractors	Large tractors used to primarily drag large buckets or other equipment around a job or mine site, and agricultural tractors have been used for the same purpose
22xx002078	Dumpers/Tenders	Small loaders and other trucks for confined space and light loads typically used for small building projects and are typically walk-behind equipment.
22xx002081	Other Construction Equipment	Miscellaneous category for equipment not categorized above; only example of this type supplied by PSR are tensioners which are large winches used in construction

The basic information contained within the Draft-NONROAD model was derived exclusively from the PSR data for population and activity estimates. The geographic distribution of emissions was accomplished through the dollar value of construction, and did not account for different construction types, regional differences in price, or other uses of construction and mining equipment including mining, landfill, and public ownership.

Texas (TNRCC, 2000) has used surveys to revise the estimates of construction and mining equipment. The surveys produced local estimates of equipment population and annual hours of use. The approach used in the TNRCC work was similar to the method used by NESCAUM (to be published in an EPA grant report) to perform similar survey work in three northeast areas. The alternative approach described below to surveying construction and mining equipment types relied on the results and experience gained in these two survey efforts.

Alternative Approaches

Alternative approaches to construction and mining equipment have depended upon survey approaches for revised population and activity (hours and load factor) estimates. A survey approach is outlined below. In addition, county allocation may be revised based on the survey results, which can provide an estimate of equipment ownership by revenue, employee, or construction type. The firm or project types that use more equipment can more appropriately apportion equipment by county according to the estimates of revenue, employees, or construction project types.

Also survey information can be used to demonstrate that certain equipment types are used in unique construction and mining operations. For instance, California has historically apportioned construction and mining equipment above 750 hp to mining operations across the state.

Survey Method Description

Because most of the emissions for this nonroad category are powered by engines greater than 25 hp, the survey can be targeted at just those equipment types which reduces the informational burden on firms that own construction equipment. A synthesis of the survey work conducted to date has identified the types of construction equipment owners listed below by Standard Industrial Code (SIC) (similar owner types can be defined for the revised code system called the North American Industry Classification System (NAICS)).

- General Building Contractors; SIC- 15
- Heavy Construction Contractors; SIC - 16
- Specialty Trade Contractors; SIC - 17
- Rental Equipment; SIC – 7353, 7359, 5082, 5083, 35, 42,
- Mining (Metals, coal, and nonmetallic); SIC 10, 12, 14
- Stone, Glass, and Concrete Products; SIC – 32, 5032
- Forestry; SIC - 08
- Lumber and Wood Products; SIC - 24
- Garden Supply and Nurseries; SIC - 5261

- Landfills; SIC - 495
- Fertilizer-Mixing (such as composting facilities); SIC - 2875
- Asphalt Paving and Roofing Material; SIC - 295
- Metals and Minerals Wholesalers-except petroleum (scrap yards); SIC – 505, 5093
- Municipal, State, Federal

A database of individual firms can be compiled from the local and state trade associations or by purchasing it from Dun and Bradstreet (D&B found at http://www.dnb.com/local_home/local_home_US/). D&B can provide a nearly complete list of private (public ownership is not well addressed here) entities that own construction equipment. D&B information includes much helpful information for conducting and analyzing surveys. The information available per business includes the type of business(es), location, phone number, contact names, number of employees, revenue, and other pertinent information for selecting and conducting surveys. Sales revenue and number of employees will determine how much construction activity is accounted for in the survey responses, and also to provide a method for scaling survey results to a given county.

Municipal owners would need to be removed from the D&B or other data because earlier work has shown that D&B lists do not completely account for publicly owned equipment, and the list of public entities will be determined through county-level resources. However, it may be necessary to add firms to the D&B list that appear in other sources.

Local trade associations or D&B data should cover the industry segments outlined above, and Census or State revenue data (if available) can be used to verify trade association or D&B data. Additional identification and cross references to this data could also compiled, especially for rental equipment companies, landfills, mines, and municipal publicly owned entities, through permits, trade associations, and other State and local information sources. Ports and railway intermodal facilities, described below, may also use construction and mining or other industrial equipment for material handling.

For construction and mining equipment, the survey results in this work can be compared with other survey results such as those in the Northeast and Houston to determine differences and check the reasonableness of the results. The pre-published Northeast survey response rates are shown in Table 4-2 and indicate a significant risk of low voluntary cooperation. Not shown but a likely important segment are rental equipment firms which did not respond at all in any county to the NESCAUM survey work. The most important other categories for equipment ownership were the excavation and demolition contractors (SIC 1794 + 1795), road contractors (SIC 16), and municipal ownership, and these owners had lower response rates than other types of owners. (The rural Franklin County survey work produced the highest response rates for two reasons; fewer entities to survey and more aggressive survey researchers).

Table 4-2. Response rate (as a fraction of revenue, or human population for municipal ownership) for the NESCAUM construction and mining survey (to be published).

SIC	Ownership Categories	Providence	Albany	Franklin County, MA
8	Forestry	5%	0%	100%
14	Nonmetallic mining	61%	0%	100%
15	Building contractors	88%	9%	83%
16	Road contractors	13%	4%	54%
17	Special contractors	40%	20%	86%
1794 + 1795	Excavation and demolition	23%	4%	67%
24	Lumber and wood products	75%	37%	92%
32	Stone, glass, and concrete	8%	0%	96%
5261	Garden Supply and Nurseries	69%	10%	80%
	Publicly or municipal owners	16%	0.3%	87%

Total equipment population or activity in each type of owner/operator grouping can be estimated by dividing the total activity within the survey results by the response rate as determined from total dollar revenue or other appropriate indicator of activity. For example, human population served by municipalities or tonnage of material for landfill and mining activities can be used for developing appropriate survey response rates.

A stratification analysis, after the surveys are collected, should be performed to determine if the size of the company (determined as a strata of $ revenue or number of employees) affected the average equipment ownership. If the size of the company affects the estimate of average equipment ownership, then the equipment should be scaled according to the average ownership per strata of the size of the company, response rate within each strata, and relative importance of that size of company to the entire ownership category.

5. INDUSTRIAL AND COMMERCIAL EQUIPMENT

Industrial and commercial equipment categories include such ubiquitous equipment types as generators, pumps, compressors, forklifts, and other general-purpose equipment. The equipment types for industrial equipment are shown in Table 5-1 and for commercial equipment in Table 5-2.

Table 5-1. Equipment types and descriptions for industrial equipment. (xx refers to '60' for 2-stroke gasoline, '65' for 4-stroke gasoline, '70' for diesel, '67' for LPG, 68 for CNG).

SCC	Equipment Type	Definition
22xx003010	Aerial Lifts	Various (telescoping, articulated, scissors, and other) lift equipment for personnel also called man lifts not to be confused with highway trucks with crane attachments running off the highway engine, though truck mounted nonroad engines\equipment exist to provide lifts for buckets
22xx003020	Forklifts	Small wheeled forklifts used for warehouses and other general purposes
22xx003030	Sweepers/Scrubbers	Off-road primarily self-propelled sweeping and scrubbing vehicles
22xx003040	Other General Industrial Equipment	Miscellaneous category with examples such as sandblasters, large vacuum\spraying\other nonroad trucks, paint sprayers, general purpose spreaders, and winches.
22xx003050	Other Material Handling Equipment	Conveyers and other bulk material handling equipment
22xx003060	Refrigeration	Self contained engine compressors for refrigeration such as used on refrigeration trucks
22xx003070	Terminal Tractors	Single driver (typically no passenger seat) off-road trucks used primarily for moving highway trailers around paved areas such as at container ports and other intermodal facilities (rarely used for moving aircraft around airports); also called yard spotters, hostlers, and hustlers.

Table 5-2. Equipment types and descriptions for commercial equipment. (xx refers to '60' for 2-stroke gasoline, '65' for 4-stroke gasoline, '70' for diesel, '67' for LPG, 68 for CNG).

SCC	Equipment Type	Definition
22xx006005	Generator Set	Trailer or skid mounted self contained engine\electric generator designed to supply electrical power at a job site
22xx006010	Pumps	Trailer or skid mounted engine powered liquid pumps
22xx006015	Air Compressors	Trailer or skid mounted engine powered engine powered air compressors to generate high pressure air for pneumatic tools or other needs for pressurized air
22xx006020	Gas Compressors	Engine compressors for commercial gas, most likely to pressurize CNG from natural gas lines or boost pressure in those lines. May be similar to area or stationary source engine compressors.
22xx006025	Welders	Engine powered arc welding support equipment not unlike a generator
22xx006030	Pressure Washers	Engine powered pumps specifically for pressure washers

The draft-NONROAD default approach for industrial and commercial equipment population activity uses the Power Systems Research estimates. The NONROAD model allocates industrial equipment to the county-level by employees engaged in manufacturing, and commercial equipment by the number of wholesale establishments.

Alternative Approaches

The commercial and industrial equipment types are the most difficult categories to analyze because the equipment types are owned and used in so many occupations and even residential uses. It is much more difficult to determine owner/operators of these equipment categories, and relevant trade associations and owner lists will be much more difficult to identify.

However, often these equipment types have service contracts with local dealers and service centers, and these dealers and service centers can be contacted to identify owner/operators. The local representatives/chapter of the Associated Equipment Distributors (http://www.aednet.org/local_group/index.cfm) could be solicited for information and contacts. In addition, some of the owners of equipment types categorized as industrial/commercial may be identified and surveyed if/when approaching owners of construction equipment. Certainly registration programs for the larger (higher horsepower) equipment types would permit the identification for these emission sources.

The relationship with the equipment usage and the allocation indicators of manufacturing employees and wholesale establishments and has not been justified. It may be equally appropriate to allocate equipment activity for most of these equipment types according to general economic activity estimates such as general business revenues. As a separate equipment type, terminal tractors may be associated with intermodal (truck depots, rail intermodal, and ports) facilities because of their primary use at those locations.

6. LAWN AND GARDEN EQUIPMENT

The lawn and garden equipment category includes a number of equipment types as shown in Table 6-1. These include many equipment types that are duplicated depending on ownership, either residential or commercial. Commercial owners have been estimated to use equipment more frequently than residential owners.

Table 6-1. Equipment types and descriptions for lawn and garden equipment. (xx refers to '60' for 2-stroke gasoline, '65' for 4-stroke gasoline, '70' for diesel, '67' for LPG, 68 for CNG).

SCC	Equipment Type	Definition
22xx004010	Lawn mowers (Residential)	Walk behind mowers owned by residences
22xx004011	Lawn mowers (Commercial)	Walk behind mowers owned by commercial landscaping and horticultural services companies as well as facility\parks\other maintenance departments.
22xx004015	Rotary Tillers < 6 HP (Residential)	Smaller walk-behind rotary tillers for residential gardens
22xx004016	Rotary Tillers < 6 HP (Commercial)	Smaller walk-behind rotary tillers for residential gardens owned by facility\ parks\other maintenance departments or landscaping professionals
22xx004020	Chain Saws < 6 HP (Residential)	Self explanatory but smaller than those used for forestry
22xx004021	Chain Saws < 6 HP (Commercial)	Self explanatory but smaller and owned by facility\parks\other maintenance departments or landscaping professionals
22xx004025	Trimmers/Edgers/Brush Cutters (Residential)	Small handheld or nonhandheld power equipment for general purpose cutting including equipment types such as string trimmers (aka Weedwackers) as well as other engine powered types
22xx004026	Trimmers/Edgers/Brush Cutters (Commercial)	Same as above but owned by facility\parks\other maintenance departments or landscaping professionals
22xx004030	Leafblowers/Vacuums (Residential)	Self explanatory
22xx004031	Leafblowers/Vacuums (Commercial)	Self explanatory owned by facility\parks\other maintenance departments or landscaping professionals
22xx004035	Snowblowers (Residential)	Self explanatory
22xx004036	Snowblowers (Commercial)	Self explanatory owned by facility\parks\other maintenance departments or landscaping professionals
22xx004040	Rear Engine Riding Mowers (Residential)	As described and designed for residential lawn mowing
22xx004041	Rear Engine Riding Mowers (Commercial)	As described and designed for lighter duty mowing than front mowers owned by facility\parks\other maintenance departments or landscaping professionals
22xx004046	Front Mowers	Heavier duty and more versatile mowers than rear engine mowers with mower attached on the front of the vehicle
22xx004051	Shredders < 6 HP	Lighter-duty equipment (than chippers\stump grinders) with internal blades to reduce small diameter wood to small pieces
22xx004055	Lawn & Garden Tractors (Residential)	Small tractors used for mowing but able to perform tasks other than mowing and owned by residences
22xx004056	Lawn & Garden Tractors (Commercial)	Small tractors used for mowing but able to perform tasks other than mowing and owned by facility\parks\other maintenance departments or landscaping professionals
22xx004066	Chippers/Stump Grinders	Internal or external bladed equipment to grind and chip various, but primarily woody biomass, materials. Heavier duty than shredders. May include road chippers, stone grinders, and other non-lawn and garden equipment types
22xx004071	Commercial Turf Equipment	Various turf equipment designed for professional use and include applications, such as aerators, dethatchers, sod cutters, hydro-seeders, turf utility vehicles, and specific golf course equipment including greens mowers and sand trap groomers
22xx004075	Other Lawn & Garden Equipment (Residential)	Any other lawn and garden maintenance equipment not otherwise classified and include such equipment types as augers, sickle-bar mowers, and wood splitters owned by residences
22xx004076	Other Lawn & Garden Equipment (Commercial)	Any other lawn and garden maintenance equipment not otherwise classified and include such equipment types as augers, sickle-bar mowers, and wood splitters owned by facility\parks\other maintenance departments or landscaping professionals

The overall NONROAD estimates of lawn and garden equipment population were derived from Power Systems Research (PSR). These estimates were split amongst residential and commercial owners according to historic sales estimates available from CARB (1992). The activity (hours per year and load factor) estimates for lawn and garden equipment were derived from information provided during the rulemaking process and were informed by survey work performed in California (CARB, 1998 and 1992; and BAH, 1991).

The draft-NONROAD model provided a comparison of emissions by equipment and owner types. For VOC emissions, where lawn and garden equipment is a significant contributor, commercially owned equipment are the greatest contributors roughly twice that of residential users. Equipment types that contribute more than 10% of the overall emissions include commercial owners of chainsaws, trimmer/edger/brush cutters, leafblowers/vacuum, and commercial turf equipment. No residentially owned equipment types are responsible for more than 10% of the emissions individually, but lawn mowers and lawn and garden tractors are responsible for more than half of the residential VOC emissions.

Alternative Approaches

There have been several survey approaches used to estimate lawn and garden equipment ownership and activity. ENVIRON (1997) described earlier studies to improve the estimates of lawn and garden activity and outlined methods to improve the inventory.

ERG (2002) used a similar approach to estimate the in-use population of portable gas containers by lawn and garden equipment owners. The residential owners were surveyed through a random selection process and conducted over WebTV. The commercial owners were surveyed through phone interviews and identified through Texas Nursery and Landscape Association (TNLA) and other contacts. The universe of owners' activity was developed through information provided by the Texas State Comptroller in terms of revenue and employees for Landscape and Horticultural services (SIC-0780) where other types owners were deemed to be negligible.

EPA funded a grant to the California Air Resources Board to survey and instrument lawn and garden equipment. They are surveying and instrumenting engines to determine activity and typical load for lawn and garden equipment types for commercial and residential owners. No reports have been released yet.

There may be additional owners of commercial lawn and garden equipment besides Landscape and Horticultural services (SIC-0780) however. Other potential owners of lawn and garden equipment could include Garden Supply and Nurseries (SIC-5261), golf courses (not included in SIC-0780), rental equipment operators (see the construction and mining section for definition of rental equipment firms), institutional (e.g. universities) and public (state, county, city, and other) owners. Local trade associations (such as TNLA or Georgia Golf Course Superintendents Association; http://www.ggcsa.com/ identified through the national association http://www.gcsaa.org/chapter/guide/chapmap.asp) should be contacted to identify owners of equipment.

A survey following the approach described for recreational marine operation where the survey would be conducted over a series of two-week periods across the year would be appropriate. A longer period of the survey may be more difficult for the owner to remember the activity of their equipment.

Because lawn care equipment (lawn mowers, commercial turf, rear engine and front mowers) is modeled to be a distinct portion of the overall lawn and garden activity, allocation by lawn cover may be used. But these equipment types are currently estimated to only represent about 16% (or 28% if lawn and garden tractors are also included) of the VOC emissions from all lawn and garden equipment.

7. LOCOMOTIVE

The LADCO area, and Chicago in particular, is an important rail center including much railway activity and a large number of railways. Most railway activity is associated with the largest railways, called Class I, and the LADCO area includes operations of all of the Class I railways; Burlington Northern Santa Fe, Union Pacific, CSXT, Norfolk Southern, Kansas City-Southern, Canadian National, Canadian Pacific, and AMTRAK. A dizzying array of smaller railways also operate in the LADCO area (23 in Illinois alone) including here just some of the railways operating in the Chicago area; Wisconsin & Southern, I&M Rail Link (now owned by Iowa Chicago & Eastern), Belt Railway Company of Chicago, Iowa Interstate, Toledo-Peoria & Western, Chicago SouthShore & South Bend, Elgin Joliet & Eastern and many others. In addition, these small railways operate either as subsidiaries of larger railways or have marketing agreements with larger railways. Both the smaller and larger railways offer and use trackage rights on others' rail lines.

Locomotive activity can be categorized into two general types; line-haul and switching. The line-haul locomotives tend to be the newest engines and move freight on long haul trips. The switching locomotives tend to be older and locally based at freight yards, intermodal facilities, maintenance and repair facilities, and other various distribution facilities.

EPA Default Approach

National fuel consumption estimates were provided to EPA in terms of switching and line-haul activity. These were distributed to the county level in the National Emission Inventory (NEI) using the Bureau of Transportation's rail freight density. The National Transportation Atlas (NTA) depicts rail routes and classifies each route in terms of a rail freight density rating, as illustrated in Figure 7-1. The Bureau of Transportation conversion software converts the NTA data into ArcInfo compatible files (http://websas.bts.gov/website/ntad02/maindownload.html). The rail freight density can then be associated with spatial features in the GIS data.

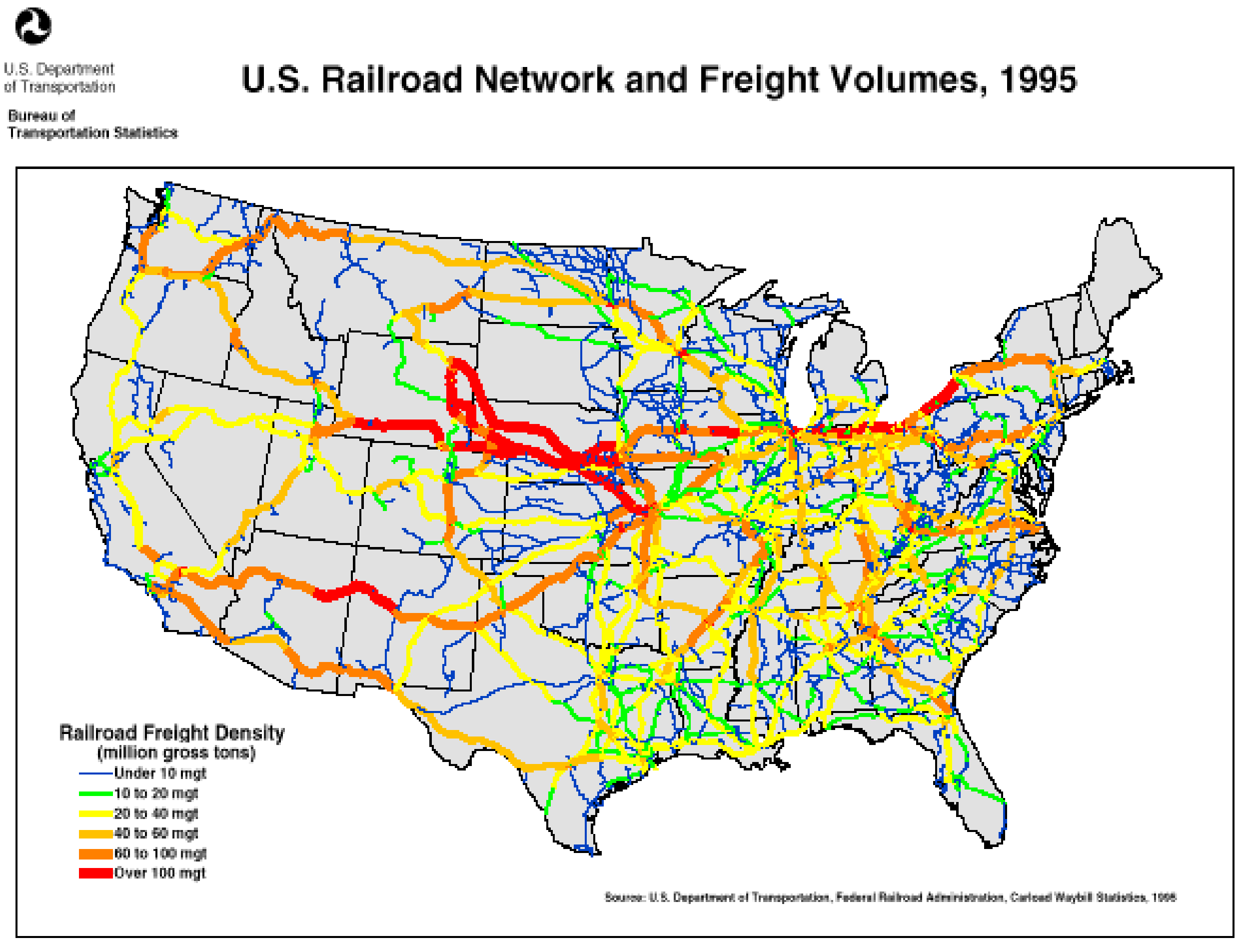

Figure 7-1. Bureau of Transportation National Transportation Atlas.

Alternative Approaches

Fuel Consumption Surveys

Typical fuel consumption by freight movements (ton-mile) obtained in other surveys for Texas and Arkansas can be used to estimate area-wide activity instead or as a complement to the estimates available from the NEI. Surveys of locomotive activity have been used to generate local emission estimates for the planning purposes. Because of the large number of railways operating within the LADCO area, a survey will be resource intensive. A survey would likely yield reasonably accurate information about the activity of the larger (Class 1) railways and encompasses the majority of the activity for a given region but may not be a complete accounting of all activity because of the large number of smaller railways. In order to determine the switching railway hours of operation may be the only available information where typical hourly fuel consumption can be derived from default estimates unless railways can provide such information.

Publicly available Freight Transfers

Another suggested approach has been that the waybills and similar activity estimates provided by firms such as Reebie Associates could be used to estimate the ton-miles of freight transfers. However, this waybill information underestimated the activity for Texas because the data provided by two railways operating in Texas indicated more freight transfers than Reebie has provided. And this data source cannot estimate the switching engine activity.

Link-Based Modeling

A more involved, and therefore costly, approach could begin the process of mapping rail links as road links are now mapped. A map of the rail links around Chicago, Figure 7-2, demonstrates the difficulty in defining the links and the activity on those links. It will be easier to apply this method to an area where the number of rail links are less numerous than Chicago such as those around Milwaukee shown in Figure 7-3 where the rail links are fewer and easier to generate activity estimates. However, the more active areas are also the areas where locomotive emissions are more significant.

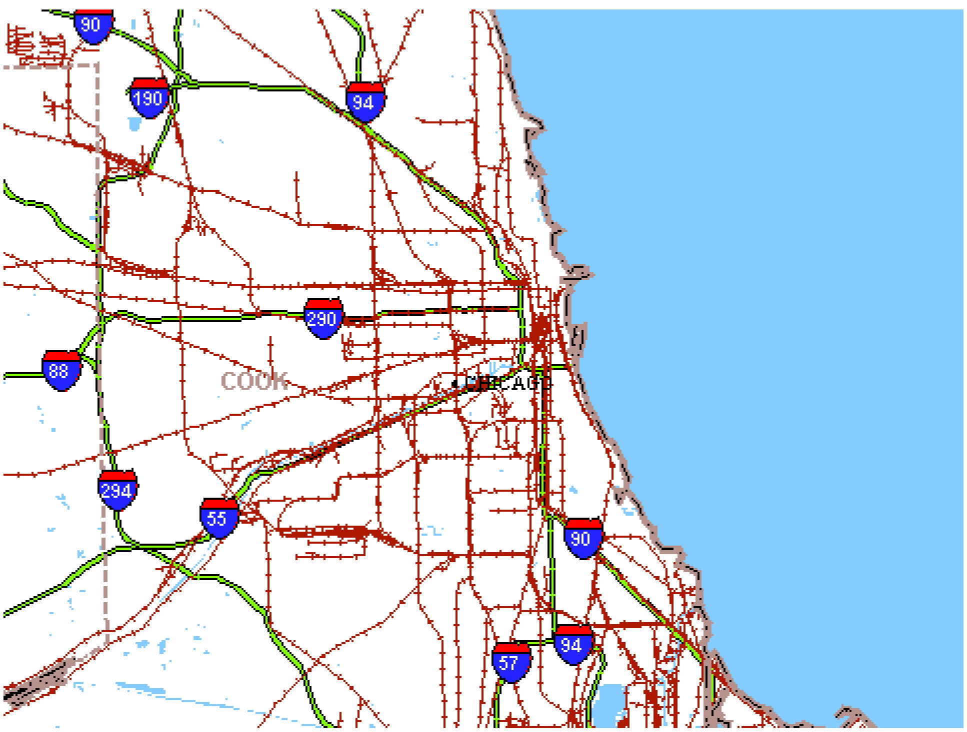

Figure 7-2. Railroad links near Chicago.

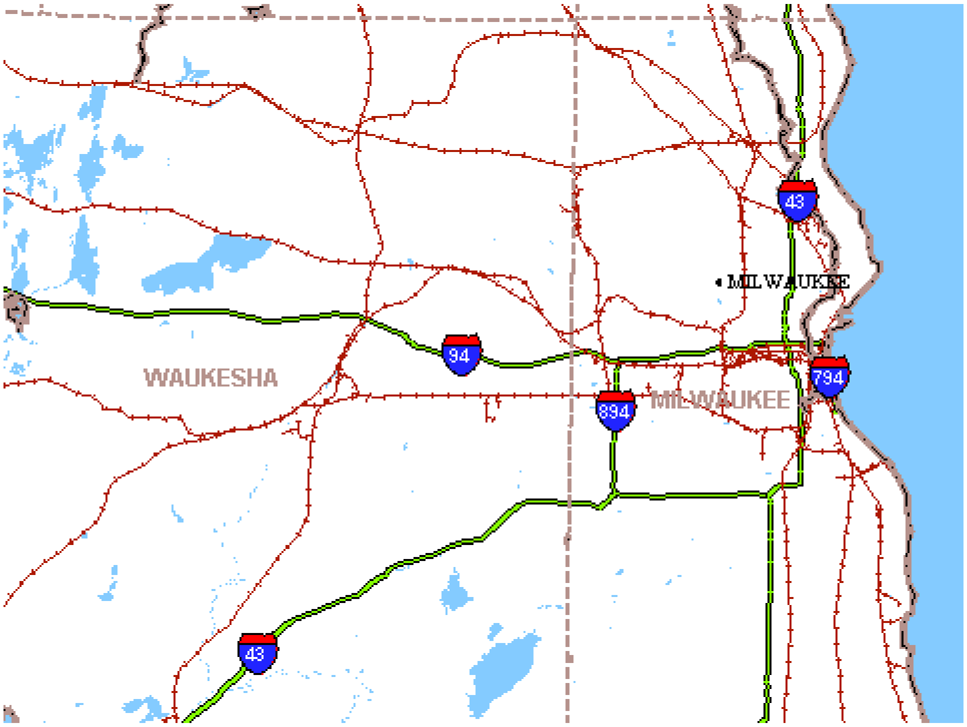

Figure 7-3. Rail links around Milwaukee.

Activity data in the form of the number of trains and typical train configurations can be coupled with fuel consumption estimates developed for those train configurations using software such as the Train Energy Model (TEM). The TEM combines train configuration and rail link data (grade, curvature, and other variables) into estimates of locomotive power and energy consumption. The TEM can be licensed from the Transportation Technology Center (http://www.railway-technology.com/contractors/training/ttc/) for $9,000 for 1 year and $4,500 for additional years, and would be used to determine lookup tables of fuel consumption for train configurations over each of the rail links.

Because of the importance of grade crossings, number of train crossings may be identified for each of several grade crossings. If the number of trains and train types crossing a given node can be determined, then an activity estimate for line-haul and local railways can be made. For areas where the rail lines are grade separated, this activity source may not be sufficient for identifying the activity along many links. However, the benefit of this approach is that it would not necessarily rely on the railways to provide activity information.

8. RECREATIONAL MARINE EQUIPMENT

Recreational marine engines are classified into three groups; outboards, inboards, and personal water craft (PWC) as shown in Table 8-1.

Table 8-1. Equipment types and descriptions for recreational marine equipment. (xx refers to '60' for 2-stroke gasoline, '65' for 4-stroke gasoline, '70' for diesel, '67' for LPG, 68 for CNG).

SCC	Equipment Type	Definition
2282005010	Gasoline Outboards	Standard outboard engines easily removed and replaced if needed
2282005015	Personal Watercraft	Engines used to provide power to jet-powered small boats and riding watercraft (aka JetSki)
2282010005	Gasoline Inboards	Primarily 4-stroke engines mounted as an integral part of the vessel
2282020005	Diesel Inboards	Diesel engines mounted as an integral part of the vessel
2282020010	Diesel Outboards	Rare, but nonzero diesel powered outboard engines.
2282020025	Diesel Sailboat Auxiliary	Not used because auxiliary integrally mounted propulsion power primarily for larger sailboats or outboard motors are included as inboards or outboards

The EPA draft-NONROAD model provided estimates for national recreational marine engine population derived from historic sales data applying a typical age life and scrappage distribution. The national population estimates were apportioned to counties by applying a water surface allocation method, and the county totals were summed to estimate the State populations. The recreational boating activity estimates were derived from data developed on fuel consumption rates derived in a Price Waterhouse (1992) survey of recreational boaters.

Alternative Approaches

The State population estimates for recreational marine can be revised using the State boat population registrations. (Unregistered boats accounted for 4% of the total fuel consumed by recreational marine vessels as found in a Price Waterhouse (1992) survey). The vessel population is available for outboards and inboards, and with the more recent introduction of PWC, some States are now tracking these vessel types separately.

Geographic and temporal allocations and activity (either hours or fuel use) can be revised through directed surveys. The most recent state survey (SAI, 1995) for California (based on and improved over an earlier Wisconsin DNR survey) supplies a blueprint for future work in this area. The registered boat owners were polled for boat usage by day of week (an example of the outcome is given in Table 8-2) and fuel purchases over a two-week period. Boat owners were polled during different seasons to address different usage across the year. Boat owners also provided the fraction of operation time in each county allowing for spatial allocation of the emissions. The two-week period was expected to induce more accurate responses and higher responses.

Table 8-2. Annual day of week temporal allocation (SAI, 1995).

Day of the Week	Relative Activity
Monday	0.0527578
Tuesday	0.0621816
Wednesday	0.0702681
Thursday	0.0723208
Friday	0.1043395
Saturday	0.3039638
Sunday	0.3341683

An earlier survey (Price Waterhouse, 1992) was conducted to determine fuel usage by boat type for the nation broken out by state. This survey was intended to discover the fuel usage by boat owners and not necessarily count or determine activity variables for individual vessel types. Combining fuel and hours of operation, the load factor can be calculated with an estimate of fuel efficiency by engine type.

The current water surface allocation of recreational boating activity has not addressed local information that may be used to modify the county allocation. For instance, general information about water surface allocation does not distinguish between boat able and nonaccessible (lake preserves or other restricted access) water surface, relative activity (popular lakes or rivers), and allocation by type of boat (for instance inboards preferentially used on large lakes). TCEQ (2002) used a revised geographic allocation method shown in Equation 1 and suggested an alternative regression approach in Equation 2 to attempt to address the revised allocation methods.

$$[A * R] / D \qquad \text{Equation 1}$$

Where,

A = *acreage of the destination lake*
R = *boat registration of the origination county*
D = *distance in miles*

$$Y = a + b + c + d + f + E \qquad \text{Equation 2}$$

Where,

Y = *attractance*
a = *area of water body*
b = *boat registration by county*
c = *inverse distance*
d = *desirability (consumer survey data)*
f = *environmental condition*
E = *regression error coefficient*

9. SHIPPING (COMMERCIAL MARINE)

The commercial marine sector includes many various types of vessels from large deep draft vessels (such as container, bulk carrier, and tanker vessels), harbor tugs (for deep draft vessel assist), barge tugs (either push boats or tow boats), ferries, excursion vessels, dredging, and commercial fishing vessels.

EPA has defined 3 categories of marine engines as described in Table 9-1 (EPA, 1999b). Larger vessels include ocean-going ships and 'Lakers,' using primarily Category 3 engines for propulsion. Smaller vessels, most significantly the push and towboats, typically use Category 1 engines for propulsion and auxiliary power. The Category 2 engines are engines with similar designs to those used in locomotives such as those produced by the Electro-Motive Division of General Motors and are typically used for auxiliary power on large vessels and as propulsion for large ferries and excursion craft. Each of these engine types have separate emissions regulations associated by engine category so it is important to keep the vessel activity distinguished by these engine types to properly account for emissions and emission reductions expected through regulations.

Table 9-1. Commercial marine engine categories.

Category	Displacement (l/cylinder)
1	< 5
2	5 to 30
3	> 30

Fuel sales or tax revenue may not be a clear measure of the commercial marine activity

Large Vessels

Large vessels are deep draft (>12 foot) vessels that either operate only within the Great Lakes ("Lakers") or are ocean-going ("Salty") proceeding in and out the St Lawrence to the Atlantic. Typically it is best to obtain port call information by vessel type and size for each port within the Great Lakes such as at Burn Harbor or Milwaukee (http://www.portsofindiana.com/BurnsHarbor/ipc_bh-fs.htm; http://www.port.mil.wi.us/). Survey work may be useful for specific ports in regions of greatest concern such as the report contracted by TNRCC for the ports in the Houston-Galveston area (Starcrest, 2000). The deep draft (those greater than 12 – 14 foot draft) vessel calls at each of the ports of interest can be associated with the installed power data supplied (for a fee) by Lloyds Vessel Registry. The overall activity can be estimated for each of several modes of operation; cruise conditions (Arcadis indicated that this occurs in the range of 10 miles from shore but could begin before then), reduce speed zone (a cautionary speed limit typically used by harbor pilots), maneuvering (near dock or between dock shifting), and at dock.

EPA contracted several reports (Arcadis 1999a and 1999b) that reviewed port call activity and provided estimates of the ocean-going vessel activity for several deep sea and Great Lakes ports. This review included both detailed vessel call information and hotelling (time at berth) times as well as detailed vessel information derived from Lloyds shipping data, which includes estimates of the installed power of each vessel. Detailed information was collected for Burns Harbor and Cleveland for 1996 along with several ocean ports. The detailed vessel information included the installed power on board each vessel. ENVIRON (2002) used this information to estimate emissions by associating the time and engine load estimates for each of several modes proceeding into and out of the detailed ports with the installed power on board the vessels derived from the Arcadis studies.

Arcadis also supplied trips (includes vessel shifts as well as each trip in and out for each port call) data gleaned from Army Corps information for vessel calls at each major port, including the busiest 38 Great Lakes ports and 21 river ports as shown in Table 9-2. ENVIRON (2002) used this information to estimate activity at each major port using the relative activity at each port compared with the Burns Harbor and Cleveland. The difficulty with the trips data (available from USACE, 2001) is that it is not readily apparent which vessels are associated with each ship type. A combination of several criteria including vessel draft and type were used to estimate the number of trips for each vessel type. No river ports in Table 9-2 were estimated to have deep draft vessel activity.

Table 9-2. Top river and lake ports, trips by ship-type 1995 (Arcadis, 1999a).

Rank	Port Name	R/L *	BC	BD	BL	CS	GC	OT	PA	RF	RO	SV	TA	TUG	UC	Grand Total
1	Port of Pittsburgh, PA	R	-	104,185	3,668	-	-	-	286	-	-	-	-	49,742	-	157,881
2	Duluth-Superior, MN & WI	L	1,808	63	6	-	84	-	-	5	-	-	670	64	566	3,265
3	Port of St. Louis, MO & IL	R	-	46,419	5,039	-	1	-	3	-	-	-	-	29,939	-	81,401
4	Port of Chicago, IL	L	690	21,739	5,964	-	10	-	1	-	-	-	166	12,523	120	41,213
5	Huntington, WV	R	-	29,154	5,769	-	-	-	-	-	-	-	-	18,595	-	53,518
6	Memphis, TN	R	-	13,888	4,748	-	2	-	4	-	-	-	-	1,893	-	20,535
7	Indiana Harbor, IN	L	679	638	1,504	-	1	-	-	-	-	-	961	2,671	92	6,546
8	Port of Detroit, MI	L	1,068	361	605	-	-	-	-	-	-	-	207	838	-	3,079
9	**Cleveland Harbor, OH**	**L**	**1,344**	**229**	**145**	**-**	**11**	**-**	**2**	**-**	**-**	**-**	**48**	**685**	**186**	**2,650**
10	Lorain Harbor, OH	L	1,061	35	0	-	12	-	-	-	-	-	-	46	37	1,191
11	Toledo Harbor, OH	L	763	80	212	2	26	-	-	-	-	-	65	346	423	1,917
12	Cincinnati, OH	R	-	12,419	2,824	-	-	-	220	-	-	-	-	3,341	-	18,804
13	**Burns Waterway Harbor, IN**	**L**	**306**	**2,634**	**88**	**-**	**10**	**-**	**-**	**-**	**-**	**-**	**214**	**2,189**	**145**	**5,587**
14	Presque Isle Harbor, MI	L	505	2	0	-	-	-	-	-	-	-	-	2	115	624
15	Ashtabula Harbor, OH	L	522	2	0	-	-	-	-	2	-	-	-	0	212	738
16	Gary Harbor, IN	L	325	1,350	0	-	-	-	-	-	-	-	88	1,089	17	2,869
17	Taconite Harbor, MN	L	339	41	0	-	-	-	-	-	-	-	-	41	-	421
18	Louisville, KY	R	-	8,864	4,034	-	-	-	-	-	-	-	-	2,238	-	15,136
19	Escanaba, MI	L	521	44	0	-	-	-	-	-	-	-	-	44	-	609
20	Stoneport, MI	L	696	32	0	-	-	-	-	2	-	-	-	29	66	825
21	Calcite, MI	L	612	51	0	-	-	-	-	-	-	-	-	46	164	873
22	Two Harbors, MN	L	317	34	0	-	-	-	-	-	-	-	-	35	-	386
23	Mount Vernon, IN	R	-	5,551	1,610	-	-	-	-	-	-	-	-	730	-	7,891
24	St. Clair, MI	L	378	6	53	-	-	19	-	-	-	-	5	42	26	529
25	Conneaut Harbor, OH	L	223	8	0	-	-	-	-	18	-	-	-	8	168	425
26	Vicksburg, MS	R	-	2,877	9,508	-	6	-	6	-	-	38	-	5,141	-	17,576
27	Port Inland, MI	L	457	111	0	-	-	-	-	-	-	-	-	109	31	708
28	St. Paul, MN	R	-	6,818	346	-	-	-	-	-	-	-	-	3,788	-	10,952
29	Victoria, TX	R	-	1,813	2,991	-	-	-	-	-	-	-	-	2,478	-	7,282
30	Silver Bay, MN	L	306	-	-	-	-	-	-	-	-	-	-	-	-	306
31	Port of Kansas City	R	-	15,983	132	-	-	-	-	-	-	-	-	15,728	-	31,843
32	Marine City, MI	L	162	-	-	-	-	-	-	-	-	-	-	-	-	162
33	Port of Nashville, TN	R	-	4,603	252	-	-	-	-	-	-	-	-	1,123	-	5,978
34	Sandusky Harbor, OH	L	183	9	-	-	-	-	8	7	-	-	-	9	517	733
35	Marblehead, OH	L	339	114	12	-	-	-	3,714	-	-	-	-	22	52	4,253

Rank	Port Name	R/L *	BC	BD	BL	CS	GC	OT	PA	RF	RO	SV	TA	TUG	UC	Grand Total
36	Milwaukee Harbor, WI	L	302	902	83	-	19	-	-	-	4	-	-	2,060	105	3,476
37	Port Dolomite, MI	L	299	75	-	-	-	-	-	-	-	-	-	71	27	472
38	Fairport Harbor, OH	L	256	36	-	-	576	-	-	-	-	-	-	35	35	938
39	Alpena Harbor, MI	L	492	2	-	-	-	-	-	-	-	-	4	1	41	540
40	Guntersville, AL	R	-	3,277	297	-	-	-	32	-	-	-	-	484	-	4,090
41	Chattanooga, TN	R	-	2,709	737	-	-	-	-	-	-	-	-	802	-	4,248
42	Green Bay Harbor, WI	L	215	1,801	6	-	-	-	-	-	-	-	14	16	-	2,052
43	Helena, AR	R	-	1,604	730	-	-	-	7	-	-	-	-	768	-	3,109
44	Monroe Harbor, MI	L	128	1	31	-	-	-	-	-	-	-	2	32	-	194
45	Greenville, MS	R	-	1,700	935	-	-	-	1	-	-	2	-	986	-	3,624
46	Port of Buffalo, NY	L	106	6	16	-	73	-	34	-	-	-	73	58	45	411
47	Muskegon Harbor, MI	L	170	37	10	-	-	-	-	-	-	-	-	33	16	266
48	Biloxi Harbor, MS	R	-	1,979	419	-	-	-	-	-	-	-	-	395	1,426	4,219
49	Drummond Island, MI	L	121	36	-	-	-	-	-	-	-	-	-	36	30	223
50	Charlevoix Harbor, MI	L	154	146	-	-	-	-	-	-	-	-	-	388	4	692
51	Tulsa, Port of Catoosa, OK	R	-	1,036	574	-	-	-	-	-	-	-	-	552	-	2,162
52	Buffington Harbor, IN	L	88	117	-	-	-	-	-	-	-	-	22	75	1	303
53	Minneapolis, MN	R	-	1,813	-	-	-	-	-	-	-	-	-	541	-	2,354
54	Ludington Harbor, MI	L	103	6	86	-	-	-	-	-	-	-	-	246	3	444
55	Huron Harbor, OH	L	87	-	-	-	-	-	-	-	-	-	-	20	30	137
56	Erie Harbor, PA	L	186	2	-	-	662	-	-	-	-	-	-	1	22	873
57	Grand Haven Harbor, MI	L	108	22	-	-	-	-	-	-	-	-	-	62	33	225
59	Washington, DC	R	-	1,041	122	-	-	-	-	-	-	-	-	144	-	1,307
60	Hempstead, NY	R	-	740	206	-	-	-	-	-	-	-	-	796	-	1,742

* 'R' are river ports and 'L' are lake ports.
BC = Bulk Cargo Carrier (self propelled large)
BD = Dry-cargo Barge (non self propelled)
BL = Liquid Cargo (Tanker) Barge (non self propelled)
CS = Container Ship (self propelled large)
GC = General Cargo (self propelled large)
OT = Other, Unknown, or Undefined
PA = Passenger, Cruise and Excursion (self propelled large)
RO = RORO and Ferry (self propelled large)
RF = Reefer (self propelled large)
SV = Supply/Support Vessel (self propelled smaller)
TA = Tanker (self propelled large)
TUG = Tugboat and Pushboat (self propelled small)
UC = Unidentified Dry-cargo (assumed self propelled large)

Another approach has been used by Corbett and Fischbeck (1998 and 2000) using freight tons by link available from the Army Corps (http://www.iwr.usace.army.mil/ndc/wcsc.htm) demonstrated by Figure 9-1. By associating the tons with the length of each link, a ton-mile estimate may be calculated. The emissions per ton-mile need to be derived from other studies, either from the surveys conducted by Arcadis (1999a) or additional survey work on the Great Lakes. Based on the results of ENVIRON (2002), this approach underestimates the emissions calculated using the individual port data even for cruise mode conditions where the two methods (Arcadis, 1999a and 1999b, and Corbett and Fischbeck, 1998) estimates would be most comparable.

The Army Corps has sponsored and provided background information for two studies of vessel activity (Burton, 2001 and 2002) and emissions primarily by large deep draft vessel shipping on the Great Lakes. These studies have used a number of vessel counts and activity between ports.

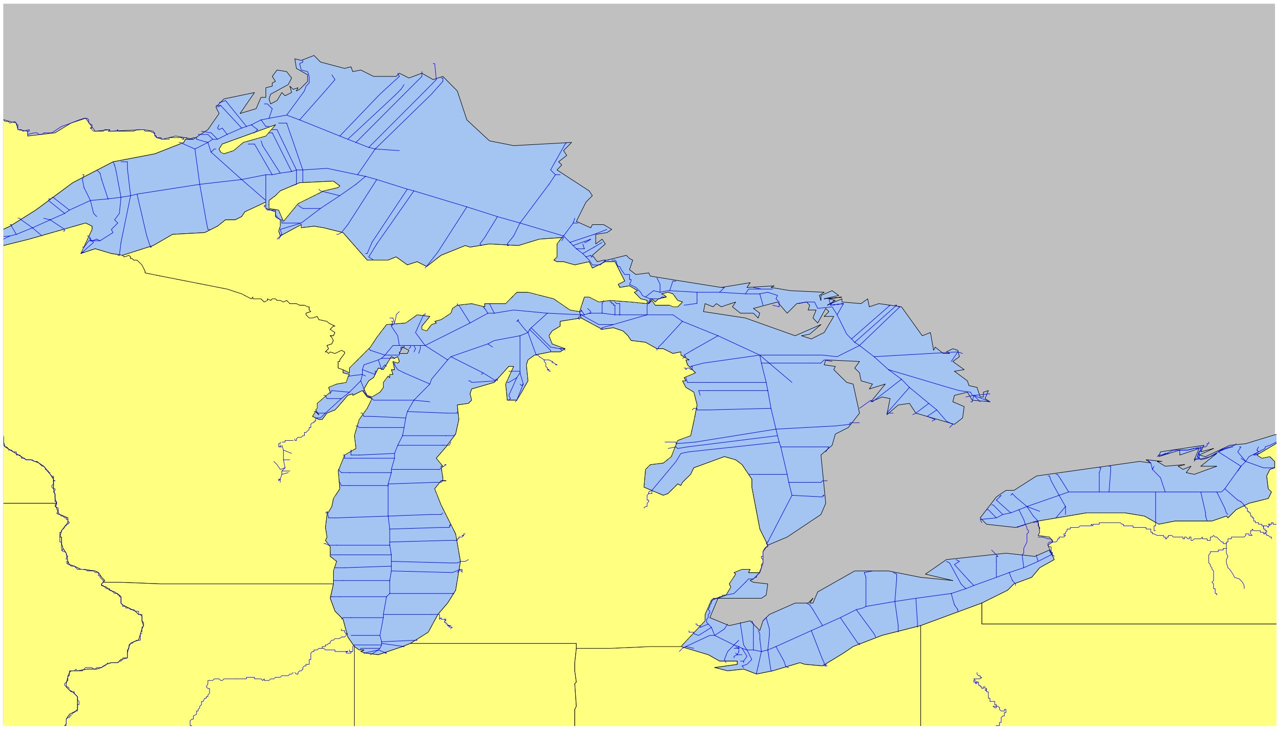

Figure 9-1. USACE Waterway Link Network (Great Lakes).

Barge Traffic

The barge traffic along the Mississippi and Illinois rivers and in the Great Lakes may be addressed by a number of sources. The Army Corps of Engineers (http://www.iwr.usace.army.mil/ndc/lockchar.htm) produces freight transfers at each lock. By associating the average freight movements between each lock with the mileage between each lock, a ton-mile estimate for each of several river links can be made. The fuel consumption per ton-mile has historically been estimated at 514 ton-miles (MARAD, 2000), but more recent and detailed estimates indicate that the fuel consumption rates vary by river system because of various reasons including the number of locks, the direction of cargo, current, and other reasons.

A more recent model of fuel consumption along river systems has been outlined by TVA (2002) and used in emission inventories in and around Washington State by Corbett (2001). This model provides estimates of fuel consumption by river link. TVA provided summary data for fuel consumption along inland rivers and includes those in the LADCO area shown in Table 9-3. The Mississippi, Ohio, and Illinois river systems are the inland river transportation links in the LADCO area.

Table 9-3. TVA barge fuel consumption by river system.

River System	1998 Fuel- gallons (ton-mile per gallons)	1999 Fuel – gallons (ton-mile per gallons)
Mississippi	51,261,419	64,649,042
(North of Missouri)	(308.2)	(275.8)
Mississippi	34,264,628	40,760,732
(Between Missouri and Ohio)	(567.9)	(510.9)
Illinois River	35,554,221	36,849,299
	(232.9)	(229.4)
Calumet-SAG Channel	573,518	517,008
	(364.7)	(346.5)
Chicago Sanitary and	596,678	647,159
Ship Canal	(399.5)	(352.7)
Chicago River, South Branch	19,789	39,889
	(317.6)	(166.1)
Ohio River	84,238,537	83,085,263
	(675.4)	(696.2)

Some barge activity occurs in the Great Lakes especially between Milwaukee and Burns Harbor including Chicago. This activity needs to be identified separately by port by associating trips at each port with average vessel power and load and time in mode for transfers between ports.

Ferries

Each State's Departments of Transportation often operate ferries, however as shown below occasional private operators can be found. For the LADCO states there are ferries operating across Lake Michigan and the Mississippi and Illinois rivers. For instance, it is possible to determine emissions for each and every ferry such as those operating on the Illinois River as shown in Table 9-4. The average vessel and operational characteristics can be chronicled and used to estimate activity and emissions for each of several operating ferries.

Table 9-4. Illinois river ferries.

River Mile	Company
3.0	Herman H. Pohlman
3.6	Div. of Waterways
32.1	Div. of Waterways
32.1	Div. of Waterways
43.1	A.T. Nelson

Excursion Craft

Excursion includes sightseeing, cruise, and casino vessels not necessarily registered with the State as recreation craft and not necessarily counted in each ports deep draft calls. These vessels would be primarily locally based (as opposed to deep draft cruise ships which may not be locally based) and registered either with the State and/or the Coast Guard. The Coast

Guard maintains a database of vessels (http://www.iwr.usace.army.mil/ndc/veslchar.htm), but this data includes tugs, ferries, commercial fishing vessels, as well as excursion craft, so care must be taken not to count the tow boats that are addressed in other estimates described above for barge traffic.

Also, it may be necessary to ensure that the excursion craft are not included in vessel calls or trips information available from the Waterborne Commerce or Port information.

A sample of the vessel information from this information source shown in Table 9-5 indicates that the vessel and power information are available, but activity and engine load would need to be estimated or surveyed. It is necessary to gather specific activity data (annual cruise times, auxiliary engine loads while docked). For instance, some of the vessels in Table 9-5 are registered but do not actually operate much time and if they do only seasonally.

Table 9-5. Example of Coast Guard information for excursion vessels in the LADCO area.

			VTCC	Length	Breadth	Draft loaded		Capacity (tons)					
Vessel Name	**CG#**	**Tonnage**	**ICSt**	**Overall Length**	**Draft light**	**Draft light**	**Hp**	**Passengers**	**Highest Point**	**Handling**	**State**	**Base**	**Year**
Dells Boat Tours													
			1A11	50	11.2	4		-					
Badger	274763	9	351	50	11.2	3.2	225	87	12	None	WI	Wisconsin Dells	1955
			1A11	54.6	11.6	5		-					
Belle Boyd	275074	36	351	54.6	11.6	3	250	122	16	None	WI	Wisconsin Dells	1952
			1A11	50	11.2	4		-					
Captain	275122	9	351	50	11.2	3.2	140	87	12	None	WI	Wisconsin Dells	1955
			1A11	55.7	13.7	5		-					
Chicagoan	281884	41	351	55.7	13.7	3	230	135	18	None	WI	Wisconsin Dells	1960
			1A11	47.2	12	5		-					
Chief	274835	9	351	47.2	12	4	150	105	14	None	WI	Wisconsin Dells	1946
			1A11	79	22	5.5		-					
Clipper Winnebago	275114	60	351	79	22	4.2	394	300	22	None	WI	Wisconsin Dells	1922
			1A11	54.8	12	5		-					
Commander	275123	12	351	54.8	12	3.3	197	87	12	None	WI	Wisconsin Dells	1950
			1A11	55	12	4.5		-					
Dell Queen	274766	18	351	55	12	3.2	325	101	13	None	WI	Wisconsin Dells	1950
			1A11	50	11.2	4.5		-					
Duchess	274767	9	351	50	11.2	3.2	225	87	12	None	WI	Wisconsin Dells	1955
			1A11	55.7	13.7	5		-					
General Bailey	298905	41	351	55.7	13.7	3	520	135	18	None	WI	Wisconsin Dells	1965
			1A11	50	11.2	3.2		-					
Hiawatha	274832	9	351	50	11.2	2	140	87	12	None	WI	Wisconsin Dells	1954
			1A11	54.6	11.6	5		-				Wisconsin	
Joliet	275060	36	351	54.6	11.6	3	450	122	16	None	WI	Dells	1952
			1A11	55.5	11.9	5		-					
Marquette	275059	28	351	55.5	11.9	3	520	139	16	None	WI	Wisconsin Dells	1952
			1A11	50	11.2	3.2		-					
North Star	274834	9	351	50	11.2	2	140	87	12	None	WI	Wisconsin Dells	1955
			1C11	33	13	1.4		-					
Osprey	1022447	5	351	33	13	1	660	41	8	None	WI	Wisconsin Dells	1975
Red Cloud	522662	45	1A11	57	12.4	5	300	-	13	None	WI	Wisconsin	1949

Vessel Name	CG#	Tonnage	VTCC ICSt	Length Overall Length	Breadth Draft light	Draft loaded Draft light	Hp	Capacity (tons) Passengers	Highest Point	Handling	State	Base	Year
			351	57	12.4	4		125				Dells	
			1A11	55.7	13.7	5		-					
Viking	285367	41	351	55.7	13.7	3	280	135	18	None	WI	Wisconsin Dells	1961
			1A11	55.7	13.7	5		-					
Voyageur	295006	41	351	55.7	13.7	3	280	135	18	None	WI	Wisconsin Dells	1964
			1A11	50	11.2	4.5		-					
Wisconsin	274765	9	351	50	11.2	3.2	325	85	21	None	WI	Wisconsin Dells	1953
			1A11	47.2	12	4.5		-					
Yellow Thunder	274833	28	351	47.2	12	3	202	117	14	None	WI	Wisconsin Dells	1952
Chicago Fireboat Cruise Co.													
			1A11	51	21	5		-					
Islander	249946	39	351	51	21	5	250	110	16	None	IL	Chicago	1946
Chicago from the Lake Ltd.													
			1A16	64.8	22	4.5		-					
Ft. Dearborn	686810	58	359	64.8	22	4.3	390	200	17.6	None	IL	Chicago	1985
			1A16	50.6	15	4		-					
Marquette	275663	26	359	50.6	15	3.5	378	68	14	None	IL	Chicago	1957
			1D16	26.5	10	5		-					
Tender No. 1	1059170	7	359	26.5	10	5	40	26	40	None	IL	Chicago	1997

Dredging Activity

Emission estimates for dredging activity is relatively sparse where the only data available is from a Houston area survey (Starcrest, 2000) where the emissions were estimated based on survey information for specific dredges and associated with the tonnage of dredged material. Other dredges may behavior differently than those specific dredges.

Historic dredging contracts are available from the Corps of Engineers (http://www.iwr.usace.army.mil/ndc/dredge.htm) and include the tonnage of material removed. Because nearly, if not all, dredging activity is contracted by the Corps or requires Corps permits to begin dredging, relative activity associated with dredge tonnage could be useful for dredging emissions estimates.

An alternative to using the Corps dredge tonnage activity information would be similar to the approach suggested for excursion vessels. Each dredge within the States of interest would be identified and categorized and average activity information would be collected by survey.

Commercial Fishing

Commercial fishing vessels are registered with the Coast Guard, so total numbers of vessels can be obtained (http://www.iwr.usace.army.mil/ndc/veslchar.htm). In this case, as with excursion vessels, the vessel counts need to be associated average activity estimates to produce emission estimates.

Another method could be to estimate the vessel activity as a function of fish landings because data is available on fish landings by state for all states and the Great Lakes region in particular and can be found at (http://www.st.nmfs.gov/st1/commercial/index.html) and shown in Tables 9-6 and 9-7. It would be necessary to determine typical vessel activity per pound of fish landing through targeted surveys.

Table 9-6. Fish landings by state.

Year	State	Metric Tons	Pounds	$
1999	Illinois	38.8	85,533	49,618
1999	Michigan	6,144.3	13,545,773	9,338,853
1999	Ohio	1,783.4	3,931,744	2,185,853
1999	Wisconsin	2,632.1	5,802,736	4,192,053
1999	Indiana	0	0	0

Table 9-7. Fish landings for Lake Michigan.

Year	Lake	State	Species	Pounds	Dollars
1999	Michigan	Illinois	Chubs	48,540	35,199
	-- State Total --			48,540	35,199
1999	Michigan	Michigan	Burbot	14,493	36
1999	Michigan	Michigan	Channel Catfish	647	45
1999	Michigan	Michigan	Chinook Salmon	8,242	2,640
1999	Michigan	Michigan	Chubs	223,330	129,611
1999	Michigan	Michigan	Cisco (Lake Herring)	925	353
1999	Michigan	Michigan	Gizzard Shad	4,419	531
1999	Michigan	Michigan	Lake Trout	979,532	431,027
1999	Michigan	Michigan	Lake Whitefish	4,758,829	3,802,224
1999	Michigan	Michigan	Rainbow Smelt	490,221	210,934
1999	Michigan	Michigan	Round Whitefish	79,233	26,947
1999	Michigan	Michigan	Suckers	44,754	6,711
1999	Michigan	Michigan	Walleye	1,326	2,096
1999	Michigan	Michigan	Yellow Perch	3,248	6,717
	-- State Total --			6,609,199	4,619,872
1999	Michigan	Wisconsin	Alewife	15,002	8,999
1999	Michigan	Wisconsin	Brown Bullhead	97	53
1999	Michigan	Wisconsin	Burbot	17,908	15,282
1999	Michigan	Wisconsin	Chubs	1,800,974	1,426,962
1999	Michigan	Wisconsin	Freshwater Drum	50	6
1999	Michigan	Wisconsin	Gizzard Shad	5,107	3,066
1999	Michigan	Wisconsin	Lake Whitefish	1,910,204	2,480,239
1999	Michigan	Wisconsin	Rainbow Smelt	846,017	1,903,632
1999	Michigan	Wisconsin	Round Whitefish	4,648	1,628
1999	Michigan	Wisconsin	Suckers	2,471	492
1999	Michigan	Wisconsin	White Bass	115	92
1999	Michigan	Wisconsin	White Perch	114	30
1999	Michigan	Wisconsin	Yellow Perch	173,524	459,675
	-- State Total --			4,776,231	6,300,156
	-- Year Total --			11,433,970	10,955,227

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