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AN ESTIMATION OF RIVER TOWBOAT AIR POLLUTION IN SAINT LOUIS, MISSOURI

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16. Abstract

This study gives an estimate of river towboat air pollution emissions for the St. Louis Air Pollution Study area. No emissions from secondary sources or from recreational boating on the river of other areas are considered. The emission estimate is based primarily on river traffic data taken by the Corps of Engineers at Lock 27 near St. Louis and on exhaust emission factors of similar engines of the Coast Guard fleet and railroad locomotives.

The emissions are given for each grid of the Environmental Protection Agency (EPA) St. Louis Grid Plan so that these results can be utilized for the St. Louis Regional Air Pollution Study.

The total annual emissions in the SLAPS region from towboats operating on the 135 miles of the Mississippi river and the 95 miles on the Missouri river are estimated to be:

Oxides of nitrogen	3,297	tons/year
Total hydrocarbons	939	" "
Carbon Monoxide	2,101	" "
Oxides of sulfur	462	" "
Particulates	198	" "

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PREFACE

This report presents the methodology for, and results of, estimating river towboat air pollution emissions for the St. Louis Air Pollution Study. The study was conducted as part of the Technology for Environmental Analysis Project (PPA-OS-522) by the DOT Environmental Measurements Branch, Transportation Systems Center, for the Energy and Environment Division, Office of the Secretary of Transportation.

The St. Louis Air Pollution Study (SLAPS) is composed of several individual studies exploring the relationships between the urban complex and air quality. These studies are investigating the sources of air pollution, the transport and transformation of air pollutants, and the effects of air pollution upon receptors.

This report is a revision of an earlier draft. It includes the following changes:

a) The revised EPA St. Louis Air Pollution Study grid layout is used.

b) Vessel emissions are given for the complete SLAPS area, including the Missouri River. The extended coverage plus the grid revisions have resulted in an increase of grid elements with vessel traffic, from 47 in the draft report, to 131.

c) Additional river traffic volume data from the Corps of Engineers for a week in January and one in April, 1974 have been used to improve the traffic data base.

d) A revised methodology estimates river traffic characteristics on the basis of a simple origin/destination analysis.

e) A simplified explanation of the methodology is given.

The results of this study are estimates of towboat exhaust emissions, and thus must be treated as approximations. However, variations in daily traffic volume are not large, and the emissions

estimates are considered representative of daily river towboat emissions. Reduced emissions occur under exceptional conditions, when river operations are severely curtailed (during periods of extreme flooding or icing, blockage of navigation, work stoppage, and so on).

The author gratefully acknowledges the assistance of Mr. Lambert Buckhold, Navigation Branch, U.S. Army Corps of Engineers, St. Louis, who provided the vessel traffic information; Lt. Wilburn Elkins, Marine Inspection Office, 2nd District, U.S. Coast Guard; Mr. J.B. King, Chief, Construction-Operations Division, U.S. Army Corps of Engineers, Omaha; and Mr. James Swift, Business Manager, Waterways Journal, St. Louis. The author also acknowledges the assistance provided by Russel R. Waesche, DOT Secretarial Representative, Region VII, and his staff; Ms. Dianne Soble, HUD Area Office, St. Louis, and the TSC staff members conducting the U.S. Coast Guard Vessel Emissions Monitoring and Control Project. The author is also grateful for the many hours of effort by Mr. David A. Knapton, Mr. Frank D. Lonergan, Mr. Robert Murphy, Mrs. Virginia Christiansen, and Mr. Paul R. Phaneuf, Raytheon Service Company.

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1. INTRODUCTION

1.1 OBJECTIVE

This report describes a method for estimating river towboat air pollution and it presents the estimates of air pollution emissions from river towboats operating in the region of St. Louis, Missouri. These emissions include: carbon monoxide (CO), oxides of nitrogen (NO_x), total hydrocarbon (THC), oxides of sulfur (SO_x), and particulates (Part). The emissions estimate will be used by participants of the St. Louis Air Pollution Study (SLAPS).

1.2 SCOPE

This study is limited to primary air pollutants emitted from river towboat diesel engines. Emissions originating from ship electrical-service generating units, cargo, loading and unloading activities, and fueling and maintenance operations are not included.*

The emissions are estimated for river towboats operating on the waterways within the SLAPS region. This area includes the Mississippi River, from Mile 100 below St. Louis to Mile 235** above St. Louis; and the Missouri River from the confluence of the Mississippi River to near Mile 95. This area is shown in Figure 1-1.

The method used consists of estimating river traffic and propulsion engine characteristics from limited statistical information on river traffic and from observations by Coast Guard and Army Corps of

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*Secondary emissions are probably rather small, as compared to the exhaust emission. For example, ship electrical service generating units have a maximum rating that is approximately three percent of the propulsion unit and they are normally operated well below capacity.

**River miles given here are based on Corps of Engineers river distance measured above the mouth of the Ohio River. The Gateway Arch in St. Louis is located near Mile 180.

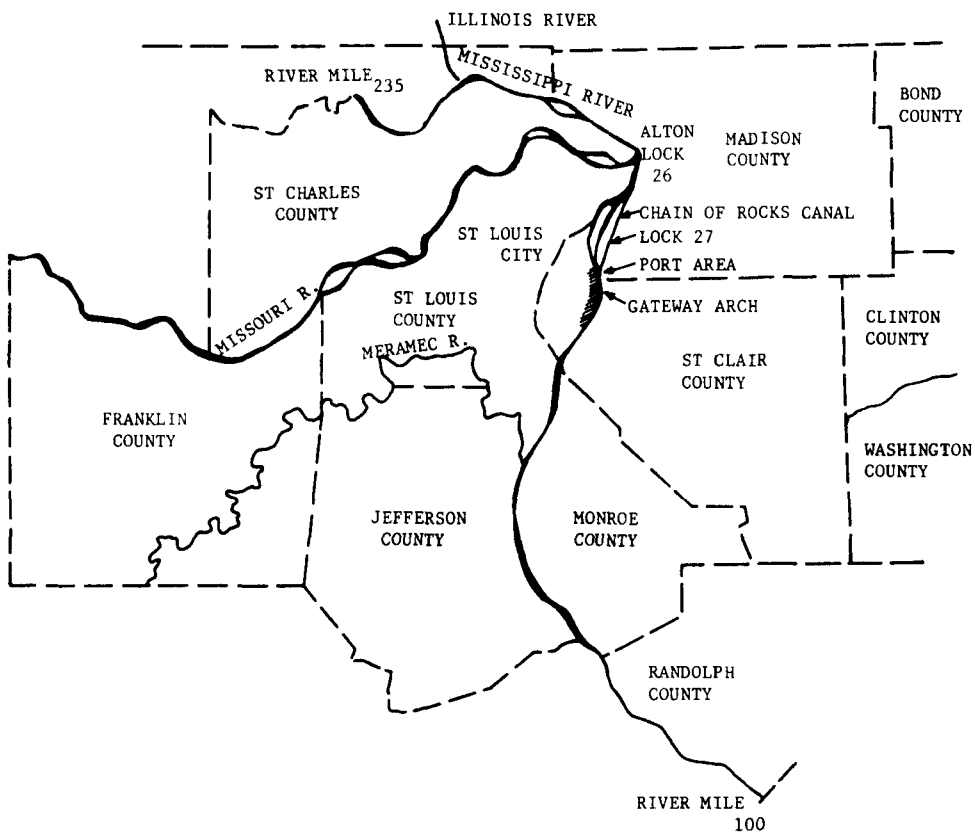

Figure 1-1. St. Louis Air Pollution Study Area

Engineers personnel familiar with river vessel operations. The traffic volumes and engine types are then used to calculate emissions, based on measurements of emissions factors for similar diesel engines used on Coast Guard vessels and rail locomotives. No emission testing of towboats was undertaken during this study.

The emissions are calculated and presented for the EPA St. Louis grid plan.* This layout divides the 10 county area into grids of 1, 2, 3, 4, 5, 6, and 10 km squares, depending upon the level of expected air pollutant emissions.

1.3 LIMITATION OF RESULTS

Emissions estimates presented are made from the averages of daily river traffic volume and towboat engine characteristics. The volume of traffic is low and the range of vessel characteristics is large, so that an estimate of hourly emission rates is not practical; therefore, the emissions are expressed only as daily estimations. No error estimate or sensitivity analysis was made, as a greater level of effort would be required to establish the distribution and accuracy of all the variables. While no verification of the emissions inventory accuracy was possible, the estimation is sufficiently accurate to determine the relative contribution of towboats to St. Louis air pollution and to serve as input data for the urban atmospheric dispersion model under development by the U.S. Environmental Protection Agency (EPA) for their Regional Air Pollution Study (RAPS).

*EPA, St. Louis Grid Square Coordinates, June, 1974.

2. RIVER TRAFFIC - ST. LOUIS, MISSOURI

2.1 HISTORICAL PERSPECTIVE

The American river system has provided a vital right-of-way for transportation. It contributed to the Western expansion of a century ago and today continues to promote the economic well-being of our nation.

In the early 19th century, keelboats were the primary mode of river traffic. Transportation downstream was relatively easy; but to move upstream, laborers had to walk the river bank, pulling the boat with ropes while others aboard pushed with poles which reached the river bottom. Although steam-powered towboats became dominant around the time of the Civil War, freight movements were still usually with the river flow. Not until the development of propeller towboats, around World War I, was there significant bi-directional freight traffic. In 1930, the diesel engine began replacing the steam engine as the primary propulsion for towboats, and by 1974 there were no steam-powered towboats on the Mississippi River system.

Since the introduction of the diesel engine and the development and improvement of existing waterways by the U.S. Army Corps of Engineers, total ton mileage has increased from 9 billion in 1930 to 210 billion in 1970.[1]*

The Mississippi River constitutes the major link for the 6,000 navigable miles of the Mississippi Valley's system of inland waterways. The river is navigable from Minneapolis, MN to New Orleans, LA, a distance of 1,837 miles. St. Louis lies near the mid-point. Above St. Louis are 28 locks and dams constructed by the U.S. Army Corps of Engineers to aid navigation. Open waters lie south of St. Louis and extend below New Orleans to the delta at the Gulf of Mexico.

*Numbers in parentheses refer to the references in Chapter 6.

2.2 ST. LOUIS - PRESENT

The Port of Metropolitan St. Louis consists of 70 miles of Mississippi River frontage between mile 138.8 and mile 208.8. Included in this stretch are Lock 27 on the Chain-of-Rocks Canal, a ten-mile canal built to bypass a low-water area approximately 6 miles above St. Louis, and Lock 26, further upstream near Alton, Ill.

St. Louis is one of the busiest inland ports in the United States. It serves as a major transfer point for both upstream and downstream traffic on the Mississippi River System. However, port freight volume has increased only about 10 percent since 1960 while other port cities along the Mississippi have sometimes doubled or tripled their freight volume over that same period.[2]

St. Louis is still the third largest port on the river and the river itself in the St. Louis area handles approximately 50,000,000 tons per year in terminal and thru traffic. This freight volume generates a significant amount of river traffic.

The vessel traffic in the St. Louis area consists of long-distance transit tows, originating and terminating long-distance tows, intra-port traffic, switcher boat fleeting operations (making and breaking tows) and the operations in passing through Lock 26 to Lock 27. Approximately 50 barges are either loaded or unloaded per day and about 700-800 barges are handled each day in making and braking tows in the St. Louis port area.[3]

Tows vary in size from one to as many as fifty or sixty barges. A typical tow is about 1,000 ft. long. Tows above the St. Louis area are restricted by the Army Corps of Engineers to 17 barges. The lock width restrictions dictate that tows be split into smaller tows with a minimum size of two barges in width by six barges in length. Below St. Louis, tows are generally larger. Typical tows are usually five barges in length by six barges in width.

Towboat engines range in size from around 100 hp to over 10,000 hp. Towboats with engine sizes under 500 hp have proved inefficient for transporting barges over large distances and are generally utilized in the immediate port vicinity for preparation of larger tows. Engine sizes substantially over 10,000 hp are unlikely in the near future, since engines in 7,000-9,000 hp range can handle as large a tow as is possible to maneuver on the Mississippi with present navigation technology.[4]

3. EMISSIONS ASSESSMENT

3.1 METHODOLOGY

The air pollutants emitted by river vessel propulsion systems are calculated by the following expression:

Emissions = Horsepower-Hours x Emission Factor

where:

Emissions (grams per day per grid element)

Horsepower-Hours (Number of towboats per grid per day) x (average HP x average throttle position) x (grid distance/average speed)

Emission Factors (grams per HP-hour for carbon monoxide (CO), oxides of nitrogen (NO_x), total hydrocarbon (THC), oxides of sulfur (SO_x), and particulates (Part)).

River traffic data (the number of towboats and engine horsepower, average throttle settings and average speeds) are estimated in Section 3.2. The selection of emission factors is presented in Section 3.3. In Section 4, the emissions are calculated by grid and in Section 5 per mile of navigable waterway in the SLAPS region.

The following methodology was used to determine river vessel exhaust emissions.

Step 1 - River Vessel Traffic Characteristics

Examine available statistical data and qualitative information on river traffic in order to divide the river and traffic into zones, where, within each zone, traffic characteristics can be assumed to be uniform. (Sections 3.2.1 and 3.2.2)

Step 2 - EPA Grid Locations and Travel Distance for each Grid

Draw grids on U.S. Geological Survey Maps using the

Universal Transverse Mercator (UTM) system coordinates specified by EPA. Vessel travel distances for each grid are then measured along the river center.

Step 3 - Determine River Traffic Volume Counts

Determine average traffic flow for the assumed types of traffic and zones determined in Step 1. (Sections 3.2.2, 3.2.3, 3.2.4, 3.2.5, 3.2.6)

Step 4 - River Vessel Horsepower

Determine average river vessel engine horsepower for the assumed traffic and zones. (Sections 3.2.2, 3.2.3, 3.2.4, 3.2.5)

Step 5 - Vessel Average Engine Duty Cycle

Determine average river engine throttle setting and times of operation (utilization factors) based on estimates made by the Corps of Engineers, for upbound and downbound traffic and switcher boats. (Sections 3.2.5, 3.2.6, 3.2.7)

Step 6 - Vessel Average Speeds

Determine vessel speeds, upbound and downbound, for the various zones of operations based on estimates made by the Corps of Engineers. (Section 3.2.7)

Step 7 - Vessel Horsepower-Hours Per Grid Per Day

Calculate river vessel horsepower-hours per grid per day by the expression;

Horsepower-Hours = (Number of towboats per grid per day) x (average HP x average throttle) x (grid distance/ average speed)

Step 8 - Emission Factors

Identify river vessel engine types by manufacturer and model representative of the towboat population.

Determine emission factors for engines identified for the proper horsepower utilization factor. Incorporate a frequency weighting factor for each engine to determine the average emission factor for the pollutants CO, NO_x, THC, SO_x and particulates. These emission factors are in grams per brake horsepower-hour. (Section 3.3)

Step 9 - Emissions

Calculate the river vessel exhaust emissions by the equation:

Emissions = Horsepower-Hours x Emission Factor where emissions are in grams per day per grid element. The emissions are calculated separately for upbound and downbound; through and local traffic and for the switcher boats in the terminal areas.

Step 10 - Yearly Distribution

Determine the estimated distribution of river traffic over the year so that the emissions calculated in Step 9 may be adjusted for time of year.

3.2 RIVER TRAFFIC

3.2.1 Daily Mississippi Towboat Traffic

Towboat operation in the SLAPS area is estimated by analyzing a combination of (1) vessel traffic records collected by the St. Louis Corps of Engineers at Lock 27, (2) estimates (by the Coast Guard and the Corps of Engineers personnel at St. Louis and at Omaha) of river traffic characteristics, and (3) from aggregate statistics of waterborne commerce issued by the Corps of Engineers at New Orleans.

The only actual count of river towboat activity is that taken at Lock 27. No other traffic records are taken at any other location in the SLAPS region. Passage through Lock 27 is recorded by the

Corps of Engineers* and includes towboat name and owner, horsepower, direction of travel, origin and destination, number of barges and cargo tonnage, and times of passage through the lock. For this study, lock traffic for four periods is used and is summarized in Table 3-1.

TABLE 3-1 SUMMARY OF TRAFFIC, LOCK 27, MISSISSIPPI RIVER

Month/Year	No. of Days	No. of Towboats/Day	Daily Average	Average HP
August, 1973	4	36, 29, 37, 33	33.8	1958
Sept., 1973	4	30, 34, 33, 24	30.2	2256
Jan., 1974	5	29, 27, 33, 34, 32	31.0	2536
April, 1974	6	35, 31, 29, 28, 42, 38	33.8	2483
Average			32.2	2336

A value of 32 towboats** per day through Lock 27 is selected for the average river traffic above St. Louis.***

3.2.2 Towboat Route and Horsepower Size Distribution at Lock 27

The averages of traffic and horsepower in Table 3-1 were considered insufficiently disaggregated for estimating emissions. Therefore, traffic through the Lock was divided by origin and destination to provide some indication of traffic volume and

*U.S. Army Corps of Engineers, St. Louis, Missouri, Form Number 68.

**This does not include towboat activity at the docks and terminals making and breaking tows, see Sections 3.2.3, 3.2.4, 3.2.5.

***The "center" of the port is assumed to be that location on the river where half the dock facilities are above that point and half the docks are below midpoint is called "above" St. Louis and downstream from the midpoint is called "below" St. Louis.

towboat horsepower characteristics on the various segments of the Mississippi River and its navigable tributaries. The traffic route and horsepower distribution for the September and April observation periods (total 10 days, 320 towboats) given in Table 3-2.

TABLE 3-2. MAJOR ROUTES OF TOWBOATS THROUGH LOCK 27 SEPTEMBER 1973 (4 DAYS) AND APRIL 1974 (6 DAYS)

Location of Upper Port	Location of Lower Port	Percent Two-Way Traffic through Lock 27	Avg. HP
Missouri	Below St. Louis	1	2667
Mississippi R.	Below St. Louis	12	3447
Illinois R.	Below St. Louis	20	3747
Alton area	Below St. Louis	9	2410
Missouri R.	St. Louis	2	3000
Mississippi R.	St. Louis	17	2481
Illinois R.	St. Louis	8	2314
Alton area	St. Louis	31	1191
		100	

Examination of the towboat "horsepower distribution" for the ten day sample indicated: (1) 1000-2000 HP class towboats are in considerable use in the St. Louis/Alton area; (2) through traffic consists of many sizes of towboats (3200 HP is the most frequent size; some are in the 5000-7000 HP range); and (3) smaller towboats of less than 2000 HP are generally used for moving small tows to the Ohio River or short distances below the St. Louis SLAPS region. The analysis also showed that the average size of towboats was smaller above St. Louis than below.

In addition to the Mississippi River System traffic above St. Louis, there are additional distinct segments of river traffic activity not shown in the Lock 27 data. These are: (1) traffic

below St. Louis; (2) Missouri River traffic; (3) St. Louis port activity associated with barge terminals; and (4) activity associated with Lock 26 and 27. For making the emissions calculations, a traffic flow split was established on the basis of the distribution shown in Table 3-2 and on the contribution of traffic from other activity described below. The traffic flow is shown in Figure 3-1.

3.2.3 Traffic Below St. Louis

The greatest uncertainty in estimating river vessel emissions is that portion contributed by towboats below St. Louis which do not go through Lock 27. Since Lock 27 is the only point in the SLAPS region where river traffic is counted, the river traffic which stays either above or below the Lock is not counted. As most of the St. Louis port activity is below the Lock, the assumption was made that little traffic stayed above the Lock 27 and therefore the emissions for such traffic could be neglected. Traffic below Lock 27 consists of: (1) traffic between ports above the lock and the port area, (2) local switcher boat activity, (3) traffic between ports above the lock and below St. Louis and (4) traffic on the lower Mississippi which either originates or terminates below Lock 27. Of these four categories, the vessels which go through the lock are counted and averaged for this calculation and the port activity is based upon Coast Guard estimates.

The Corps of Engineers annual inland waterway statistical summary[5] indicates that the annual number of towboats on the Mississippi River below St. Louis averages 20 vessels per day. For our calculations, we have assumed that 24 vessels per day use the Mississippi below St. Louis. The routes of sixteen of these include passage through Lock 27 and are counted. An additional eight are assumed to either start or end their journeys below Lock 27. This is only half the number observed that either start or end their journeys below Lock 27 and whose trips are above St. Louis. The tows below St. Louis are normally larger than those going above St. Louis, and below the city there is likely to be no

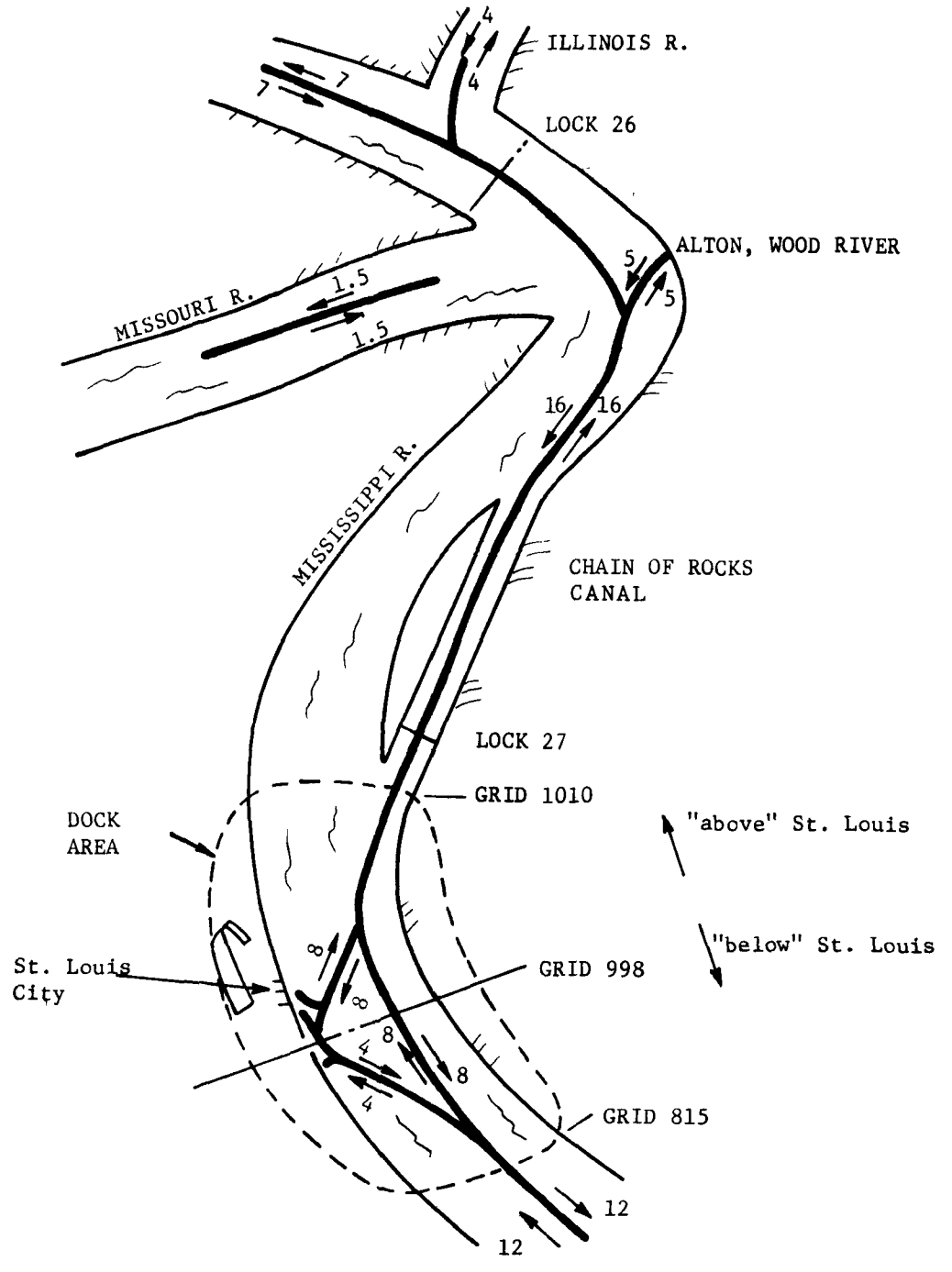

Figure 3-1. St. Louis Area River Vessel Traffic Estimates (Numbers Refer to Vessels Per Day)

concentration of inter port activity similar to that between the city and the Alton area. Therefore, a smaller number of tows but of average larger size is assumed below St. Louis.*

3.2.4 Missouri River Traffic

Traffic information on the Missouri River was provided by the Corps of Engineers at Omaha. They estimated that during the navigation season approximately 3 tows per day (total, both directions) are on the lower end of the Missouri River.** For this estimate 1-1/2 tows, each direction per day were used. Speeds estimated by the Coast Guard are 6 mph upbound and 10 mph downbound. Average horsepower from Omaha Corps of Engineers information was 2400 HP.

3.2.5 Port Area Traffic

In the St. Louis port area, switcher boats are responsible for "spotting" barges when making and breaking tows and moving barges to docks and yards.

Estimates of port area activity from the U.S. Coast Guard Office in St. Louis was that 15 towboats operating as switcher boats were within the port area. Since this was the only information available, switcher boat traffic density was assumed to be 15 vessels per day in the port area.

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*A check on the traffic estimate is given by estimating the number of barges handled per day in the St. Louis area (see Figure 3-1). The traffic estimate check consists of calculating total barges for: (1) 16 tows/day between St. Louis and the upper Mississippi River System (18 barges/tow), (2) 10 tows/day originating or terminating in the Alton area (18 barges/tow), (3) 8 tows/day between St. Louis and the lower reaches of the Mississippi River (30 barges/tow). This calculation shows 708 barges per day handled in the St. Louis port area. This total number of barges is in agreement with that indicated by Kearney (3), who estimated 50 barges loaded and unloaded per day and 700-800 barges handled in making and breaking tows per day.

**See Section 3.2.8.1 for monthly variation.

Switcher boats operate part of the day with their engines at idle because of the nature of their operations; therefore, the following duty cycle was assumed:

1/2 of the operating period at idle

1/2 of the operating period at 50 percent power setting.

The duty cycle was assumed to be applicable for all switcher boats in the port area, and that the duty cycle for switcher boats was 8 hours for a normal working day.

Switcher boat engines usually range from 300 to 500 horsepower. An average of 400 hp was used for this analysis. Therefore, the 15 port area switcher boats contribute an estimated 12,000 hp-hr daily.

The distribution of port activity was determined from an Army Corps of Engineers' publication listing Mississippi River terminals, docks, mooring locations and warehouses which located the terminals and docking areas within each grid element.[6] Table 3-3 cites those grids (Column 1) and gives the number of terminals within that grid (Column 2). Column 3 lists the weighting factors arrived at by dividing the number of terminals within each grid element by the 67 total number of terminals. Column 4 gives horsepower-hours contributed by switcher boats to each grid.

3.2.6 Passage through Locks 26 and 27

River traffic on the Mississippi River must traverse two locks in the SLAPS region, Lock 26 at Alton and Lock 27 on the Chain-of-Rocks Canal. Frequently the tow must be broken into two segments before entering the lock and additional time is required for re-assembling it. Corps of Engineers personnel estimate an average combined time of delay while waiting to enter the locks, possibly breaking the tow, lock passage, and re-making the tow at three hours for Lock 27 and five hours for Lock 26. The emissions for each lock are calculated on the basis of the waiting periods (engines at idle) without consideration for short periods of propulsion used in positioning the tows and traversing the locks. The lock traffic data are shown in Table 3-4.

TABLE 3-3. ALLOCATION OF SWITCHING BOAT HP-HR TO GRID AREAS

(1) GRID #	(2) NO. OF TERMINALS(8)	(3) WEIGHTING FACTORS	(4) HP-HR* PER GRID
1010	5	.08	960
1073	4	.06	720
1072	6	.08	960
1069	4	.06	720
1038	2	.03	360
1032	4	.06	720
1031	4	.06	720
1030	5	.08	960
999	4	.06	720
998	6	.09	1,080
955	8	.12	1,440
924	3	.04	480
849	2	.03	360
848	3	.04	480
847	4	.06	720
815	3	.04	480
Total	67	.99*	11,880**

*as % of 12,000 hp-hr.

**1% due to rounding = 120 hp-hr.

TABLE 3-4. TOWBOAT PASSAGE THROUGH LOCKS IN SLAPS REGION

Lock	Grid used for Wait		Wait Time (hrs)	Towboats (both directions) and HP
	Upbound	Downbound		
26	1019	1048	5	22 (2900 HP)
27	1078	1010	3	22 (2900 HP) and 10 (1200 HP)

3.2.7 Towboat Speeds and Throttle Settings

Towboat speeds are influenced primarily by the river current and difficulty of navigation. For this study the river system is broken into three zones of different speed operation:

1. Chain-of-Rocks Canal,
2. Missouri River,
3. Mississippi River.

The Chain-of-Rocks Canal is essentially a constant level pool with no current. Narrowness of the waterway restricts speeds to 5-7 mph. Six mph was used for our calculations. Towboat speeds on the Missouri River are 6 mph upbound and 10 mph downbound. These speeds were suggested by the St. Louis Coast Guard Office.

The Mississippi River towboat speeds used are 5 mph upbound and 10 mph downbound. This is the average speed indicated by the American Waterways Operators, Inc. for traffic between St. Louis and New Orleans.

Average horsepower utilization factors (throttle settings) were obtained from personnel of the U.S. Coast Guard Marine Inspection Office in St. Louis. Their estimates were based on personal experience and information obtained from the towboat industry. Throttle settings used in this study are shown in Table 3-5.

TABLE 3-5. THROTTLE SETTING VALUES ON THE UPPER MISSISSIPPI RIVER SYSTEM[4]

Waterway Segment	Throttle Setting*
Mississippi River (exclusive of Chain-of-Rocks Canal)	Upbound 0.85 Downbound 0.50
Missouri River	Upbound 0.75 Downbound 0.50
Chain-of-Rocks Canal	
Large Towboats	Upbound 0.33 Downbound 0.33
Small Towboats	Upbound 0.75 Downbound 0.75
Lock 26, 27	Idle
Port Area Activity	Switcher boat duty cycle (See Section 3.2.5)

*Idle throttle setting: 0
Full-power throttle setting: 1.00

3.2.8 Temporal Distribution of Traffic

3.2.8.1 Daily and Monthly - The traffic data acquired for this study displayed little variation on a daily or monthly basis. From other information sources, it is known that ice on the Missouri River and on the upper reaches of the Mississippi curtail vessel movements during the winter months. Likewise, periods of high water, i.e., flooding, also reduce (if not completely stop) towboat operations. The Illinois River and the Mississippi River throughout the SLAPS region are normally open to river traffic all year long. Short periods of cold weather may cause ice on the Mississippi pool above Lock 26.[8] Stoppages in towboat operations are infrequent and thus no emission reduction is assumed for this area. The Missouri River is normally closed to navigation from the beginning of December to the first of March. (The actual dates are a function of the weather conditions.) Therefore,

vessel emissions are considered to be zero for the Missouri River from 1 December to 1 March each year.

3.2.8.2 Hourly - River vessel traffic cannot be estimated on an hourly basis. Therefore, there can be no disaggregation of emission rates on an hourly time scale and have it remain meaningful. Actual hourly emissions per grid range from zero (when no towboat is in the grid) to as much as five times the hourly average based on daily emission rates when a large towboat is traveling upbound.

3.2.9 Summary of River Traffic Data Used for Emissions Calculations

In Figure 3-1 values used for the river traffic data in calculating horsepower-hours are illustrated. Values of vessel traffic and engine characteristics are shown in Table 3-6.

3.3 EMISSION FACTORS

As shown in section 3.1, towboat emissions are calculated by taking the product of horsepower hours and emission factors, the latter are expressed in mass of pollutant per horsepower-hour.

An emission factor is a statistical average, or a quantitative estimate, of the rate at which a pollutant is emitted as a result of a particular activity, divided by the level of that activity. Emission factors are estimated by a variety of techniques, including measurements of typical sources, process material balances and engineering estimates. As such, they are not precise indicators of single source emissions; they are more valid when estimating emissions from an aggregation of sources. In addition, the accuracy of emissions calculated by emission factors improves as the similarity increases between the source used when establishing the emission factors and the source(s) being estimated.

In this study, emission factors are based on measurements taken of diesel engines used on both Coast Guard vessels and on railroad locomotives.[9,10,11,12] The towboat prime movers are similar to the engines of the Coast Guard fleet and locomotives. The two variables used in determining the emission factors are:

TABLE 3-6. SLAPS TOWBOAT TRAFFIC CHARACTERISTICS

SECTION	DESCRIPTION	TYPE OF TRAFFIC	END GRIDS		NO. EACH VESSLES DIRECTION	AVG. HP	THROTTLE SETTING		SPEED (mph)	
			NORTH	SOUTH			UP*	DOWN*	UP*	DOWN
1	Missouri R.	Through	4(West)	2302	1.5	2400	.75	.50	6	10
2	Mississippi R. above Ill. R.	Through	141	242	7	2900	.85	.50	5	10
3	Mississippi R. Ill. R. to Alton	Through	394	1019	11	2900	.85	.50	5	10
4	Mississippi R. Alton to Canal	Through	1087	1233	11	2900	.85	.50	5	10
	Mississippi R. Alton to Canal	Local	1087	1233	5	1200	.85	.50	5	10
5	Chain-of-Rocks Canal	Through	1082	1079	11	2900	.33	.33	6	6
	Chain-of-Rocks Canal	Local	1082	1079	5	1200	.75	.75	6	6
6	Lock 27	Through	1010	1078	11	2900	Idle	Idle		
		Local	1010	1078	5	1200	Idle	Idle		
7	Mississippi R. Canal to Middle of Port	Through	1040	1030	11	2900	.85	.50	5	10
	Mississippi R. Canal to Middle of Port	Local	1040	1030	5	1200	.85	.50	5	10
		Switcher Boats	1030	1030	15	400	Switcher Boat Duty Cycle			
8	Mississippi R. Middle of Port to End of Port	Through		815	12	2900	.85	.50	5	10
		Switcher Boats	1234	815	15	400	Switcher Boat Duty Cycle			
9	Mississippi R. Below Port	Through	998	1685	12	2900	.85	.50	5	10
10	Lock 26	Through	1048	1019	11	2900	Idle	Idle		

*Up: upward-bound vessels.
*DOWN: downward-bound vessels.

(1) manufacturer and type of engine, (2) the percentage of throttle opening since emissions are non-linear with throttle load. Information on towboat engine types was obtained from the Inland River Records,[4] which documents approximately 3500 river vessels. Data available for each vessel include: vessel size and power plant type and size, age, manufacturer and model type.

A simple random sample of 250 observations was taken (reference, 4). Essential information about each observation was documented for analysis; e.g., total engine horsepower, engine manufacturer, engine type, etc.

According to reference 4, the manufacturers of towboat diesel engines are:

56 percent manufactured by General Motors Corporation (GMC)

21 percent by Caterpillar

6 percent by Cummins

5 percent by Superior

3 percent by Copper-Bessomer

The remaining 9 percent of the engines are manufactured by companies having less than 1 percent of the market.

Further analysis of the GMC data indicated that the three most common types of GMC engines present in the sample were:

1. GMC 567
2. GMC 645
3. GMC 71 Series.

The emission factors for these three engine series were aggregated to form composite emission factors. These three engine types propel the majority of the towboat fleet and their emission factor data are readily available. Figure 3-2 illustrates the total horsepower of the three engine series for the established sample; the figures were derived by multiplying the horsepower per engine by the number of engines in the sample. GM engines were

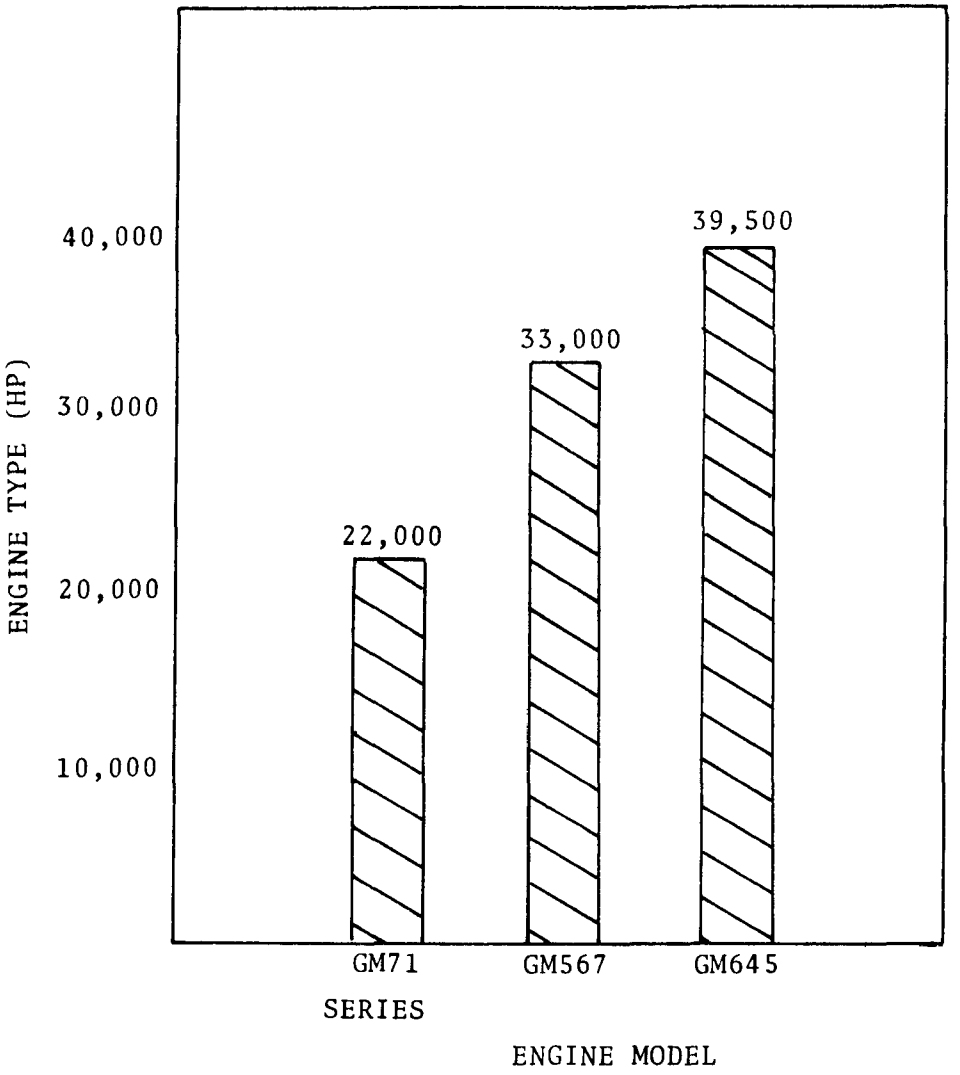

Figure 3-2. Horsepower Times Number of Engines in Statistical Sample[4]

used exclusively because the GM engine represents over 75 percent of the total horsepower in the statistical sample taken from The Inland River Record.

Table 3-7 shows the data used to determine the emission factors for CO, NO_x, and THC for upward bound towboats. The emission factors are for the three GM engines and are the values for 85 percent of full power which represent most of the upward-bound traffic (see Table 3-6). Similarly Table 3-8 presents the data used to determine the emission factors for CO, NO_x, and THC for downward-bound towboats, based on 50 percent of full power. The final emissions for CO, NO_x, and THC for upward-bound and downward-bound towboats are shown in Table 3-9.

Emission factors for SO_x and particulates were not available from actual measurements as were the other primary pollutants. Therefore, an EPA document[12] was used which gives these emission factors for heavy-duty truck and locomotive diesel engines. Since towboat engines are essentially the same as truck and locomotive engines, with slight modifications, these emission factors were considered acceptable for this study. Factors of 1.4 grams per horsepower-hour for SO_x and .6 grams per horsepower-hour for particulates were derived from the calculations presented in Table 3-10.

The emission factors for the upward-bound towboats are based on 85 percent of full power. They are assumed to be the same for the towboats at 75 percent of full power (upward-bound on the Missouri River and "local traffic" on the Chain-of-Rocks Canal). The emission factors for downward-bound towboats are based on 50 percent of full power. They are assumed to be the same for those towboats at 33 percent of full power (through traffic on the Chain-of-Rocks Canal).

In actual measurements of exhaust emissions little difference is noted between emissions in gm/hp-hr at 75 and 85 percent of full power. Also, some measurements show little difference between 33 and 50 percent of full power. Therefore, while some error may be introduced by using a single emission factor for upward-bound

TABLE 3-7. EMISSION FACTORS (CO, NO_x AND THC) FOR THE MOST PROMINENT GM ENGINES (85% OF FULL POWER) (IN GRAMS PER HORSEPOWER-HOUR)

ENGINE	EMISSION FACTORS		
	g/hp-hr		
	CO	NO_x	THC
GM-645[9,10]*	2.1	11.8	.6
	2.4	13.0	.8
	2.5	8.2	.6
	3.5	7.7	.5
Avg. g/hp hr	2.6	10.1	.6
GM-567[7]*	3.2	11.4	1.3
	3.8	11.7	1.1
	.9	8.6	3.2
	.9	8.4	3.4
Avg. g/hp hr	2.2	10.0	2.3
GM-71 Series*	6.8	10.7	1.1
	8.7	12.8	5.1
	11.2	13.5	4.1
Avg. g/hp hr	8.9	12.3	3.4

*Multiple data points.

TABLE 3-8. EMISSIONS FACTORS (CO, NO_x AND THC) FOR THE MOST PROMINENT GM ENGINES (50% OF FULL POWER) (IN GRAMS PER HORSEPOWER-HOUR)

ENGINE	EMISSION FACTORS		
	g/hp hr		
	CO	NO_x	THC
GM-645 [7,8]*	2.0	13.0	.7
	1.0	10.0	.8
	8.2	7.6	.4
	8.3	7.3	.4
	4.9	7.5	.4
	8.6	6.8	.5
Avg. g/hp hr	5.5	8.7	.5
GM-567 [7]*	1.9	8.1	4.5
	1.8	5.0	4.1
	1.3	6.1	4.1
Avg. g/hp hr	1.6	6.4	4.2
GM-71 Series *	2.6	10.5	2.8
	3.0	12.1	5.7
	6.8	14.1	4.2
Avg. g/hp hr	4.2	12.2	4.2

*Multiple data points

TABLE 3-9. COMPOSITE EMISSIONS FACTORS (CO, NO_X AND THC)

ENGINE	% OF TOTAL HP	Emission Factors g/hp-hr			Weighted Emission Factors (g/hp-hr X %)			Composite Emission Factors g/hp-hr
		CO	NO_X	THC	CO	NO_X	THC	
AT 85% OF FULL POWER SETTING								
GM71 Series	23%	8.9	12.3	3.4	2.0	2.8	0.8	CO 3.9
GM567	35%	2.2	10.0	2.3	0.8	3.5	0.8	NO_X 10.6
GM645	42%	2.6	10.1	.6	1.1	4.3	0.2	THC 1.8
AT 50% POWER SETTINGS								
GM71 Series	23%	4.2	12.2	4.2	1.0	3.0	1.0	CO 3.9
GM567	35%	1.7	6.4	4.2	0.6	2.2	1.5	NO_X 8.9
GM645	42%	5.5	8.7	0.5	2.3	3.7	0.2	THC 2.7

TABLE 3-10. EMISSIONS FACTORS FOR SO_x AND PARTICULATES[12]

Emissions in Grams per HP Hour*		
	Diesel truck engine (GM-71 Series)	Locomotive engine (GM 567 and 645)
Part	.3 g/hp hr	.6 g/hp hr
SO_x	.7 g/hp hr	1.6 g/hp hr

Weighted Emission Factors - Particulates

Engine Types	% of Total	Emission Factors	Weighted Emission Factors
GM-71 Series	23%	.3 g/hp hr	.1
GM567 & 645	77%	.6 g/hp hr	.5
			.6g/hp hr

Weighted Emission Factors - SO_x

Engine Types	% of Total	Emission Factors	Weighted Emission Factors
GM-71 Series	23%	.7	.2
GM 567 & 645	77%	1.6	1.2
			1.4 g/hp hr

*Emission factors were presented in lbs of pollutants per thousand gallons of fuel in the reference source. Emission factors were converted to grams per hp hour in keeping with the study methodology by using the conversion factor 0.4 lbs of fuel consumed per horsepower-hour.

traffic and a single emission factor for downward-bound traffic, the uncertainty is less than for other factors and assumptions. The horsepower-hour calculations are based on the actual estimated percentages of engine loads to account for some of the possible differences in emissions due to different loadings.

The emission rates in grams per hour for an engine at idle are given in Table 3-11.

TABLE 3-11. EMISSIONS FACTORS AT IDLE[10,12]

400-HP Diesel Engine	
CO	1560 grams/hour
NO_x	95 grams/hour
THC	535 grams/hour
SO_x	27 grams/hour
Part	13 grams/hour

4. EMISSIONS CALCULATIONS

This section presents the emission estimates in tabular form. Table 4-1 is an index of the tables showing the table numbers for the various sections of waterway.

Tables 4-2 through 4-17 show the estimated river vessel horsepower-hours and emissions. The emissions are given for CO, THC, NO_x, SO_x and particulates for each grid and are in units of grams per day.

Table 4-18 summarizes the river vessel emissions for all the sections of waterway and for the entire SLAPS area. The emissions associated with the switcher boats at idle were calculated for a 400 hp GM-71 Series engine. This engine is considered representative of the total switcher boat population operating in the port area. Emissions of the larger towboats at idle waiting at the locks are taken in proportion to their horsepower and to the values shown in Table 3-11.

TABLE 4-1. EMISSIONS CALCULATION OUTLINE

			TABLE NO.	
SECTION	DESCRIPTION	TYPE OF TRAFFIC	HP-HOURS	EMISSIONS
1	Missouri R.	Through	4-2	4-3
2	Upper Mississippi to Ill. R.	Through	4-4	4-5
3	Ill. R. to Alton	Through	4-4	4-5
4	Ill. R. to Chain-of-Rocks C.	Through Local	4-4 4-4	4-5 4-5
5	Chain-of-Rocks Canal	Through Local	4-6 4-6	4-7 4-7
6	Lock 27	Through Local	3-4 3-4	4-17 4-17
7	St. Louis Port Area - North	Through Local Switcher Boats TOTAL(ZONE 7)	4-8 4-8 3-3	4-9 4-9 4-10 4-11
8	St. Louis Port Area - South	Through Switcher Boats TOTAL(ZONE 8)	4-12 3-3	4-13 4-10 4-14
9	Below Port Area	Through	4-15	4-16
10	Lock 26	Through	3-4	4-17
	TOTAL SLAPS			4-18

TABLE 4-2. TOWBOAT TRAFFIC (HP-HR PER GRID PER DAY), MISSOURI RIVER

(HERMANN TO MISSISSIPPI RIVER - SECTION 1)
(2400 HP AVG., UPBOUND 6 mph, 0.75 FULL POWER DOWNBOUND 10 mph, 0.50 FULL POWER, MARCH 1 TO NOV. 30)

GRID NO. (42 GRIDS)	GRID DIST. (KM)	GRID DIST. (MILES)	AVG. DAILY VESSELS UPBOUND DOWN-BOUND	TIME (HOURS) UP-BOUND	HP-HR UPBOUND	TIME (HOURS) DOWN-BOUND	HP-HR DOWN-BOUND
2,302	1.3	.807	1.5	.135	364.5	.0807	145.26
2,295	2.3	1.428		.238	642.6	.1428	257.04
2,287	2.4	1.490		.248	669.6	.1490	268.20
914	5.7	3.540		.590	159.3	.3540	637.20
737	4.0	2.484		.414	1117.8	.2484	447.12
738	2.8	1.739		.290	783.0	.1739	313.02
569	6.5	4.037		.673	1817.1	.4037	726.66
568	2.9	1.801		.300	810.0	.1801	324.18
392	6.0	3.726		.621	1676.7	.3726	670.68
309	3.7	2.298		.383	1034.1	.2298	413.64
308	3.3	2.049		.342	923.4	.2049	368.82
288	3.0	1.863		.311	839.7	.1863	335.34
287	1.1	.683		.114	307.8	.0683	122.94
286	1.0	.621		.104	280.8	.0621	111.78
2,149	.4	.248		.041	110.7	.0248	44.64
2,127	1.9	1.180		.197	531.9	.1180	212.40
2,126	1.985	1.233		.206	556.2	.1233	221.94
2,105	.885	.550		.092	248.4	.0550	99.00
2,104	1.731	1.075		.179	483.3	.1075	193.50
2,078	2.231	1.385		.231	623.7	.1385	249.30
2,085	1.038	.645		.108	291.6	.0645	116.10
2,084	1.038	.645		.108	291.6	.0645	116.10
2,083	1.154	.717		.120	324.0	.0717	129.06
192	4.692	2.914		.486	1312.2	.2914	524.54
160	3.462	2.150		.358	966.6	.2150	387.00
2,045	2.077	1.290		.215	580.5	.1290	232.20
135	5.346	3.320		.553	1493.1	.3320	597.60
106	4.769	2.962		.494	1333.8	.2962	533.16
105	4.438	2.756		.459	1239.3	.2756	496.08
87	5.8	3.602		.600	1620.0	.3602	648.36
74	3.7	2.298		.383	1034.1	.2298	413.64
73	2.6	1.615		.269	726.3	.1615	290.70
68	5.7	3.540		.590	1593.0	.3540	637.20
59	5.6	3.478		.580	1566.0	.3478	626.04
52	1.2	.745		.124	334.8	.0745	134.10
47	1.2	.745		.124	334.8	.0745	134.10
2,011	3.5	2.174		.362	977.4	.2174	391.32
22	10.5	6.521		1.087	2934.9	.6521	1173.78
14	3.2	1.987		.331	893.7	.1987	357.66
15	5.2	3.229		.538	1452.6	.3229	581.22
9	4.2	2.608		.435	1174.5	.2608	469.44
4	4.8	2.981	1.5	.497	1341.9	.2981	536.53
TOTALS	140.348	87.159					

TABLE 4-3. TOWBOAT EMISSIONS (GRAMS PER GRID PER DAY), MISSOURI RIVER (HERMANN TO MISSISSIPPI RIVER - SECTION 1, MARCH 1 TO NOV. 30)

GRID NO.	THC 1.8 G PER HP-HR UP	THC 2.7 PER HP-HR DOWN	NO_x 10.6 G PER HP-HR UP	NO_x 8.9 G PER HP-HR DOWN	CO 3.9 G PER HP-HR UP	CO 3.9 G PER HP-HR DOWN	SO_x 1.4 GR PER HP-HR UP	SO_x 1.4 GR PER HP-HR DOWN	PART .6 G PER HP-HR UP	PART .6 G PER HP-HR DOWN
2,302	656	392	3,864	1,293	1,422	567	510	203	219	87
2,295	1,157	694	6,811	2,288	2,506	1,002	900	360	386	154
2,287	1,205	724	7,098	2,387	2,611	1,046	937	375	402	161
914	287	1,720	1,689	5,671	621	2,485	223	893	96	382
737	2,012	1,207	11,849	3,979	4,359	1,744	1,565	626	671	269
738	1,409	845	8,300	2,786	3,058	1,221	1,096	438	470	188
569	3,271	1,962	19,261	6,467	7,087	2,834	2,544	1,017	1,090	436
568	1,458	875	8,586	2,885	3,159	1,264	1,134	454	486	195
392	3,018	1,811	17,773	5,969	6,539	2,616	2,347	939	1,006	402
309	1,861	1,117	10,961	3,681	4,003	1,613	1,448	579	620	248
308	1,662	996	9,788	3,282	3,601	1,438	1,293	516	554	221
288	1,511	905	8,901	2,984	3,275	1,308	1,176	469	504	201
287	554	332	3,263	1,094	1,200	479	431	172	185	74
286	505	302	2,976	995	1,095	436	393	156	168	67
2,149	199	121	1,173	397	432	174	155	62	66	27
2,127	957	573	5,638	1,890	2,074	828	745	297	319	127
2,126	1,001	599	5,896	1,975	2,169	866	779	311	334	133
2,105	447	267	2,633	881	969	386	348	139	149	59
2 104	870	522	5,123	1,722	1,885	755	677	271	290	116
2,078	1,123	673	6,611	2,219	2,432	972	873	349	374	150
2,085	525	313	3,091	1,033	1,137	453	408	163	175	70
2,084	525	313	3,091	1,033	1,137	453	408	163	175	70
2,083	583	348	3,434	1,149	1,264	503	454	181	194	77
192	2,362	1,416	13,909	4,668	5,118	2,046	1,837	734	787	315
160	1,740	1,045	10,246	3,444	3,770	1,509	1,353	542	580	232
2 045	1,045	627	6,153	2,067	2,264	906	813	325	348	139
135	2,688	1,614	15,827	5,319	5,823	2,331	2,090	837	896	359
106	2,401	1,440	14,139	4,745	5,202	2,079	1,867	746	800	320
105	2,231	1,339	13,137	4,415	4,833	1,935	1,735	695	744	298
87	2,916	1,751	17,172	5,770	6,318	2,529	2,268	908	972	389
74	1,861	1,117	10,961	3,681	4,033	1,613	1,448	579	620	248
73	1,307	785	7,699	2,587	2,833	1,134	1,017	407	436	174
68	2,867	1,720	16,886	5,671	6,213	2,485	2,230	892	956	382
59	2,818	1,690	16,600	5,572	6,107	2,442	2,192	876	940	376
52	603	362	3,549	1,193	1,306	523	469	188	201	80
47	603	362	3,549	1,193	1,306	523	469	187	201	80
2,011	1,760	1,056	10,360	3,483	3,812	1,526	1,368	548	586	235
22	5,283	3,169	31,110	10,447	11,446	4,578	4,109	1,643	1,761	704
14	1,609	966	9,473	3,183	3,485	1,395	1,251	501	536	215
15	2,615	1,569	15,398	5,173	5,665	2,267	2,034	814	872	349
9	2,114	1,267	12,450	4,178	4,581	1,831	1,644	657	705	282
4	2,415	1,449	14,224	4,776	5,233	2,093	1,879	751	805	322
TOTALS	68,035	42,359	400,651	139,629	147,409	61,186	52,916	21,964	22,678	9,413

TABLE 4-4. TOWBOAT TRAFFIC (HP-HR PER GRID PER DAY) MISSISSIPPI RIVER (ALTON TO CHAIN-OF-ROCKS CANAL - SECTION 4; ILLINOIS RIVER TO ALTON - SECTION 3; PERUQUE ISLAND TO ILLINOIS RIVER - SECTION 2)
(LOCAL TRAFFIC 1200 HP AVG., THROUGH TRAFFIC 2900 HP AVG.) (UPBOUND - 5 MPH .85 FULL POWER) (DOWNBOUND - 10 MPH, 50 FULL POWER)

SEC.	GRID NO.	GRID DIST. (KM)	GRID DIST. (MILES)	AVG. DAILY VESSELS NORTH & SOUTH	TIME (HOURS) NORTH	HP-HR NORTH	TIME (HOURS) SOUTH	HP-HR SOUTH
	1,233	2.769	1.720		.342	11,018	.172	3,259
	2,302	2.077	1.290		.258	8,311.47	.129	2,444.55
	1,235	1.038	.645		.130	4,187.95	.065	1,231.75
	1,236	1.231	.764		.152	4,896.68	.076	1,140.20
	1,237	.462	.287		.058	1,868.47	.029	549.55
4	2,300	1.654	1.027		.206	6,636.29	.103	1,951.85
	1,167	.615	.382		.076	2,448,34	.038	720.10
	1,133	1.154	.717	11 / 5 LOCAL TRAFFIC	.144	4,638,96	.072	1,364.40
	1,108	.308	.191		.038	1,224.17	.019	360.05
	1,109	1.0	.621		.124	3,994.66	.062	1,174.90
	1,086	.8	.497		.100	3,221.50	.050	947.50
	1,087	.4	.248		.050	1,610.75	.025	473.75
	1,019	1.1	.683		.136	3,687.64	.068	1,084.60
	915	.3	.186		.038	1,030.37	.019	303.05
	977	1.1	.683		.136	3,687.64	.068	1,084.60
3	916	1.8	1.118	11	.224	6,073.76	.112	1,786.40
	917	.9	.559		.112	3,036.88	.056	893.20
	739	5.3	3.291		.658	17,841.67	.329	5,247.55
	2,234	2.8	1.739		.348	9.436.02	.174	2,775.30
	394	3.8	2.360		.472	12,798.28	.236	3,764.20
	242	8.9	5.527		1.106	19,084.03	.553	5,612.95
2	197	1.8	1.118	7	.224	3,865.12	.112	1,136.80
	166	.7	.435		.088	1,518.44	.044	446.60
	141	2.1	1.304		.260	4,486.30	.130	1,319.50

TABLE 4-5. TOWBOAT EMISSIONS (GRAMS PER GRID PER DAY), MISSISSIPPI RIVER (ALTON TO CHAIN-OF-ROCKS CANAL - SECTION 4; ILLINOIS RIVER TO ALTON - SECTION 3; PERUQUE ISLAND TO ILLINOIS RIVER - SECTION 2) (LOCAL TRAFFIC 1200 HP AVG., THROUGH TRAFFIC 2900 HP AVG.) (UPBOUND - 5 MPH, .85 FULL POWER) (DOWNBOUND - 10 MPH, .50 FULL POWER)

GRID NO.	THC 1.8 G PER HP-HR NORTH	THC 2.7 G PER HP-HR SOUTH	NO_x 10.6 G PER HP-HR NORTH	NO_x 8.9 G PER HP-HR SOUTH	CO 3.9 G PER HP-HR		SO_x 1.4 G PER HP-HR		PART .6 G PER HP-HR	
					NORTH	SOUTH	NORTH	SOUTH	NORTH	SOUTH
1,233	19,832	8,800	116,786	29,009	42,968	12,712	15,425	4,563	6,611	1,956
2,302	14,961	6,600	88,102	21,756	32,415	9,533	11,636	3,422	4,987	1,766
1,235	7,538	3,326	44,392	10,963	16,333	4,804	5,863	1,724	2,513	739
1,236	8,814	3,079	51,905	10,148	19,097	4,447	6,855	1,596	2,938	684
1,237	3,363	1,484	19,806	4,891	7,287	2,143	2,610	769	1,121	330
2,300	11,945	5,270	70,345	17,371	25,882	7,612	9,291	2,733	3,982	1,171
1,167	4,407	1,944	25,952	6,409	9,549	2,808	3,428	1,008	1,469	432
1,133	8,350	3,684	49,173	12,143	18,092	5,321	6,495	1,910	2,783	819
1,108	2,204	972	12,976	3,204	4,774	1,404	1,714	504	734	216
1,109	7,190	3,172	42,343	10,457	15,579	4,582	5,593	1,650	2,397	705
1,086	5,799	2,558	34,148	8,433	12,564	3,695	4,510	1,326	1,933	568
1,087	2,899	1,279	17,074	4,216	6,282	1,848	2,255	663	966	284
1,019	6,638	2,928	39,089	9,653	14,382	4,230	5,163	1,518	2,213	651
915	1,855	818	10,922	2,697	4,019	1,182	1,443	424	618	182
977	6,638	2,928	39,089	9,653	14,382	4,230	5,163	1,518	2,213	651
916	10,933	4,823	64,382	15,899	23,688	6,967	8,503	2,501	3,644	1,972
917	5,466	2,412	32,191	7,949	11,844	3,483	4,252	1,250	1,822	536
739	32,115	14,168	189,122	46,703	69,583	20,465	24,978	7,347	10,705	3,149
2,234	16,985	7,493	100,022	24,700	36,800	10,824	13,210	3,885	5,662	1,665
394	23,036	10,163	135,662	33,501	49,913	14,680	17,918	5,270	7,679	2,259
242	34,351	15,155	202,291	49,955	74,428	21,891	26,718	7,858	11,450	3,368
197	6,957	3,069	40,970	10,118	15,074	4,434	5,411	1,592	2,319	682
166	2,733	1,206	16,095	3,975	5,922	1,742	2,126	625	911	268
141	8,075	3,563	47,555	11,744	17,497	5,146	6,281	1,847	2,692	792

TABLE 4-6. TOWBOAT TRAFFIC (HP-HR PER GRID PER DAY), MISSISSIPPI RIVER (CHAIN-OF-ROCKS CANAL TO LOCK 27 LOCALE E - SECTION 5)
(LOCAL TRAFFIC: 1200 AVG. HP, 6 MPH, .85 FULL POWER)
(THROUGH TRAFFIC: 2900 AVG. HP, 6 MPH, .33 FULL POWER)

GRID NO.	GRID DIST. (KM)	GRID DIST. (MILES)	AVG. DAILY VESSELS NORTH & SOUTH EACH		TIME (HR) NORTH & SOUTH	HP-HR 85% NORTH & SOUTH	HP-HR 33% NORTH & SOUTH
			THROUGH TRAFFIC	LOCAL TRAFFIC			
1,082	2,423	1.505			.251	2,560.2	5,337.93
1,195	.5	.311			.052	530.4	1,105.87
1,166	.654	.406			.068	693.6	1,446.13
1,165	1.154	.717			.120	1,224.0	2,552.00
1,164	.308	.191			.032	326.4	680.53
1,081	.692	.430	11	5	.072	734.4	1,531.20
1,132	1.192	.740			.123	1,254.6	2,615.80
1,131	.269	.167			.028	285.6	595.47
1,080	.846	.525			.088	897.6	1,871.47
1,079	2.192	1.361			.227	2,315.4	4,827.53

TABLE 4-7. TOWBOAT EMISSIONS (GRAMS PER GRID PER DAY), MISSISSIPPI RIVER (CHAIN-OF-ROCKS CANAL TO LOCK 27 LOCALE E - SECTION 5) (LOCAL TRAFFIC: 1200 AVG. HP, 6 MPH, .85 FULL POWER) (THROUGH TRAFFIC: 2900 AVG. HP, 6 MPH, .33 FULL POWER)

GRID NO.	THC 1.8 G PER HP-HR (.85)	THC 2.7 G PER HP-HR (.33)	NO_x 10.6 G PER HP-HR (.85)	NO_x 8.9 G PER HP-HR (.33)	CO 3.9 G PER HP-HR (.85)	CO 3.9 G PER HP-HR (.33)	SO_x 1.4 G PER HP-HR (.85)	SO_x 1.4 G PER HP-HR (.33)	PART .6 G PER HP-HR (.85)	PART .6 G PER HP-HR (.33)
1082	4,608	14,412	27,138	47,508	9,985	20,818	3,584	7,473	1,536	3 203
1195	955	2,986	5,622	9,842	2,069	4,313	743	1,548	318	664
1166	1,248	3,905	7,352	12,871	2,705	5,640	971	2,025	416	868
1165	2,203	6,890	12,974	22,713	4,774	9,953	1,714	3,573	734	1,531
1164	588	1,837	3,460	6,057	1,273	2,654	457	953	196	408
1081	1,322	4,134	7,785	13,628	2,864	5,972	1,028	2,144	441	919
1132	2,258	7,063	13,299	23,281	4,893	10,202	1,756	3,662	753	1,569
1131	514	1,608	3,027	5,300	1,114	2,322	400	834	171	357
1080	1,616	5,053	9,515	16,656	3,501	7,299	1,257	2,620	539	1,123
1079	4,168	13,034	24,543	42,965	9,030	18,827	3,242	6,759	1,389	2,897

TABLE 4-8. TOWBOAT TRAFFIC (HP-HR PER GRID PER DAY), MISSISSIPPI RIVER (CHAIN-OF-ROCKS CANAL TO MONSANTO - SECTION 7)

(LOCAL TRAFFIC: 1200 HP AVG. THROUGH TRAFFIC 2900 HP AVG.)
(UPBOUND - 5 MPH, FULL POWER)
(DOWNBOUND - 10 MPH, FULL POWER)

GRID NO.	GRID DIST. (KM)	GRID DIST. (MILES)	AVG. DAILY VESSELS NORTHBOUND & SOUTHBOUND	TIME (HR) NORTH	HP-HR NORTH	TIME (HR) SOUTH	HP-HR SOUTH
1,040	1.0	.621	THROUGH TRAFFIC / LOCAL TRAFFIC	.124	3,994.66	.062	1,174.90
1,039	1.115	.692		.138	4,445.67	.069	1,307.55
1,038	.5	.311		.062	1,997.33	.031	587.45
1,074	.538	.334		.066	2,126.19	.033	625.35
1,073	1.077	.669		.134	4,316.81	.067	1,269.95
1,072	1.0	.621		.124	3,994.66	.062	1,174.90
1,071	1.0	.621		.124	3,994.66	.062	1,174.90
1,070	1.1	.621		.124	3,994.66	.062	1,174.90
1,069	1.0	.621		.124	3,994.66	.062	1,174.90
1,068	1.038	.645		.130	4,187.95	.065	1,231.75
1,067	.192	.119		.024	773.16	.012	227.40
1,031	.923	.573	11 5	.114	3,672.51	.057	1,080.15
1,030	1.192	.740	↓ ↓	.148	4,767.82	.074	1,402.30

TABLE 4-9. TOWBOAT TRAFFIC (HP-HR PER GRID PER DAY), MISSISSIPPI RIVER (CHAIN -OF-ROCKS CANAL TO MONSANTO - SECTION 7)
(LOCAL TRAFFIC: 1200 HP AVG. THROUGH TRAFFIC: 2900 HP AVG.)
(UPBOUND: 5 MPH, FULL POWER) (DOWNBOUND - 10 MPH, FULL POWER)

GRID NO.	THC 1.8 G PER HP-HR NORTH	THC 2.7 G PER HP-HR SOUTH	NO_x 10.6 G PER HP-HR NORTH	NO_x 8.9 G PER HP-HR SOUTH	CO 3.9 G PER HP-HR		SO_x 1.4 G PER HP-HR		PART .6 G PER HP-HR	
					NORTH	SOUTH	NORTH	SOUTH	NORTH	SOUTH
1,040	7,190	3,172	42,343	10,457	15,579	4,582	5,593	1,645	2,397	705
1,039	8,002	3,530	47,124	11,637	17,338	5,099	6,224	1,831	2,667	785
1,038	3,595	1,586	21,172	5,228	7,790	2,291	2,796	822	1,198	352
1,074	3,827	1,688	22,538	5,566	8,292	2,439	2,977	875	1,276	375
1,073	7,770	3,428	45,758	11,300	16,836	4,952	6,044	1,778	2,590	762
1,072	7,190	3,172	42,343	10,457	15,579	4,582	5,593	1,645	2,397	705
1,071	7,190	3,172	42,343	10,457	15,579	4,582	5,593	1,645	2,397	705
1,070	7,190	3,172	42,343	10,457	15,579	4,582	5,593	1,645	2,397	705
1,069	7,190	3,172	42,343	10,457	15,579	4,582	5,593	1,645	2,397	705
1,068	7,538	3,326	44,392	10,963	16,333	4,804	5,863	1,724	2,513	739
1,067	1,392	614	8,195	2,024	3,015	887	1,082	318	464	136
1,031	6,611	2,916	38,929	9,613	14,323	4,213	5,142	1,512	2,204	648
1,030	8,582	3,786	50,539	12,480	18,594	5,469	6,675	1,963	2,861	841

TABLE 4-10. TOTAL EMISSIONS FOR SWITCHBOATS GRAMS PER GRID PER DAY

Grid	CO	NO_x	THC	SO_x	Part
1010	11,520	12,168	6,600	957	425
1073	8,640	9,126	4,950	718	319
1072	11,520	12,168	6,600	957	425
1069	8,640	9,126	4,950	718	319
1038	4,320	4,563	2,475	359	159
1032	8,640	9,126	4,950	718	319
1031	8,640	9,126	4,950	718	319
1030	11,520	12,168	6,660	957	425
999	8,640	9,126	4,950	718	319
998	12,960	13,689	7,425	1,077	478
955	17,280	18,252	9,900	1,436	638
924	5,760	6,084	3,300	479	213
849	4,320	4,563	2,475	359	159
848	5,760	6,084	3,300	479	213
847	8,640	9,126	4,950	718	319
815	5,760	6,084	3,300	479	213

TABLE 4-11. TOWBOAT EMISSIONS (GRAMS PER GRID PER DAY)
MISSISSIPPI RIVER - ST. LOUIS PORT AREA,
NORTH (CHAIN-OF-ROCKS CANAL TO MONSANTO -
SECTION 7)
EMISSIONS SUM OF: LOCAL TRAFFIC AND
THROUGH TRAFFIC (TABLE 4-9)
AND SWITCHER BOATS (TABLE 4-10)

GRID NO.	THC	NO_x	CO	SO_x	PART.
1,040	10,362	52,800	20,161	7,238	3,102
1,039	11,532	58,761	22,437	8,055	3,452
1,038	7,656	30,963	14,401	3,978	1,710
1,074	5,515	28,104	10,731	3,852	1,651
1,073	16,148	66,184	30,427	8,539	3,671
1,072	16,963	64,968	31,681	8,194	3,527
1,071	10,362	52,800	20,161	7,238	3,102
1,070	10,362	50,800	20,161	7,238	3,102
1,069	15,313	61,926	28,801	7,955	3,421
1,068	10,864	55,355	21,137	7,587	3,252
1,067	2,006	10,219	3,902	1,400	600
1,031	14,477	57,768	27,175	7,372	3,171
1,030	19,028	75,187	35,583	9,595	4,127
1,032	4,950	9,126	8,640	718	319
999	4,950	9,126	8,640	718	319

TABLE 4-12. TOWBOAT TRAFFIC (HP-HR PER GRID PER DAY), MISSISSIPPI RIVER (MONSANTO TO SUGAR LOAF - SECTION 8)
(2900 AVG. HP, UPBOUND 5 MPH, .85 FULL POWER)
DOWNBOUND 10 MPH, .50 FULL POWER)

NO.	GRID DIST. (KM)	GRID DIST. (MILES)	AVG. DAILY VESSELS NORTHBOUND & SOUTHBOUND	TIME (HOURS) NORTH	HP-HR NORTH	(HOURS) SOUTH	HP-HR SOUTH
998	1.423	.884		.176	5,206.08	.088	1,530.59
956	.115	.071		.014	414.12	.007	121.75
955	1.231	.764		.152	4,496.16	.076	1,321.87
925	.385	.239		.048	1,419.84	.024	417.43
924	1.192	.740		.148	4,377.84	.074	1,287.08
923	.269	.167		.034	1,005.72	.017	295.68
888	1.0	.621	12	.124	3,667.92	.062	1,078.37
887	.962	.597		.120	3,549.60	.060	1,043,58
849	.231	.143		.028	828.24	.014	243.50
848	1.154	.717		.144	4,259.52	.072	1,252.30
847	.923	.573		.114	3,372.12	.057	991.40
815	.231	.143		.028	828.24	.014	243.50

TABLE 4-13. TOWBOAT EMISSIONS (GRAMS PER GRID PER DAY), MISSISSIPPI RIVER (MONSANTO TO SUGAR LOAF - SECTION 8) (2900 AVG. HP, UPBOUND 5 MPH, .85 FULL POWER) (DOWNBOUND 10 MPH, .50 FULL POWER)

GRID NO.	NO_x 10.6 G PER HP-HR UP	THC 1.8 G PER HP-HR UP	NO_x 8.9 G PER HP-HR DOWN	THC 2.7 G PER HP-HR DOWN	CO 3.9 G PER HP-HR		SO_x 1.4 G PER HP-HR		PART .6 G PER HP-HR	
					UP	DOWN	UP	DOWN	UP	DOWN
998	55,184	9,371	13,622	4,133	20,304	5,969	7,289	2,143	3,124	918
956	4,390	745	1,084	329	1,615	475	580	170	248	73
955	47,659	8,093	11,765	3,569	17,535	5,155	6,295	1,851	2,698	793
925	15,050	2,551	3,715	1,127	5,537	1,628	1,988	584	852	250
924	46,405	7,880	11,455	3,475	17,074	5,020	6,129	1,802	2,627	772
923	10,661	1,810	2,632	798	3,922	1,153	1,408	414	603	177
888	38,880	6,602	9,597	2,912	14,305	4,206	5,135	1,510	2,201	647
887	37,626	6,389	9,288	2,818	13,843	4,070	4,969	1,461	2,130	626
849	8,779	1,491	2,167	657	3,230	950	1,160	341	497	146
848	45,151	7,667	11,145	3,381	16,612	4,884	5,963	1,753	2,556	751
847	35,744	6,070	8,823	2,677	13,151	3,866	4,721	1,388	2,023	595
815	8,779	1,491	2,167	657	3,230	950	1,160	341	497	146

TABLE 4-14. TOWBOAT EMISSIONS (GRAMS PER GRID PER DAY), MISSISSIPPI RIVER - ST. LOUIS PORT AREA. SOUTH (MONSANTO TO SUGAR LOAF - SECTION 8) (EMISSIONS SUM OF: THROUGH TRAFFIC (TABLE 4-13) AND SWITCHER BOATS (TABLE 4-10)

GRID NO.	THC	NO_x	CO	SO_x	PART
998	20,929	82,496	39,233	10,508	4,520
956	1,074	5,474	2,090	750	321
955	21,562	77,676	39,970	9,581	4,129
925	3,678	18,765	7,165	2,572	1,102
924	14,655	63,944	27,853	8,410	3,612
923	13,293	2,608	5,075	1,822	780
888	9,514	48,477	18,511	6,645	2,857
887	9,207	46,914	17,913	6,430	2,756
849	4,623	15,509	8,500	1,859	802
848	14,348	62,380	27,256	8,196	3,520
847	13,697	53,694	25,658	6,827	2,937
815	5,448	17,030	8,990	1,979	856

TABLE 4-15. TOWBOAT TRAFFIC (HP-HR PER GRID PER DAY), MISSISSIPPI RIVER (SUGAR LOAF TO ROCKWOOD ISLAND - SECTION 9)
(2900 AVG. HP UPBOUND 5 MPH, .85 FULL POWER)
(DOWNBOUND 10 MPH, .50 FULL POWER)

GRID NO.	GRID DIST. (KM)	GRID DIST. (MILES)	AVG. DAILY VESSELS UPBOUND, DOWNBOUND	TIME (HPURS) UPBOUND	HP-HR UPBOUND	TIME (HOURS) DOWNBOUND	HP-HR DOWNBOUND
814	1.077	.699		.134	3,963.72	.067	1,165.33
813	2.038	1.266		.254	7,513.32	.127	2,208.92
2,260	3.077	1.911		.382	11,299.56	.191	3,322.07
2,261	2.038	1.266	12	.254	7,513.32	.127	2,208.92
699	5.385	3.344		.668	19,759.44	.334	5,809.28
2,248	1.692	1.051		.210	6,211.80	.105	1,826.27
2,237	4.7	2.919		.584	17,274.72	.292	5,078.77
2,236	1.2	.745		.150	4,437.00	.075	1,304.48
2,218	1.0	.621		.124	3,667.92	.062	1,078.37
2,233	1.0	.683		.136	4,022.88	.068	1,182.73
2,232	1.6	.994		.198	5,856.84	.099	1,721.91
2,203	.5	.311		.062	1,833.96	.031	539.18
355	5.1	3.167		.634	18,753.72	.317	5,513.59
503	1.1	.683		.136	4,022.88	.068	1,182.73
529	4.2	2.608		.522	15,440.76	.261	4,539.58
528	6.2	3.850		.770	22,776.60	.385	6,696.32
527	8.1	5.03		1.006	29,757.48	.503	8,752.20
877	5.638	3.501		.700	20,706.00	.350	6,090.00
1,203	3.692	2.293		.458	13,547.64	.229	3,983.01
1,579	12.7	7.887		1.578	46,677.24	.789	13,728.60
2,410	.4	.248		.050	1,479.00	.025	435.00
2,409	1.9	1.180		.236	6,980.88	.118	2,053.20
2,414	.4	.248		.050	1,479.00	.025	435.00
2,413	.9	.559		.112	3,312.96	.056	974.40
2,417	.7	.435	12	.088	2,603.04	.044	765.60
2,412	.7	.435		.088	2,603.04	.044	765.60
2,419	2.3	1.428		.286	8,459.88	.143	2,488.20
2,430	1.2	.745		.150	4,437.00	.075	1,305.00
2,429	.9	.559		.112	3,312.96	.056	974.40
2,437	2.4	1.490		.298	8,814.84	.149	2,592.60
1,685	8.331	5.174		1.034	30,585.72	.517	8,995.8

TABLE 4-16. TOWBOAT EMISSIONS (GRAMS PER GRID PER DAY) MISSISSIPPI RIVER (SUGAR LOAF TO ROCKWOOD ISLAND - SECTION 9) 2900 AVG. HP, UPBOUND 5 MPH, .85 FULL POWER DOWNBOUND 10 MPH, .50 THROTTLE FULL POWER.

GRID NO.	THC 1.8 G PER HP-HR UP	THC 2.7 G PER HP-HR DOWN	NO_x 10.6 G PER HP-HR UP	NO_x 8.9 G PER HP-HR DOWN	CO 3.9 G PER HP-HR UP	CO 3.9 G PER HP-HR DOWN	SO_x 1.4 G PER HP-HR UP	SO_x 1.4 G PER HP-HR DOWN	PART .6 G PER HP-HR UP	PART .6 G PER HP-HR DOWN
814	7,135	3,146	42,015	10,371	15,459	4,545	5,549	1,631	2,378	699
813	13,524	5,964	79,641	19,659	29,302	8,615	10,519	3,092	4,508	1,325
2,260	20,339	8,970	119,775	29,566	44,068	12,956	15,819	4,651	6,780	1,993
2,261	13,524	5,964	79,641	19,659	29,302	8,615	10,519	3,092	4,508	1,325
699	35,567	15,685	209,450	51,703	77,062	22,656	27,663	8,133	11,856	3,486
2,248	11,181	4,931	65,845	16,254	24,226	7,122	8,697	2,557	3,727	1,096
2,237	31,095	13,713	183.112	45,201	67,371	19,807	24,185	7,110	10,365	3,047
2,236	7,987	3,522	47,032	11,610	17,304	5,087	6,212	1,826	2,662	783
2,218	6,602	2,912	38,880	9,597	14,305	4,206	5,135	1,510	2,201	647
2,233	7,241	3,193	42,643	10,526	15,689	4,613	5,632	1,656	2,414	710
2,232	10,542	4,649	62,083	15,325	22,847	6,715	8,200	2,411	3,514	1,033
2,203	3,301	1,456	19,440	4,799	7,152	2,103	2,568	755	1,100	324
355	33,757	14,887	198.789	49,071	73,140	21,503	26,255	7,719	11,252	3,308
503	7,241	3,193	47,643	10,526	15,689	4,613	5,632	1,656	2,414	710
529	27,793	12,257	163,672	40,402	60,219	17,704	21,617	6,355	9,264	2,724
528	40,998	18,080	241,432	59,597	88,829	26,116	31,887	9,375	13,666	4,018
527	53,563	23,631	315,429	77,895	116,054	34,134	41,660	12,253	17,854	5,251
877	37,271	16,443	219,484	54,201	80,753	23,751	28,988	8,526	12,424	3,654
1,203	24,386	10,754	143,605	35,449	52,836	15,534	18,967	5,576	8,129	2,390
1,579	84,019	37,067	494,779	122,184	182,041	53,542	65,348	19,220	28,006	8,237
2,410	2,662	1,175	15,677	3,872	5,768	1,697	2,071	609	887	261
2,409	12,566	5,544	73,997	18,273	27,225	8,007	9,773	2,874	4,189	1,232
2,414	2,662	1,175	15,677	3,872	5,768	1,697	2,071	609	887	261
2,413	5,963	2,631	35,117	8,672	12,921	3,800	4,638	1,364	1,988	585
2,417	4,685	2,067	27,592	6,814	10,152	2,986	3,644	1,072	1,562	459
2,412	4,685	2,067	27,592	6,814	10,152	2,986	3,644	1,072	1,562	459
2,419	15,228	6,718	89,675	22,154	32,994	9.704	11,844	3,483	5,076	1,493
2,430	7,987	3,524	47,032	11,615	17,304	5,090	6,212	1,827	2,662	783
2,429	5,963	2,631	35,117	8,672	12,921	3,800	4,638	1,364	1,988	585
2,437	15,867	7,000	93,437	23,047	34,378	10,111	12,341	3,630	5,289	1,556
1,685	55,054	24,289	324,209	80,063	119,284	35,084	42,820	12,594	18,351	5,397

TABLE 4-17. TOWBOAT EMISSIONS (GRAMS PER GRID PER DAY) FOR LOCK 26 - SECTION 10, AND LOCK 27 - SECTION 6, ENGINES AT IDLE

SECTION	GRID	LOCK	NO_x	THC	CO	SO_x	PART
10	1019	26	37,895	213,290	622,050	10,780	5,170
10	1048	26	37,895	213,290	622,050	10,780	5,170
6	1010	27	27,012	152,049	443,430	7,683	3,687
6	1078	27	27,012	152,049	443,430	7,683	3,687

TABLE 4-18. RIVER VESSEL EMISSIONS IN ST. LOUIS AIR POLLUTION STUDY REGION, BY ZONE (GRAMS PER GRID PER DAY)

SECTION	NO_x UP	NO_x DOWN	NO_x TOTAL	THC UP	THC DOWN	THC TOTAL	CO UP	CO DOWN	CO TOTAL
1	400,651	139,629	540,280	68,035	42,359	110,394	147,409	61,186	208,595
2	306,911	75,791	382,702	52,117	22,992	75,109	112,920	33,212	146,132
3	571,389	141,103	712,492	97,028	42,807	139,835	210,228	61,832	272,060
4	573,002	139,000	712,002	97,302	42,169	139,471	210,821	60,910	271,732
5	157,767	157,767	315,534	40,201	40,201	80,403	65,103	65,103	130,206
6	27,012	27,012	54,024	152,049	152,049	304,098	443,430	443,430	886,860
7	490,364	121,094	611,458	83,269	36,737	120,006	180,417	53,064	233,481
8	354,309	87,461	441,770	60,166	26,533	86,699	130,359	38,325	168,685
9	3,594,513	887,430	4,481,996	610,389	269,238	879,627	1,322,509	388,898	1,711,407
10	37,895	37,895	75,790	213,290	213,290	426,580	622,050	622,050	1,244,100
TOTALS	6,513,814	1,814,235	8,328,049	1,473,847	888,375	2,362,222	3,445,247	1,828,010	5,273,257

SECTION	SO_x UP	SO_x DOWN	SO_x TOTAL	PM UP	PM DOWN	PM TOTAL
1	52,916	21,964	74,880	22,678	9,413	32,092
2	40,535	11,922	52,458	17,372	5,110	22,482
3	75,466	22,196	97,662	32,343	9,513	41,855
4	75,679	21,865	97,545	32,434	9,371	41,805
5	23,370	23,370	46,741	10,016	10,016	20,032
6	7,683	7,683	15,366	3,687	3,687	7,374
7	64,765	19,049	83,814	27,756	8,164	35,920
8	46,796	13,753	60,553	20,055	5,896	25,951
9	478,748	139,602	618,350	203,463	59,831	263,294
10	10,780	10,780	21,560	5,170	5,170	10,340
TOTALS	876,830	292,189	1,169,019	374,975	126,170	501,145

5. SUMMARY AND CONCLUSIONS

5.1 DATA BASE

Vessel exhaust emissions estimates in this study are considered to be sufficiently comprehensive for the specific area involved. Limitations encountered which influence the conclusions include the availability of river vessel traffic information, appropriate vessel duty cycles, and operational characteristics.

Towboat traffic estimates south of St. Louis were based on aggregate estimates of traffic on the Mississippi between the Missouri and Ohio Rivers, and are not as accurate as actual vessel counts. Corps of Engineers Lock Number 27 has served as the source of information for vessel traffic north of St. Louis. Port traffic allocations are based upon the total port traffic estimates from industry spokesmen and the fact that traffic density within each port grid element is based on the number of terminals within that grid. If these assumptions differ substantially from the actual conditions, the grid elements emission estimates will be erroneous. It was the author's intent to show the significance of switchboat operations, and the methodology and data used were considered the best available.

The critical assumption affecting the calculated emissions are the towboat power setting (duty cycles). Any major deviation from the assumed values of power settings for towboats will cause an almost direct proportional change in exhaust emissions. Similarly, any change in the assumed duty cycle for port traffic will affect the calculated emissions for the respective grids.

5.2 RESULTS

In Table 5-1 vessel emissions per mile of the various zones of waterway in the SLAPS region are shown. The effects of waiting periods with the towboat engine at idle and time going through the locks result in high THC and CO emissions for zone 6 (Lock 27) and zone 10 (Lock 26). The emission rates per mile allow quick

comparison with other point and area emission sources.

In Table 5-2, vessel emissions relative to other emission sources are shown. On a percentage basis for the entire AQCR, towboat emissions are minor. Upon the completion of the EPA-RAPS emission inventory, the relative towboat emissions on a per-grid will be available.

TABLE 5-1. RIVER VESSEL EMISSIONS (GRAMS PER RIVER MILE PER DAY)

SECTION	NO_x	THC	CO	SO_x	PART
1	6,199	1,267	2,393	859	368
2	45,639	8,957	17,427	6,256	2,681
3	71,364	14,006	27,250	9,782	4,192
4	84,764	16,646	32,372	11,621	4,980
5	49,773	12,683	20,539	7,373	2,266
6	36,478	205,333	598,825	10,375	4,979
7	85,024	16,687	32,466	11,654	4,995
8	78,064	15,320	29,808	10,700	4,586
9	78,064	15,320	29,808	10,700	4,586
10	55,332	312,257	910.806	15,784	7,570

TABLE 5-2. ANNUAL EMISSIONS FOR ST. LOUIS AIR QUALITY CONTROL REGION (#70)[2]

	Pollutant Tons/Year				
Emissions Source	NO_x	THC	CO	SO_x	Part
Towboats*	5,297	939	2,101	462	198
Transportation[15]	105,932	198,063	980,944	7,887	8,940
Total Emission[15]	433,637	295,124	3,852,753	1,234,395	354,672

*This study.

1) Emissions for period of towboat activity on Missouri River (Zone 1), March 1 to November 30.

2) Annual towboat emissions based on 9 months towboat activity on Missouri River and 12 months activity for rest of region.

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