SEATTLE TACOMA INTERNATIONAL AIRPORT:

AIR POLLUTANT CONTRIBUTION

May 1991

Air Quality Program

Department of Ecology

Olympia, Washington

This is the [illegible] Rep. Greg Fisher worked for.

TABLE OF CONTENTS

LIST OF FIGURES

I. BACKGROUND INFORMATION

A. Nature and Toxicity of Airport Air Emissions

Combustion and volatilization processes at airports introduce a variety of pollutants into the air. These pollutants may then be transported by the wind, transformed in the atmosphere, and deposited in surrounding areas.

The nature of the pollutants emitted from airports is no different than those emitted from other human activities. Carbon monoxide, sulfur and nitrogen oxides, and unburned hydrocarbons are commonly emitted from combustion processes. The specific composition of the emissions depends on the temperature, residence time and other conditions in which the combustion process takes place. Pollutants that evolve from volatilization are usually hydrocarbons of low molecular weight that sublime from a solid mass or evaporate from a liquid such as a fuel or a solvent.

Carbon monoxide, sulfur dioxide, and nitrogen dioxide are criteria pollutants, and have been regulated since National Ambient Air Quality Standards (NAAQS) were established in the Clean Air Act of 1970. Hydrocarbons exist as either particulates, in which case they are also criteria pollutants, or as gases. Whether they are particulates or gases, hydrocarbons may also be air toxics. Air toxics, or Hazardous Air Pollutants (HAP), while not criteria pollutants, have been the subject of much attention in recent years. Title III of the Clean Air Act Amendments (CAAA) of 1990 is entirely devoted to the regulation of HAPs.

ACKNOWLEDGEMENT

Howard Segal and Paul Hamilton of the Federal Aviation Administration devoted much time and effort to the successful completion of this project. Their valuable contribution is greatly appreciated.

Report prepared by:

Cris Figueroa
Clint Bowman
Frank Soiza

INTRODUCTION

The purpose of this study is to estimate the emission rates of operation at the Seattle Tacoma International Airport and evaluate in a screening mode (worst case) their impact on ground level air quality in surrounding communities. This study was conducted at the request of Washington State Representative Greg Fisher. Sea-Tac Airport's emissions were inventoried with the aid of the first part of a two part model, EDMS, the Federal Aviation Administration's airport air quality model which will be released later this year. The contribution of Sea-Tac Airport to the ambient air concentrations of pollutants at ground level were then estimated with EDMS. In September of 1990, EPA nominated EDMS as a guideline air quality model.

Part I of this report provides background information on airport operations, the types and toxicities of air pollutants emitted from airports, aircraft engine emissions, the regulatory status of airports from an air quality standpoint and the EDMS model. Part II includes specific information on Sea-Tac Airport operations, current facilities and proposed expansion. The data collected and assumptions made for using the EDMS model are also provided in Part II along with the results of a literature search and the modeling effort. Part III lists conclusions and recommendations.

Hydrocarbons can be divided into: alkanes, alkenes, alkynes, and cyclics which can be aromatic or non-aromatic. Hydrocarbons can be gases or particulates.

Volatile organic compounds (VOC) are gaseous hydrocarbons of low molecular weight. VOCs react with oxidizing agents present in the atmosphere such as the hydroxyl ion (OH) or ozone (O_3) and result in the formation of free radicals which undergo further reactions with other pollutants in the atmosphere and with oxygen to produce photochemical smog. Photochemical smog drastically reduces visibility. VOCs are also precursors of ozone, and are stringently regulated in those areas that do not meet the ozone NAAQS. The 1990 CAAA divides ozone non-attainment areas into six categories depending on the severity of the problem. All non-attainment areas will have to reduce their VOC emissions.

The particulates, either liquid or solid, of concern from a human health standpoint are those that have diameters ranging from 0.1 to 3 microns [3] because they can enter the small passageways in the lungs and become lodged there. The chemical composition of the particulates is also a determinant factor on their effect upon human health. Some particulates, because of their composition, are air toxics regulated under Title III of the 1990 CAAA. Particulates with diameter less than ten microns are also criteria pollutants.

The exact composition of the aircraft hydrocarbon emissions and its possible toxicity has not been studied. It is expected that such hydrocarbons would be unburned olefins, paraffins and naphthalenes, but the ratio is not known. Naphthalene, xylene and benzene are listed under Title III of the 1990 CAAA as HAPs.

3. Sulfur Dioxide

Sulfur dioxide is a nonflammable, nonexplosive, colorless gas. It reacts in the atmosphere to form sulfur trioxide and sulfuric acid. Sulfur dioxide, sulfuric acid, and other inorganic sulfates act as bronchoconstrictors. The asthmatic population is highly impacted by bronchoconstrictors which decrease the respiratory functions both at the acute and chronic levels. [4] Sulfur dioxide contributes to acid

Air pollutants adversely impact human health and welfare, and the entire biosphere. In the rest of this section, the physical state, effects on the environment, and national standards are outlined for each of the criteria pollutants mentioned above as well as for hydrocarbons.

1. Carbon Monoxide

Carbon monoxide (CO) is a colorless and odorless gas which interferes with oxygen transport in the blood by forming a bond with hemoglobin, producing a stable complex called carboxyhemoglobin (CoHb). Exposure to extremely high levels of carbon monoxide may cause death. According to the EPA, when 2.5% of carboxyhemoglobin is present in the blood, decreased exercise capacity results in patients with cardiovascular disease. Blood levels of CoHb greater than 5% decrease visual perception, manual dexterity and performance of complex sensimotor tasks. [1] CO has also been associated with lower birth weight and increased deaths of infants in highly polluted areas.

Primary NAAQS have been set at 9 ppm in an eight hour average and 35 ppm in a one hour average. These health-based standards are equal to the secondary standards which are in place to deter environmental degradation. Fifty-two cities and towns across the country, including Seattle and Spokane, do not meet the CO NAAQS. [2] The Clean Air Act Amendments of 1990 establish two different categories of CO non-attainment areas: moderate and serious. Transportation control measures will be required of areas that are classified as serious.

2. Hydrocarbons

In gaseous form, hydrocarbons are not a criteria pollutant. They are a wide variety of compounds resulting from the release of unburned fuel or incomplete combustion of fuel. They are produced, along with CO, when the combustion process is not efficient.

deposition. Other well-known effects of SO_2 are metal corrosion, dissolution of limestone, marble and mortar, and fading of dyed fabrics. Sulfur dioxide can injure plant tissues, suppressing growth and yield.

Two primary NAAQS standards exist for SO_2: an annual average of 0.03 ppm and a 24 hour average of 0.14 ppm. A secondary 3 hour average standard of 0.50 ppm has been established. The State of Washington has established a one-hour average standard of 0.40 ppm.

4. Nitrogen Oxides

Nitrogen oxides (NO and NO_2) result from the high temperature oxidation of nitrogen present in air. Nitrogen dioxide is a gas that can color plumes brown, red or yellow. [5] In the presence of moisture, nitrogen oxides can form particulates by coalescing, reducing visibility and contributing to acid deposition. Nitrogen dioxide, like sulfur dioxide, is also a bronchoconstrictor that can cause irritation and injury to the lungs.

An annual average NAAQS for nitrogen dioxide exists (0.05 ppm); however, because NO_2 is also an ozone precursor, the 1990 CAAA requires that major NO_x sources meet reductions similar to VOC sources unless otherwise prescribed by EPA. The State of California has a one-hour average nitrogen dioxide limit of 0.12 ppm.

B. Sources and Rates of Airport Emissions

The main air pollution sources at airports are: aircraft, motor vehicles, boilers, and fueling operations. Wayson and Bowlby [6], in their *Inventorying Airport Air Pollutant Emissions*, list ground support equipment emissions in a separate category and subdivide aircraft into large commercial aircraft and small aircraft and military operations. They point out that small aircraft may be significant in the summation of an airport's emissions. Training fires and engine test cells are minor sources at airports. The contribution of each of these sources to and expands a compressed mass of air which rotates a turbine and provides thrust as it exits the small diameter exhaust nozzle. Gas-turbine engines may be turbojet, turboprop or turbofan.

The most popular engine used in large commercial airliners today is the turbofan engine. The European A-300, and the U.S. models B-727, B-737, B-747, B-757, B-767, DC-8, DC-9, and DC-10 all utilize turbofan engines. In a turbofan engine, a turbine drives the compressor and a fan accelerates a portion of the air through and out of the engine. Worldwide, there are four manufacturers of turbofan engines: Pratt & Whitney (JT3D, JT8D, JT9D,2037), Rolls Royce (RB-211), General Electric (CF-6) and Garrett (ATF3-6, TFE731).

Aircraft engines emit CO, SO_x, hydrocarbons, NO_x, and particulates as by-products from the combustion process. The emission rates are determined by engine types. The ratios of pollutants emitted vary with the operating mode of the engine. At low engine power settings, such as idling when waiting in a queue, or at start-up, more CO and hydrocarbons are produced due to incomplete combustion. (Turbulence and vertical dispersion of the plume aids considerably in CO dilution.)[8] The amount of NO_x produced from the oxidation of atmospheric nitrogen increases as the temperature within the combustion chamber rises. The amount of NO_x produced during start-up is small compared to that produced during takeoff. Most of the NO_x from aircraft exhaust is in the form of nitrogen oxide (NO) rather than nitrogen dioxide (NO_2)[9]. SO_2 results from the oxidation of sulfur compounds in the fuel. Jet fuel is highly refined, and contains about 0.1% sulphur. [10] Particulate emissions are a function of the engine design, the operating mode, and fuel type. A 1979 FAA study determined that the composition of particulates emitted by turbine engines is essentially carbonaceous with extremely small diameters ranging from 0.04 to 0.12 microns for the three types of engines tested (TF30, JT8D, and JT9D). [11] Figure 1 shows the percentages of total aircraft emissions from each mode of operation by pollutant for hydrocarbon (HC), carbon monoxide (CO), and nitrogen oxides (NO). [12]

the total amount of pollutants emitted from each airport varies. The breakdown for Sea-Tac Airport is reported in Part II.

1. Aircraft

The quantity of pollutants emitted into the atmosphere is a function of the type of aircraft and engine, the mode of operation, and how long the engine is operated in each mode. The modes of operation that are usually considered to determine emission factors are:

1. Taxi or idle
2. Takeoff
3. Climbout (to 3500 ft.)
4. Approach (from 3500 ft.)
5. Landing

The combination of these five modes constitutes one landing and take-off cycle (LTO). Note that the emission factors are calculated for climbout and approach up to 3500 ft. Emissions from higher altitudes cannot produce significant ground level concentration. Each aircraft model has its own characteristic LTO times. In understanding the difference in emissions it is useful to have a knowledge of aircraft, their engines, and their operation. The following paragraphs briefly highlight various aspects of aircraft and their operation.

Airplanes move forward as a reaction to the backward motion of the mass of air that is accelerated to a high velocity by the airplane's engine. Aircraft can have either reciprocating or gas-turbine engines. The reciprocating or piston engines, used in the smaller aircraft, are powered by the combustion of fuel which drives the four stroke cycle of the pistons. In the gas-turbine engines, the combustion of fuel heats

The only aircraft exhaust toxics estimate available is in a 1984 report to Ecology, in which Radian Corporation roughly estimated that toxic air emissions from jet exhaust at Sea-Tac Airport were 12.7 tons per year of benzene, and 298 tons per year of xylene. In quoting these values, Radian emphasized their high degree of uncertainty.

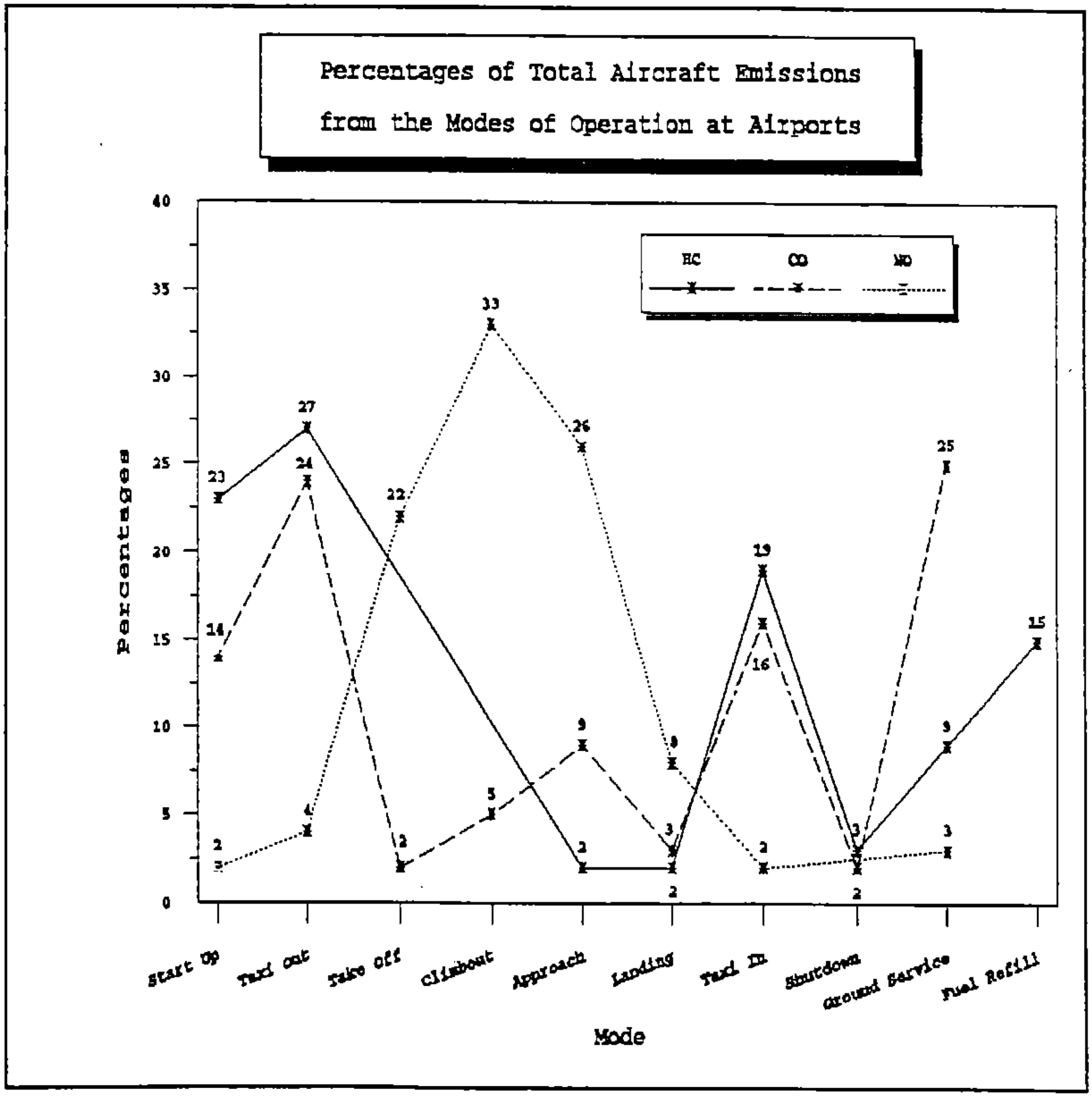


FIGURE 1

2. Motor Vehicles

A downward trend in the ambient concentration of air pollutants generated by motor vehicles, especially CO, has been observed in the Seattle area over the past decade. The replacement of older vehicles with newer, cleaner ones has been a major factor for the downward trend, but also the Inspection and Maintenance (I/M) program that the Department of Ecology required in the Seattle area since 1982 deserves part of the credit. CO emissions have been reduced by 13% in Seattle due to the I/M program. A projected carbon monoxide motor vehicle emission trend through 1995 with and without the I/M program in King, Pierce, Snohomish, and Kitsap counties predicts that during that period the I/M program will prevent the emission of approximately 1000 metric tons. [13]

3. Boilers

Air pollution from boilers varies greatly depending on the fuel used, and the manner in which the boiler is operated. At Sea-Tac Airport the boilers are run on natural gas, the least polluting fuel, and oil is used as a back-up fuel. At least one boiler is running twenty-four hours a day, every day of the year, to power heat exchangers in the terminal building.

4. Fueling Operations

Low molecular weight hydrocarbons volatilize during fueling operations at varying degrees depending on the type of fuel and the efficiency of the operation. The fuel requirements for piston and turbine engines differ widely. Piston engines require a gasoline with a high octane rating for its anti-knocking characteristics. Jet engines can utilize much heavier fuel, usually Jet-A fuel or aviation kerosine. Aviation kerosine is similar to the kerosine for domestic household use. Typically, the boiling point of Jet-A fuel is in the range of 144-252 degrees Centigrade (291-486 degrees Fahrenheit). Aviation gasoline used for the piston engine powered aircraft is much more volatile than Jet-A fuel. Appendix 3 contains fuel specifications.

At Sea-Tac Airport, a collection trench around the runway and taxiing area drains stormwater and any fuel spilled during the fueling operations to a wastewater treatment plant located on the airport. The wastewater treatment plant consists of flotation units which separate the oil from the water. Because of Jet A fuel's high boiling point and extremely low vapor pressure, the amount of hydrocarbons that volatilize from these trenches is insignificant.

5. Fuel Venting from Landing Aircraft

Fuel venting from landing aircraft is not included as a possible source in EDMS and is not addressed in this study. The operations personnel at Sea-Tac indicated that due to the high cost of fuel, it usually is the airlines' policy to avoid such dumping as much as possible. It usually occurs only under emergency situations; however, each airline has its own rules regarding fuel venting.

C. Regulations that Apply to Airports and Aircraft

Airports as sources of air pollution fall under the indirect source category. An indirect source is defined as " a facility, building, structure, installation, real property, road, or highway which attracts, or may attract, mobile sources of air pollution." Indirect sources and indirect source review were defined in the Federal Clean Air Act of 1970, however; it was not until 1973, prompted by a lawsuit (NRDC v. EPA), that EPA required states to conduct indirect source review as part of the State Implementation Plan (SIP) process. The purpose of the indirect source review was to account for the impact of growth on air quality. [14] In the CAAA of 1977, Congress severely restricted EPA's authority to require states to perform indirect source review, and most states, including Washington, that had developed indirect source regulations decided to repeal them. Although several states kept their indirect source rules, those rules have extremely limited impact since they do not require mitigation of emissions, and no program is designed to monitor or enforce mitigations.

The Clean Air Act, Title II, Part B, directs the EPA to establish aircraft emission standards, and to study " the extent to which such emissions affect air quality in air quality control regions throughout the United States, and the technological feasibility of controlling such

?

6. Since emission factors for air toxics from aircraft have not been developed, the model output lumps hydrocarbons into one category.

emissions." In response to this mandate, a thorough and well documented series of studies conducted prior to 1980 were compiled and analyzed in a report published jointly by the FAA and EPA titled *Impact of Aircraft Emissions on Air Quality in the Vicinity of Airports.* It is an excellent reference for the work that has been done in this area up to 1980. At that time, violations of NAAQS due to aircraft exhaust alone were thought to be improbable. The conclusions of that study will be mentioned further at the end of this report. The Code of Federal Regulations volume 40, part 87 contains engine emission standards that apply only to large commercial passenger jets. The FAA is responsible for implementing the standards, and it does so through engine certification data provided by the manufacturers. These regulations do not extend to piston powered, smaller turbofan or military aircraft. [15]

EPA has not been active in a any regulatory development relating to aircraft since the early eighties. EPA is currently in the process of updating aircraft emission factors. Additional information is needed for military aircraft which may be substantially different. [16]

The 1990 CAAA did not modify Part B of Title II nor does it call for new standards or for more research. The 1990 CAAA did not amend the law pertaining to indirect sources either. At the state level, however, indirect source regulations have again become popular as a tool for land-use planning. The most progressive efforts in indirect source regulation have been undertaken in California. The California Clean Air Act, effective in January 1, 1989, provided districts with the authority to regulate indirect sources, and in July, 1990, the Air Resources Board published a technical support document titled: *California Clean Air Act Guidance for the Development of Indirect Source Control Programs*.

D. The Emissions and Dispersions Modeling System (EDMS)

The United States Air Force and the Federal Aviation Administration, after developing separate models to calculate the emissions and predict an airport's contribution to ambient pollutant levels, agreed in 1985 to join their efforts in updating the previous models. EDMS is the result of that joint effort.

Initially the model calculates the emission rates from miscellaneous point sources such as powerplants, heating plants, fuel storage tanks, and training fires; roadway sources; parking lot sources; and both aircraft queues and takeoffs. The aircraft emission factors for these calculations are based on 1980 EPA factors that have been extrapolated to date with the aid of engine manufacturers. Although approach, and taxi-in factors are calculated in EDMS, landings are not considered in the model either in the emission or dispersion part. Emission rates are calculated only for taxi-in/out, takeoffs, queues, and climb-out and approach. Appendix 4 contains the emission factors in the EDMS database for engines currently in use. Cornell Aeronautical Laboratory developed the emission factors for EPA in 1978. Cornell determined factors for only CO, hydrocarbons, and nitrogen oxides. EPA last updated the emission factors in 1980. Since then, cleaner engines have been manufactured prompting the FAA to update some of the EPA data. EDMS contains the updated engine emission factors obtained from engine certification tests conducted by the manufacturers. [7] Refer to Appendix 1. The emission rates for motor vehicles are estimated using MOBILE 4, an EPA guideline emissions model.

After calculating emission rates, EDMS models aircraft as accelerating point sources with an integrated puff model; and roadways, parking lots, and stationary sources are modeled with the Point-Area-Line (PAL) equations to estimate dispersion. The contributions from each source are then combined to provide an estimate of the concentrations of each pollutant at the receptor locations.

EDMS is an extremely useful tool in evaluating airport air pollution impacts. The shortcomings of the model are:

1. Variation in terrain is not accounted for.
2. Vertical stability in the atmosphere is represented by a single classification.
3. It is reliable within only a 1 km radius from the source.
4. It is currently under development, and thus still requires fine-tuning.
5. The queue is restricted to be modeled as a straight line connected at one end to the runway thereby making it impossible to model a parallel taxiway.

II. AIR QUALITY IMPACT OF SEATTLE-TACOMA INTERNATIONAL AIRPORT

A. Description of Sea-Tac Airport

Sea-Tac Airport has two runways referred to as 16L/34R and 16R/34L. Both runways are oriented along north to south parallels. Please refer to Appendix 4 for a layout of the facility. Ninety percent of the time 16L is used for departures and 16R for arrivals. Aircraft usually take off from the north end of the runway if wind conditions permit. Most of the time, aircraft queues are located in the airfield space adjacent to the north end of 16L. The length of the queues rarely exceeds eight aircraft.

The Olympic Pipeline Company provides Jet A fuel to Sea-Tac Airport. A main tank farm composed of eight above ground tanks with fixed cone roofs stores 500,000 barrels. Northwest and United Airlines have two intermediate tank farms composed of 14 underground 40,000 gallon tanks. These intermediate tanks provide enough pressure to fuel aircraft at the gates. The other airlines use a fleet of approximately 40 fueling trucks to fuel their aircraft.

Sixty percent of the ground traffic to the airport comes from the north on North Entry Drive with the remainder arriving from the south on Pacific Highway. The main parking facility has a capacity of 3500 vehicles.

B. Proposed Expansions

The goals for the expansion of Sea-Tac Airport are to reduce arrival and departure delays and to reduce queuing. The parking garage will be expanded to house an additional 4000 vehicles within the next two years. In the airfield, the taxiways will be expanded by 1993, and a queuing area enlarged to accommodate two B-747's side by side. Such queuing area could also be used for aircraft parking if necessary. Please refer to Appendix 5 for Sea-Tac Airport's Master Plan Update. In the long term, the planning group at the airport is looking at several alternatives to facilitate airport access such as improving 28th Avenue South into a five lane arterial, or providing airport access using highways 509 or 210.

C. Input to EDMS

Statistics on the aircraft operations, roadway vehicle traffic and the boiler at the airport were collected from Sea-Tac Airport's staff. Department of Ecology personnel toured the airport, and obtained information on fueling operations, the main boiler, and aircraft operations. Peak aircraft activity was used. Howard Segal (FAA) provided data on the parking lot facility which was collected in 1987 when he and other colleagues were conducting a study on the effects of canyons on the concentrations of pollutants in parking lots. Geraldine Heckendorn (Sea-Tac Airport) provided roadway traffic volumes for the airport access roads which were also compiled in 1987. Appendix 3 contains a printout of all the input data.

Three case scenarios were modeled with the wind directions being 0, 170 and 345 degrees to account for the prevailing winds coming from the south or the north. In all cases the E stability category was used with a wind speed of 1 meter per second and a temperature of 40 degrees Fahrenheit, typical of an overcast winter day. These conditions are not conducive to dispersion, and will result in the highest concentrations of pollutants.

The aircraft operations input were developed from the August 1989 operations log. During that month the peak hour had 72 operations. For the emissions part of the model, temporal factors were incorporated to take into account the amount of activity taking place on an hourly, daily and monthly basis to come up with realistic annual emission rates. Only the peak hourly data were used to define a worse case scenario for the dispersion part.

III. CONCLUSIONS AND RECOMMENDATIONS

A. Results and Conclusions

EDMS calculated emission rates for all the criteria pollutants plus hydrocarbons for Sea-Tac Airport's typical activity on an annual basis. Those emission reported in figures 2 through 8 and in Appendix 4.

After calculating emission rates, EDMS was used to calculate ambient concentrations during peak-hour activity. This dispersion output was contoured with an interpolating and plotting package called SURFER. The interpolating technique used was Krigning. The results obtained from the plotting exercise are shown in figures 9 through 22 found in Appendix 5, and, although they serve the purpose of providing a graphical illustration of the results, they must be used with caution. Because of the low density of points in certain data sets, some contours were not completed. Other contours contain waves and other artifacts that are not a true reflection of the data, but rather reflect weaknesses of the interpolating algorithm in handling the steep gradients in regions with few data points. Practical considerations relating to computer run time precluded using more calculation points.

1. Sea-Tac Airport is a major indirect source of air pollutants. It contributes approximately 8% of the carbon monoxide and 5% of the nitrogen oxide emissions in King County. Refer to Figure 2.

2. The emission inventory obtained for Sea-Tac Airport shows that the boilers, tank farms, and training fire are minor, even insignificant, sources compared to aircraft and motor vehicles which together comprise 99.9% of the emissions.

Refer to Table 1 and Figure 3. Note that Figure 3 depicts the airport's hydrocarbon emissions in a logarithmic scale. Appendix 4 contains Sea-Tac's emission inventory in more detail.

The tank farms contribute only hydrocarbons from evaporation loses. The training fires take place quarterly, at night, and

1991 EDMS
D.O.E. STUDY

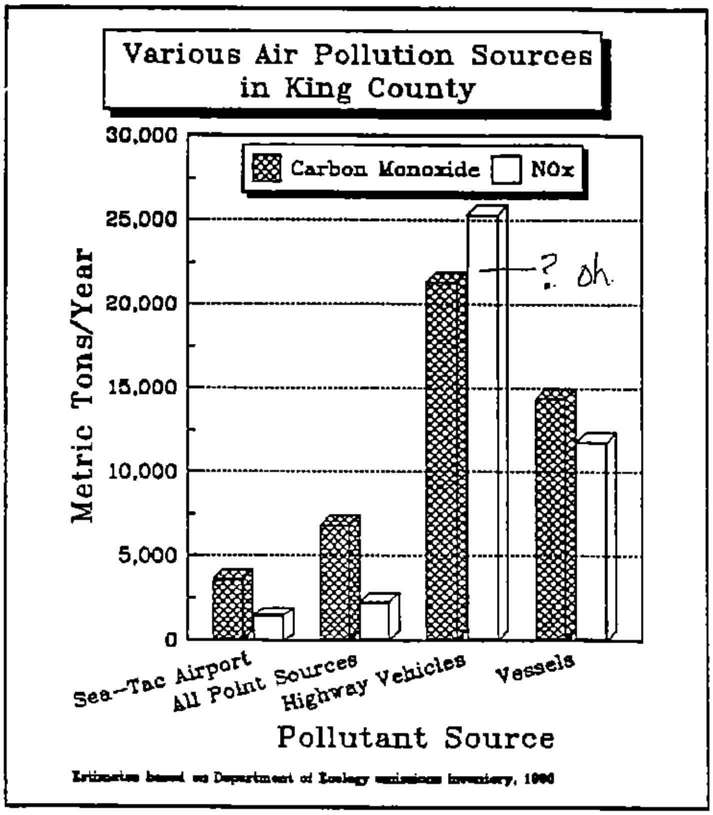


FIGURE 2

constitute a small source compared to motor vehicle and aircraft emissions. The boiler, which is powered with natural gas, is also a minor source. The rest of the figures pertaining to emissions will include only the major sources: aircraft and motor vehicles.

TABLE 1. AIR POLLUTION SOURCES AT SEA-TAC AIRPORT

Source	CO	HC	NOx	SOx	TSP
Tank Farms	0	0.006	0	0	0
Motor Vehicles	502	37.2	23.03	0.018	0.118
Aircraft	3121	1277	1874	162	61.44
Boiler	3.36	2.77	0.012	0.003	0.371
Total	3628	1315	1897	163	62

Units - metric tons per year

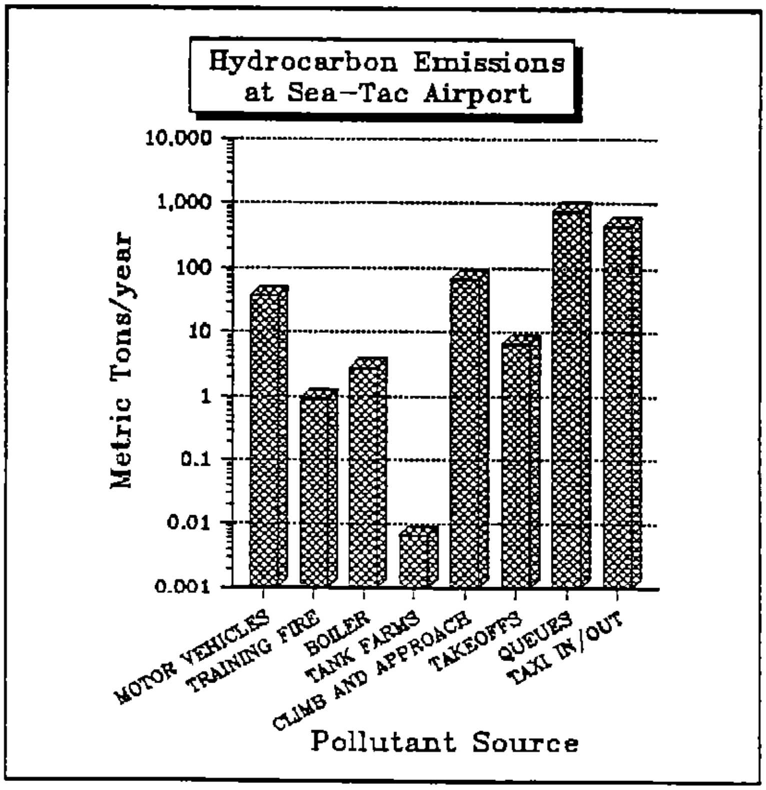


FIGURE 3

100 TONS/YR HC TO + CO

3. During peak hours aircraft queues represent 54% of the total aircraft CO emissions, 59% of the hydrocarbon emissions, 6% of the NO_x emissions, and 21% of the SO_x emissions and of the particulate emissions. Note that the figures show a peak queuing hour situation and that the motor vehicle figures were computed from daily traffic 1987 volumes.

4. Aircraft queues are the major source of carbon monoxide and hydrocarbons. Climb and approach emissions, which are calculated from ground level up to 3500 feet, are the major source of nitrogen oxide emissions, and aircraft takeoffs contribute about 25% of the total. Sulfur oxide and particulate emissions are more evenly divided among the four aircraft modes with climb and approach still being the most significant contributing mode. Refer to Figures 4-8.

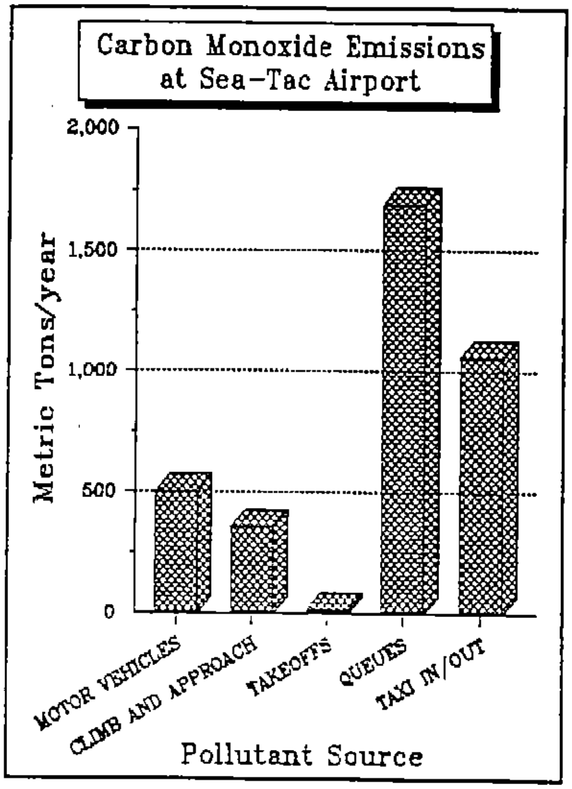


FIGURE 4

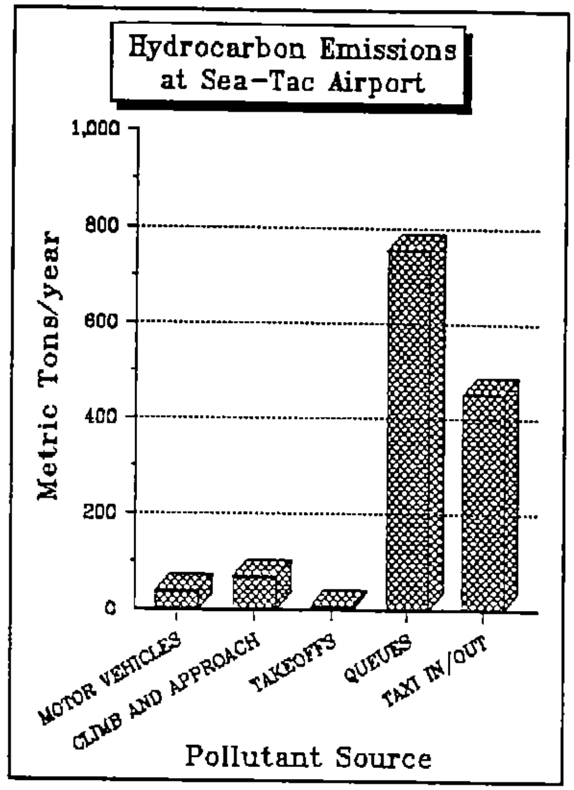


FIGURE 5

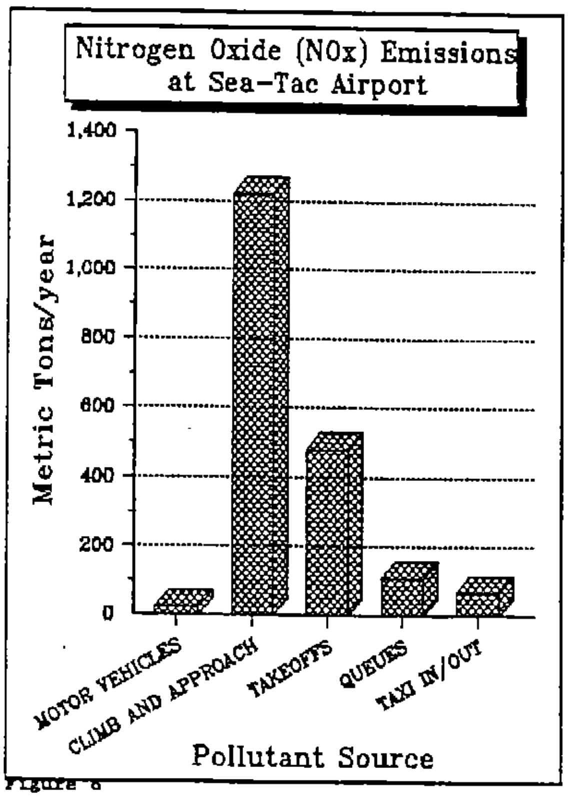


FIGURE 6

11. The only Ecology air monitoring data from the vicinity of Sea-Tac Airport came from a 1983 CO study from a monitor which was set up at S. 188th Pacific Highway, approximately half a mile (800 meters) east of the south end of Sea-Tac Airport's runway. The 8-hour average concentrations at that site ranged from 2.6 to 7.6 ppm or 29% to 84%, respectively, of the NAAQS limit of 9 ppm. The location of that site did not coincide with the areas of maximum or moderate impact from Sea-Tac identified by EDMS.

B. Recommendations

It is important to recognize that this study is only the first step, the screening process, of the usual approach taken when evaluating a source. The possibility of ambient air quality violations for nitrogen dioxide and particulates solely from Sea-Tac Airport contributions has been identified. It also appears that Sea-Tac is a significant contributor of hydrocarbons and carbon monoxide, and, to a lesser degree, of sulfur oxides. The following recommendations are based on those results.

1. Minimize queuing at Sea-Tac Airport to reduce all emissions, especially CO and hydrocarbon emissions. The Seattle area is a CO non-attainment area; the hydrocarbon emissions promote ozone formation and some of the components are known toxic air pollutants, particularly benzene. This study has shown that the ASIL for benzene may be greatly exceeded in the vicinity of the airport.

2. Explore options to reduce the nitrogen oxide emissions that result from takeoffs.

3. Support a strong and widespread I/M program which will reduce motor vehicle emissions associated with all indirect sources.

4. Provide fast and easy public access to the airport terminal via a well-organized mass transportation system to avoid attracting more motor vehicle traffic. Discourage drivers from idling their car engines in the parking lot.

5. Study the feasibility of switching the ground support vehicles at Sea-Tac Airport from gasoline to an alternate, cleaner burning fuel such

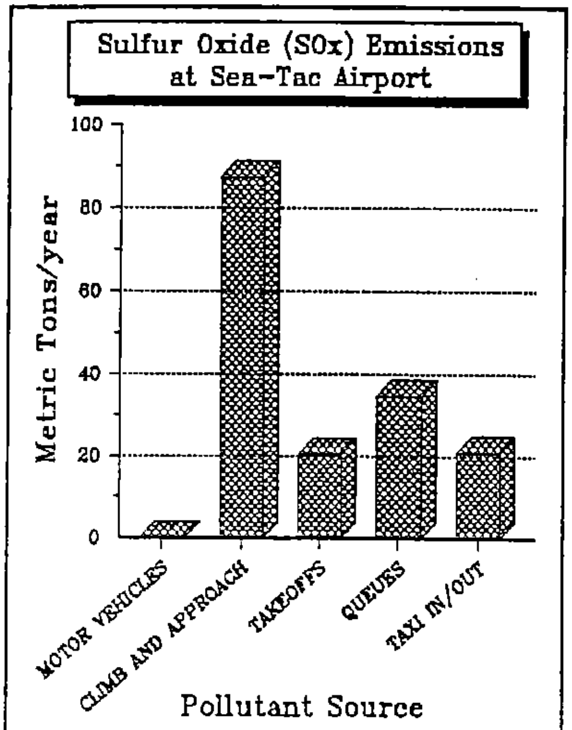


Figure 7.

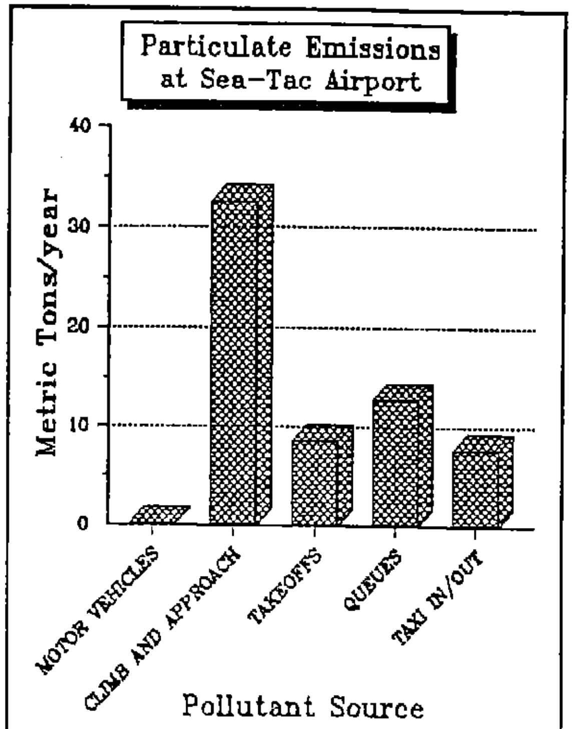


Figure 8.

5. EDMS predicted significantly high levels of nitrogen oxide (up to 28 ppm on a one-hour average about 100 meters south of the runway) in the worst case conditions. Note that the gradients around these hot spots are extremely steep, and the concentrations rapidly go to zero. A one-hour average standard does not exist for nitrogen oxides; however an annual average standard of 0.05 ppm exists for nitrogen dioxide. It is expected that a more refined study with actual meteorological data and variation of temporal factors would reduce, on an annual basis, the predicted value ten-fold, or more --maybe even below the 0.05 limit. Another factor to point out is that most of the nitrogen oxides in the aircraft exhaust are in the form of nitrogen monoxide (NO). It is expected that NO will be dispersed and oxidized to NO_2 over a wide area, maybe kilometers away from the point of emission, therefore reducing the concentrations near the airport. Nevertheless, the predicted concentrations of NOx are a reason for concern. Refering to figure 16 which contains contour lines for the 170 degree case, the contouring routine produced artifacts because of the low point density in this particular data set; the actual shape of the contours is expected to be much narrower and symmetrical as in the two other cases. In this

particular run EDMS predicted a concentration of 19 ppm NO_2 in a receptor location right on 154th street. With the wind blowing directly from the north (0 degrees) the Tyee Golf Course can be getting as much as 12 ppm NO_2 one-hour average during worst-case conditions.

6. Predicted maximum one-hour concentrations of carbon monoxide during worst-case conditions are about 20 ppm in the terminal area, due almost entirely to traffic, and range up to 59 ppm at the runway, rapidly decreasing to about 15 ppm one kilometer downwind of the maximum concentration. In the case where the wind direction is zero degrees, the plume spreads out around the queuing area, and 1 km south of the queue the impact is still about 10 ppm. In figure 9 an island of zero concentration is located next to the 2 ppm contour. As expected, due to the meteorology chosen and the nature of the source, there is a steep gradient in the east-west direction and a more moderate one along the north-south axis. In the 345 degree case illustrated in figure 11, a one-hour average contribution to the housing development immediately east of the Tyee Golf Course, Angle Lake School and Seattle Christian School of approximately 9-5 ppm was predicted.

The one-hour standard for CO is 35 ppm. It is predicted that the maximum one-hour concentration of CO due to aircraft alone is about 20 ppm, or 57% of the standard, in an area of public access during a peak hour and low-dispersive meteorological conditions.

7. EDMS revealed localized hot-spots of particulate concentrations in the range of 800 micrograms per cubic meter, particularly in the 170 degree case illustrated in figure 22. Note that 154th. Street is located at the hot spot. At approximately 1 km north of the runway, the concentration has decreased to 157 micrograms per cubic meter.

The 24-hour standard for fine particulate matter (PM-10) is 150 micrograms per cubic meter. Measurements have shown that all of the particulate matter from aircraft exhaust can be classified as fine, ranging in diameter from 0.03 to 0.1 micrometers.[17]

dangerous levels of particulate

8. The airport is also a significant source of hydrocarbons contributing up to 5 ppm worst-case, ground-level concentrations. The housing development around Seattle Christian School and the school itself may get around 4 ppm of hydrocarbons as illustrated in figure 14, the 345

degree case. From a toxics standpoint that may be quite significant depending on the actual composition of the hydrocarbons. For example, assuming that 4% (based on the Radian estimates) of the hydrocarbon emissions are benzene, the benzene contribution to the hourly average from the airport would be of about 0.16 *parts per million* (or 24000 *parts per trillion* annual average). As a point of reference, the acceptable source impact level (ASIL) for new sources proposed in WAC 173-460 is 0.063 *parts per trillion*.

9. The contribution of traffic to sulfur oxide pollution is minimal. A high of 0.5 ppm SO_2 was predicted on the runway in the 0 degree case on figure 18 decreasing to 0.1 ppm 1 km south of the queuing area, in the vicinity of 200th Street. A one-hour average national standard for SO_2 does not exist, Washington's one-hour average standard is 0.4 ppm.

10. It is important to mention the conclusions that the FAA/EPA team reached in their 1980 report *Impact of Aircraft Emissions on Air Quality in the Vicinity of Airports* mentioned earlier. This report compiled both monitoring and modeling analyses of airports throughout the country: Washington National, Los Angeles International, Dulles International, Lakeland, John F. Kennedy, and Chicago O'Hare. They summarized their conclusions in the following manner:

" * Maximum hourly average CO concentrations from aircraft are unlikely to exceed 5 ppm in areas of public exposure and are thus small in comparison to the NAAQS of 35 ppm.

* Maximum hourly HC concentrations from aircraft can exceed 0.25 ppm over an area several times the size of the airport.

* While annual average NO_2 concentrations from aircraft are estimated to contribute only 10 to 20 percent of the NAAQS limit level, these concentrations, when averaged over a one hour time period are estimated to produce concentrations as high as 0.5 ppm if one assumes that all engine produced NO is converted to NO_2 by the time these emissions reach public exposure. This value is at the upper end of the concentration range being considered for the short term NO_2 standard presently under review and cannot be ignored."

The above excerpt identifies nitrogen oxides and hydrocarbons as two pollutants to be concerned about at airports; however, this screening study of Sea-Tac's emissions showed that the airport's contribution to ground-level pollutant concentrations is higher than expected.

as natural gas, ethanol or methanol. A project of that nature is underway at the Denver Airport.

6. Consider indirect source legislation to control the growth and operation of indirect sources when such sources pose a significant threat to ambient air quality. California is leading the way in that effort.

7. Conduct a refined study to be able to better identify the impact of Sea-Tac Airport on the ground-level pollutant concentrations.

8. Utilize the mobile monitor van to do some sampling in the areas around Sea-Tac Airport expected to have the highest impacts especially for benzene which, as discussed earlier, may pose a large risk to the nearby communities.

13. John Raymond, Department of Ecology, Air Quality Program, Personal Conversation

14. A History of New Indirect Source Regulatory Efforts, Technical Assessment Document, California Air Resources Board, June 1990

15. Richard Wilcox, EPA, Office of Mobile Sources, Ann Arbor, Michigan, Personal Conversation

16. Idem

17. Stockham, John D. and Luebecke, Erdmann H., Turbine Engine Particulate Emission Characterization, Prepared for: Federal Aviation Administration, Report No. FAA-RD-79-15, January, 1979

BIBLIOGRAPHY

1. Stern, Arthur C.; Boubel, Richard W.; Turner, D. Bruce; Fox, Donald L.; Fundamentals of Air Pollution, 2nd. edition, Academic Press, Inc., 1984, p.348

2. Report of the Committee on Energy and Commerce on the Clean Air Act Amendments of 1990 H.R. 3030, May 17,1990, p. 148

3. To Breathe Clean Air, Report of The National Commission on Air Quality, Washington D.C., March 1981, p.74

4. Lippman, Morton, 1988. *Health Significance of Pulmonary Function Responses to Airborne Irritants*, Journal of Air Pollution Control and Waste Management, 38-7, July, pp 881-887

5. Stern, Arthur C., et al., p. 145

6. Wayson, Roger L.; Bowlby, William; *Inventorying Airport Air Pollutant Emissions*, Journal of Transportation Engineering, vol. 114, no.1, January 1988, p.9

7. Segal, Howard; Federal Aviation Administration; Manager, Modeling and Monitoring, personal conversation

8. Yamartino, R.J., Smith, D.A., Bremer, S.A., Heinold, D., Lamich, D., Taylor, B., 1980. Impact of Aircraft Emissions on Air Quality in the Vicinity of Airports, Report No. FAA-EE-09A

9. Jordan, Bruce; Broderick, Anthony J.; *Emissions of Oxides of Nitrogen from Aircraft*, Proceedings: Air Quality and Aviation: An International Conference, October 16-18, 1978, Reston, VA, p.10-11

10. Wayson et al., p. 5

11. Stockham, John D., Luebcke, Erdmann H., 1979. Turbine Engine Particulate Emission Characterization, Report NO. FAA-RD-79-15

12. Jordan, et al., p.11 (Data for Figure 1 obtained from this source)

AP-42 VOL II MOBILE SOURCES EPA

A I R C R A F T E M I S S I O N S F A C T O R S

Aircraft AIRCFT 1ENGPIST
Geographic mode GEOMODE 1
Fuel FUEL.CD 13
Number of engines ENG.NUM 1
Time in mode TIMEMOD .30 minutes
(NOTE: Queueing Times in mode, Geomode 2, are entered in the runway screen)
Takeoff speed TOSPEED .00 meters/sec (it has meaning only for geomode #1, it is ignored otherwise)

Geomode 1 - Takeoff
Geomode 2 - Runway Queue
Geomode 3 - Touch & Go
Geomode 4 - Taxi in/out
Geomode 5 - Aircraft Parking
Geomode 6 - Engine Testing
Geomode 7 - Aircraft Climb
Geomode 8 - Aircraft Approach

Emission rates in kg/hr (per engine)

CO	43.500000
HC	.480000
NOx	.090000
SOx	.010000
Part	.080000

Aircraft AIRCFT 1ENGPIST
Geographic mode GEOMODE 2
Fuel FUEL.CD 13
Number of engines ENG.NUM 1
Time in mode TIMEMOD 10.00 minutes
(NOTE: Queueing Times in mode, Geomode 2, are entered in the runway screen)
Takeoff speed TOSPEED .00 meters/sec (it has meaning only for geomode #1, it is ignored otherwise)

Geomode 1 - Takeoff
Geomode 2 - Runway Queue
Geomode 3 - Touch & Go
Geomode 4 - Taxi in/out
Geomode 5 - Aircraft Parking
Geomode 6 - Engine Testing
Geomode 7 - Aircraft Climb
Geomode 8 - Aircraft Approach

Emission rates in kg/hr (per engine)

CO	4.600000
HC	.160000
NOx	.000000
SOx	.000000
Part	.010000

Aircraft AIRCFT 1ENGPIST
Geographic mode GEOMODE 3
Fuel FUEL.CD 13
Number of engines ENG.NUM 1
Time in mode TIMEMOD 11.00 minutes
(NOTE: Queueing Times in mode, Geomode 2, are entered in the runway screen)
Takeoff speed TOSPEED .00 meters/sec (it has meaning only for geomode #1, it is ignored otherwise)

Geomode 1 - Takeoff
Geomode 2 - Runway Queue
Geomode 3 - Touch & Go
Geomode 4 - Taxi in/out
Geomode 5 - Aircraft Parking
Geomode 6 - Engine Testing
Geomode 7 - Aircraft Climb
Geomode 8 - Aircraft Approach

Emission rates in kg/hr (per engine)

CO	4.600000
HC	.160000
NOx	.000000
SOx	.000000
Part	.010000

Geomode 1 - Takeoff

APPENDIX I: ENGINE EMISSION FACTORS FROM THE EDMS DATABASE

```
Aircraft                   AIRCFT   1ENGPIST              Geomode 2 - Runway Queue
Geographic mode            GEOMODE         4              Geomode 3 - Touch & Go
                                                          Geomode 4 - Taxi in/out
Fuel                       FUEL.CD        13              Geomode 5 - Aircraft Parking
Number of engines          ENG.NUM         1              Geomode 6 - Engine Testing
                                                          Geomode 7 - Aircraft Climb
Time in mode               TIMEMOD     6.00 minutes       Geomode 8 - Aircraft Approach
  (NOTE: Queueing Times in mode, Geomode 2, are entered in the runway screen)
Takeoff speed              TOSPEED       .00 meters/sec (it has meaning only for
                                              geomode #1, it is ignored otherwise)

Emission rates in kg/hr (per engine)

   CO       4.600000
   HC        .160000
   NOx       .000000
   SOx       .000000
   Part      .010000
```

```
                                                          Geomode 1 - Takeoff
Aircraft                   AIRCFT   1ENGPIST              Geomode 2 - Runway Queue
Geographic mode            GEOMODE         5              Geomode 3 - Touch & Go
                                                          Geomode 4 - Taxi in/out
Fuel                       FUEL.CD        13              Geomode 5 - Aircraft Parking
Number of engines          ENG.NUM         1              Geomode 6 - Engine Testing
                                                          Geomode 7 - Aircraft Climb
Time in mode               TIMEMOD     3.00 minutes       Geomode 8 - Aircraft Approach
  (NOTE: Queueing Times in mode, Geomode 2, are entered in the runway screen)
Takeoff speed              TOSPEED       .00 meters/sec (it has meaning only for
                                              geomode #1, it is ignored otherwise)

Emission rates in kg/hr (per engine)

   CO       4.600000
   HC        .160000
   NOx       .000000
   SOx       .000000
   Part      .010000
```

```
                                                          Geomode 1 - Takeoff
Aircraft                   AIRCFT   1ENGPIST              Geomode 2 - Runway Queue
Geographic mode            GEOMODE         6              Geomode 3 - Touch & Go
                                                          Geomode 4 - Taxi in/out
Fuel                       FUEL.CD        13              Geomode 5 - Aircraft Parking
Number of engines          ENG.NUM         1              Geomode 6 - Engine Testing
                                                          Geomode 7 - Aircraft Climb
Time in mode               TIMEMOD     4.00 minutes       Geomode 8 - Aircraft Approach
  (NOTE: Queueing Times in mode, Geomode 2, are entered in the runway screen)
Takeoff speed              TOSPEED       .00 meters/sec (it has meaning only for
                                              geomode #1, it is ignored otherwise)

Emission rates in kg/hr (per engine)

   CO       4.600000
   HC        .160000
   NOx       .000000
   SOx       .000000
   Part      .010000
```

```
                                                          Geomode 1 - Takeoff
Aircraft                   AIRCFT   1ENGPIST              Geomode 2 - Runway Queue
Geographic mode            GEOMODE         7              Geomode 3 - Touch & Go
                                                          Geomode 4 - Taxi in/out

Fuel                       FUEL.CD        13              Geomode 5 - Aircraft Parking
Number of engines          ENG.NUM         1              Geomode 6 - Engine Testing
                                                          Geomode 7 - Aircraft Climb
Time in mode               TIMEMOD     5.00 minutes       Geomode 8 - Aircraft Approach
  (NOTE: Queueing Times in mode, Geomode 2, are entered in the runway scre
Takeoff speed              TOSPEED       .00 meters/sec (it has meaning only f
                                              geomode #1, it is ignored oth

Emission rates in kg/hr (per engine)

   CO      29.900000
   HC        .380000
   NOx       .120000
   SOx       .010000
   Part      .060000
```

```
                                                          Geomode 1 - Takeoff
Aircraft                   AIRCFT   1ENGPIST              Geomode 2 - Runway Queue
Geographic mode            GEOMODE         8              Geomode 3 - Touch & Go
                                                          Geomode 4 - Taxi in/out
Fuel                       FUEL.CD        13              Geomode 5 - Aircraft Parking
Number of engines          ENG.NUM         1              Geomode 6 - Engine Testing
                                                          Geomode 7 - Aircraft Climb
Time in mode               TIMEMOD     6.00 minutes       Geomode 8 - Aircraft Approach
  (NOTE: Queueing Times in mode, Geomode 2, are entered in the runway screen)
Takeoff speed              TOSPEED       .00 meters/sec (it has meaning only for
                                              geomode #1, it is ignored otherwise)

Emission rates in kg/hr (per engine)

   CO      25.800000
   HC        .410000
   NOx       .020000
```

Aircraft	AIRCFT	CNA441
Geographic mode	GEOMODE	6
Fuel	FUEL.CD	13
Number of engines	ENG.NUM	2
Time in mode	TIMEMOD	4.00 minutes
Takeoff speed	TOSPEED	.00 meters/sec (it has meaning only for geomode #1, it is ignored otherwise)

(NOTE: Queueing Times in mode, Geomode 2, are entered in the runway screen)

Geomode 1 - Takeoff
Geomode 2 - Runway Queue
Geomode 3 - Touch & Go
Geomode 4 - Taxi in/out
Geomode 5 - Aircraft Parking
Geomode 6 - Engine Testing
Geomode 7 - Aircraft Climb
Geomode 8 - Aircraft Approach

Emission rates in kg/hr (per engine)

CO	3.120000
HC	4.020000
NOx	.150000
SOx	.050000
Part	.140000

Aircraft	AIRCFT	CNA441
Geographic mode	GEOMODE	7
Fuel	FUEL.CD	13
Number of engines	ENG.NUM	2
Time in mode	TIMEMOD	2.50 minutes
Takeoff speed	TOSPEED	.00 meters/sec (it has meaning only for geomode #1, it is ignored otherwise)

(NOTE: Queueing Times in mode, Geomode 2, are entered in the runway screen)

Geomode 1 - Takeoff
Geomode 2 - Runway Queue
Geomode 3 - Touch & Go
Geomode 4 - Taxi in/out
Geomode 5 - Aircraft Parking
Geomode 6 - Engine Testing
Geomode 7 - Aircraft Climb
Geomode 8 - Aircraft Approach

Emission rates in kg/hr (per engine)

CO	.180000
HC	.030000
NOx	2.200000
SOx	.190000
Part	.270000

Aircraft	AIRCFT	CNA441
Geographic mode	GEOMODE	8
Fuel	FUEL.CD	13
Number of engines	ENG.NUM	2
Time in mode	TIMEMOD	4.50 minutes
Takeoff speed	TOSPEED	.00 meters/sec (it has meaning only for geomode #1, it is ignored otherwise)

(NOTE: Queueing Times in mode, Geomode 2, are entered in the runway screen)

Geomode 1 - Takeoff
Geomode 2 - Runway Queue
Geomode 3 - Touch & Go
Geomode 4 - Taxi in/out
Geomode 5 - Aircraft Parking
Geomode 6 - Engine Testing
Geomode 7 - Aircraft Climb
Geomode 8 - Aircraft Approach

Emission rates in kg/hr (per engine)

CO	.790000
HC	.070000
NOx	1.120000
SOx	.110000
[illegible]	[illegible]

Part .050000

A I R C R A F T   E M I S S I O N S   F A C T O R S

2 OPERATIONS

Aircraft	AIRCFT	CNA441
Geographic mode	GEOMODE	1
Fuel	FUEL.CD	13
Number of engines	ENG.NUM	2
Time in mode	TIMEMOD	.50 minutes
Takeoff speed	TOSPEED	.00 meters/sec (it has meaning only for geomode #1, it is ignored otherwise)

(NOTE: Queueing Times in mode, Geomode 2, are entered in the runway screen)

Geomode 1 - Takeoff
Geomode 2 - Runway Queue
Geomode 3 - Touch & Go
Geomode 4 - Taxi in/out
Geomode 5 - Aircraft Parking
Geomode 6 - Engine Testing
Geomode 7 - Aircraft Climb
Geomode 8 - Aircraft Approach

Emission rates in kg/hr (per engine)

CO	.160000
HC	.020000
NOx	2.570000
SOx	.210000
Part	.360000

Aircraft	AIRCFT	CNA441
Geographic mode	GEOMODE	2
Fuel	FUEL.CD	13
Number of engines	ENG.NUM	2
Time in mode	TIMEMOD	20.00 minutes
Takeoff speed	TOSPEED	.00 meters/sec (it has meaning only for geomode #1, it is ignored otherwise)

(NOTE: Queueing Times in mode, Geomode 2, are entered in the runway screen)

Geomode 1 - Takeoff
Geomode 2 - Runway
Geomode 3 - Touch &
Geomode 4 - Taxi in/out
Geomode 5 - Aircraft Parking
Geomode 6 - Engine Testing
Geomode 7 - Aircraft Climb
Geomode 8 - Aircraft Approach

Emission rates in kg/hr (per engine)

CO	3.120000
HC	4.020000
NOx	.150000
SOx	.050000
Part	.140000

Aircraft	AIRCFT	CNA441
Geographic mode	GEOMODE	3
Fuel	FUEL.CD	13
Number of engines	ENG.NUM	2
Time in mode	TIMEMOD	7.00 minutes
Takeoff speed	TOSPEED	.00 meters/sec (it has meaning only for geomode #1, it is ignored otherwise)

(NOTE: Queueing Times in mode, Geomode 2, are entered in the runway screen)

Geomode 1 - Takeoff
Geomode 2 - Runway Queue
Geomode 3 - Touch & Go
Geomode 4 - Taxi in/out
Geomode 5 - Aircraft Parking
Geomode 6 - Engine Testing
Geomode 7 - Aircraft Climb
Geomode 8 - Aircraft Approach

Emission rates in kg/hr (per engine)

CO	3.120000
HC	4.020000
NOx	.150000
SOx	.050000
Part	.140000

Aircraft	AIRCFT	CNA441
Geographic mode	GEOMODE	4
Fuel	FUEL.CD	13
Number of engines	ENG.NUM	2
Time in mode	TIMEMOD	6.00 minutes
Takeoff speed	TOSPEED	.00 meters/sec (it has meaning only for geomode #1, it is ignored otherwise)

(NOTE: Queueing Times in mode, Geomode 2, are entered in the runway screen)

Geomode 1 - Takeoff
Geomode 2 - Runway Queue
Geomode 3 - Touch & Go
Geomode 4 - Taxi in/out
Geomode 5 - Aircraft Parking
Geomode 6 - Engine Testing
Geomode 7 - Aircraft Climb
Geomode 8 - Aircraft Approach

Emission rates in kg/hr (per engine)

CO	3.120000
HC	4.020000
NOx	.150000
SOx	.050000
Part	.140000

Aircraft	AIRCFT	CNA441
Geographic mode	GEOMODE	5
Fuel	FUEL.CD	13
Number of engines	ENG.NUM	2
Time in mode	TIMEMOD	3.00 minutes
Takeoff speed	TOSPEED	.00 meters/sec (it has meaning only for geomode #1, it is ignored otherwise)

(NOTE: Queueing Times in mode, Geomode 2, are entered in the runway screen)

Geomode 1 - Takeoff
Geomode 2 - Runway Queue
Geomode 3 - Touch & Go
Geomode 4 - Taxi in/out
Geomode 5 - Aircraft Parking
Geomode 6 - Engine Testing
Geomode 7 - Aircraft Climb
Geomode 8 - Aircraft Approach

Emission rates in kg/hr (per engine)

CO	3.120000
HC	4.020000
NOx	.150000

AIRCRAFT EMISSIONS FACTORS

2 T/O

Aircraft	AIRCFT	DC10
Geographic mode	GEOMODE	1
Fuel	FUEL.CD	13
Number of engines	ENG.NUM	3
Time in mode	TIMEMOD	.70 minutes
Takeoff speed	TOSPEED	.00 meters/sec

Geomode 1 - Takeoff
Geomode 2 - Runway Queue
Geomode 3 - Touch & Go
Geomode 4 - Taxi in/out
Geomode 5 - Aircraft Parkir
Geomode 6 - Engine Testing
Geomode 7 - Aircraft Climb
Geomode 8 - Aircraft Approa

(NOTE: Queueing Times in mode, Geomode 2, are entered in the runway screen)
(it has meaning only for geomode #1, it is ignored otherwis

Emission rates in kg/hr (per engine)

CO	1.470000
HC	.360000
NOx	215.300000
SOx	7.320000
Part	1.700000

Aircraft	AIRCFT	DC10
Geographic mode	GEOMODE	2
Fuel	FUEL.CD	13
Number of engines	ENG.NUM	3
Time in mode	TIMEMOD	20.00 minutes
Takeoff speed	TOSPEED	.00 meters/sec

Geomode 1 - Takeoff
Geomode 2 - Runway Queue
Geomode 3 - Touch & Go
Geomode 4 - Taxi in/out
Geomode 5 - Aircraft Parkir
Geomode 6 - Engine Testing
Geomode 7 - Aircraft Climb
Geomode 8 - Aircraft Approa

(NOTE: Queueing Times in mode, Geomode 2, are entered in the runway screen)
(it has meaning only for geomode #1, it is ignored otherwis

Emission rates in kg/hr (per engine)

CO	64.590000
HC	24.990000
NOx	2.600000
SOx	.840000
Part	1.000000

Aircraft	AIRCFT	DC10
Geographic mode	GEOMODE	3
Fuel	FUEL.CD	13
Number of engines	ENG.NUM	3
Time in mode	TIMEMOD	2.00 minutes
Takeoff speed	TOSPEED	.00 meters/sec

Geomode 1 - Takeoff
Geomode 2 - Runway Queue
Geomode 3 - Touch & Go
Geomode 4 - Taxi in/out
Geomode 5 - Aircraft Parking
Geomode 6 - Engine Testing
Geomode 7 - Aircraft Climb
Geomode 8 - Aircraft Approach

(NOTE: Queueing Times in mode, Geomode 2, are entered in the runway screen)
(it has meaning only for geomode #1, it is ignored otherwise)

Emission rates in kg/hr (per engine)

CO	64.590000
HC	24.990000
NOx	2.600000
SOx	.840000
Part	1.000000

Aircraft	AIRCFT	DC10
Geographic mode	GEOMODE	4
Fuel	FUEL.CD	13
Number of engines	ENG.NUM	3
Time in mode	TIMEMOD	6.00 minutes
Takeoff speed	TOSPEED	.00 meters/sec

Geomode 1 - Takeoff
Geomode 2 - Runway Queue
Geomode 3 - Touch & Go
Geomode 4 - Taxi in/out
Geomode 5 - Aircraft Parking
Geomode 6 - Engine Testing
Geomode 7 - Aircraft Climb
Geomode 8 - Aircraft Approach

(NOTE: Queueing Times in mode, Geomode 2, are entered in the runway screen)
(it has meaning only for geomode #1, it is ignored otherwise)

Emission rates in kg/hr (per engine)

CO	64.590000
HC	24.990000
NOx	2.600000
SOx	.840000
Part	1.000000

Aircraft	AIRCFT	DC10
Geographic mode	GEOMODE	5
Fuel	FUEL.CD	13
Number of engines	ENG.NUM	3
Time in mode	TIMEMOD	3.00 minutes
Takeoff speed	TOSPEED	.00 meters/sec (it has meaning only for geomode #1, it is ignored otherwise)

(NOTE: Queueing Times in mode, Geomode 2, are entered in the runway screen)

Geomode 1 - Takeoff
Geomode 2 - Runway Queue
Geomode 3 - Touch & Go
Geomode 4 - Taxi in/out
Geomode 5 - Aircraft Parking
Geomode 6 - Engine Testing
Geomode 7 - Aircraft Climb
Geomode 8 - Aircraft Approach

Emission rates in kg/hr (per engine)

CO	64.590000
HC	24.990000
NOx	2.600000
SOx	.840000
Part	1.000000

Aircraft	AIRCFT	DC10
Geographic mode	GEOMODE	6
Fuel	FUEL.CD	13
Number of engines	ENG.NUM	3
Time in mode	TIMEMOD	4.00 minutes
Takeoff speed	TOSPEED	.00 meters/sec (it has meaning only for geomode #1, it is ignored otherwise)

(NOTE: Queueing Times in mode, Geomode 2, are entered in the runway screen)

Geomode 1 - Takeoff
Geomode 2 - Runway Queue
Geomode 3 - Touch & Go
Geomode 4 - Taxi in/out
Geomode 5 - Aircraft Parking
Geomode 6 - Engine Testing
Geomode 7 - Aircraft Climb
Geomode 8 - Aircraft Approach

Emission rates in kg/hr (per engine)

CO	64.590000
HC	24.990000
NOx	2.600000
SOx	.840000
Part	1.000000

Aircraft	AIRCFT	DC10
Geographic mode	GEOMODE	7
Fuel	FUEL.CD	13
Number of engines	ENG.NUM	3
Time in mode	TIMEMOD	2.20 minutes
Takeoff speed	TOSPEED	.00 meters/sec (it has meaning only for geomode #1, it is ignored otherwise)

(NOTE: Queueing Times in mode, Geomode 2, are entered in the runway screen)

Geomode 1 - Takeoff
Geomode 2 - Runway Queue
Geomode 3 - Touch & Go
Geomode 4 - Taxi in/out
Geomode 5 - Aircraft Parking
Geomode 6 - Engine Testing
Geomode 7 - Aircraft Climb
Geomode 8 - Aircraft Approach

Emission rates in kg/hr (per engine)

CO	2.990000
HC	.600000
NOx	128.000000
SOx	5.980000
Part	1.800000

Aircraft	AIRCFT	DC10
Geographic mode	GEOMODE	8
Fuel	FUEL.CD	13
Number of engines	ENG.NUM	3
Time in mode	TIMEMOD	4.00 minutes
Takeoff speed	TOSPEED	.00 meters/sec (it has meaning only for geomode #1, it is ignored otherwise)

(NOTE: Queueing Times in mode, Geomode 2, are entered in the runway screen)

Geomode 1 - Takeoff
Geomode 2 - Runway Queue
Geomode 3 - Touch & Go
Geomode 4 - Taxi in/out
Geomode 5 - Aircraft Parking
Geomode 6 - Engine Testing
Geomode 7 - Aircraft Climb
Geomode 8 - Aircraft Approach

Emission rates in kg/hr (per engine)

CO	20.240000
HC	2.110000
NOx	16.440000
SOx	2.110000

2.13 kg/min ea. engine
x2.2046 = 4.69 lb. ea engine per min.
x 3 = 14.07 lb all engines per min
x2.2 min = 30.95 CLIMBOUT NOx lb.

```
                                               Geomode 1 - Takeoff
                                               Geomode 2 - Runway Queue
Aircraft              AIRCFT  747              Geomode 3 - Touch & Go
Geographic mode       GEOMODE         6        Geomode 4 - Taxi in/out
                                               Geomode 5 - Aircraft Parking
Fuel                  FUEL.CD        13        Geomode 6 - Engine Testing
Number of engines     ENG.NUM         4        Geomode 7 - Aircraft Climb

Time in mode           TIMEMOD     4.00 minutes   Geomode 8 - Aircraft Apprcac
  (NOTE: Queueing Times in mode, Geomode 2, are entered in the runway screen)
Takeoff speed          TOSPEED      .00 meters/sec (it has meaning only for
                                        geomode #1, it is ignored otherwise

Emission rates in kg/hr (per engine)

   CO     64.590000
   HC     24.990000
   NOx     2.600000
   SOx      .840000
   Part    1.000000

                                               Geomode 1 - Takeo
                                               Geomode 2 - Runway ...
Aircraft              AIRCFT  747              Geomode 3 - Touch & Go
Geographic mode       GEOMODE         7        Geomode 4 - Taxi in/out
                                               Geomode 5 - Aircraft Parkin
Fuel                  FUEL.CD        13        Geomode 6 - Engine Testing
Number of engines     ENG.NUM         4        Geomode 7 - Aircraft Climb
                                               Geomode 8 - Aircraft Approa
Time in mode           TIMEMOD     2.20 minutes
  (NOTE: Queueing Times in mode, Geomode 2, are entered in the runway screen)
Takeoff speed          TOSPEED      .00 meters/sec (it has meaning only for
                                        geomode #1, it is ignored otherwis

Emission rates in kg/hr (per engine)

   CO      2.990000
   HC       .600000
   NOx   128.000000
   SOx     5.980000
   Part    1.800000

                                               Geomode 1 - Takeoff
                                               Geomode 2 - Runway Queue
Aircraft              AIRCFT  747              Geomode 3 - Touch & Go
Geographic mode       GEOMODE         8        Geomode 4 - Taxi in/out
                                               Geomode 5 - Aircraft Parkin
Fuel                  FUEL.CD        13        Geomode 6 - Engine Testing
Number of engines     ENG.NUM         4        Geomode 7 - Aircraft Climb
                                               Geomode 8 - Aircraft Approa
Time in mode           TIMEMOD     4.00 minutes
  (NOTE: Queueing Times in mode, Geomode 2, are entered in the runway screen)
Takeoff speed          TOSPEED      .00 meters/sec (it has meaning only for
                                        geomode #1, it is ignored otherwis

Emission rates in kg/hr (per engine)

   CO     20.240000
   HC      2.110000
   NOx    16.440000
   SOx     2.110000
   Part    1.000000
```

AIRCRAFT EMISSIONS FACTORS

2 T/O

Aircraft	AIRCFT	747
Geographic mode	GEOMODE	1
Fuel	FUEL.CD	13
Number of engines	ENG.NUM	4
Time in mode	TIMEMOD	.70 minutes
Takeoff speed	TOSPEED	.00 meters/sec (it has meaning only for geomode #1, it is ignored otherwise)

(NOTE: Queueing Times in mode, Geomode 2, are entered in the runway screen)

Geomode 1 - Takeoff
Geomode 2 - Runway Queue
Geomode 3 - Touch & Go
Geomode 4 - Taxi in/out
Geomode 5 - Aircraft Parking
Geomode 6 - Engine Testing
Geomode 7 - Aircraft Climb
Geomode 8 - Aircraft Approach

Emission rates in kg/hr (per engine)

CO	1.470000
HC	.360000
NOx	215.300000
SOx	7.320000
Part	1.700000

Aircraft	AIRCFT	747
Geographic mode	GEOMODE	2
Fuel	FUEL.CD	13
Number of engines	ENG.NUM	4
Time in mode	TIMEMOD	20.00 minutes
Takeoff speed	TOSPEED	.00 meters/sec (it has meaning only for geomode #1, it is ignored otherwise)

(NOTE: Queueing Times in mode, Geomode 2, are entered in the runway screen)

Geomode 1 - Takeoff
Geomode 2 - Runway Queue
Geomode 3 - Touch & Go
Geomode 4 - Taxi in/out
Geomode 5 - Aircraft Parking
Geomode 6 - Engine Testing
Geomode 7 - Aircraft Climb
Geomode 8 - Aircraft Approach

Emission rates in kg/hr (per engine)

CO	64.590000
HC	24.990000
NOx	2.600000
SOx	.840000
Part	1.000000

Aircraft	AIRCFT	747
Geographic mode	GEOMODE	3
Fuel	FUEL.CD	13
Number of engines	ENG.NUM	4
Time in mode	TIMEMOD	2.00 minutes
Takeoff speed	TOSPEED	.00 meters/sec (it has meaning only for geomode #1, it is ignored otherwise)

(NOTE: Queueing Times in mode, Geomode 2, are entered in the runway screen)

Geomode 1 - Takeoff
Geomode 2 - Runway Queue
Geomode 3 - Touch & Go
Geomode 4 - Taxi in/out
Geomode 5 - Aircraft Parking
Geomode 6 - Engine Testing
Geomode 7 - Aircraft Climb
Geomode 8 - Aircraft Approach

Emission rates in kg/hr (per engine)

CO	64.590000
HC	24.990000
NOx	2.600000
SOx	.840000
Part	1.000000

Aircraft	AIRCFT	747
Geographic mode	GEOMODE	4
Fuel	FUEL.CD	13
Number of engines	ENG.NUM	4
Time in mode	TIMEMOD	6.00 minutes
Takeoff speed	TOSPEED	.00 meters/sec (it has meaning only for geomode #1, it is ignored otherwise)

(NOTE: Queueing Times in mode, Geomode 2, are entered in the runway screen)

Geomode 1 - Takeoff
Geomode 2 - Runway Queue
Geomode 3 - Touch & Go
Geomode 4 - Taxi in/out
Geomode 5 - Aircraft Parking
Geomode 6 - Engine Testing
Geomode 7 - Aircraft Climb
Geomode 8 - Aircraft Approach

Emission rates in kg/hr (per engine)

CO	64.590000
HC	24.990000
NOx	2.600000
SOx	.840000
Part	1.000000

Aircraft	AIRCFT	747
Geographic mode	GEOMODE	5
Fuel	FUEL.CD	13
Number of engines	ENG.NUM	4
Time in mode	TIMEMOD	3.00 minutes
Takeoff speed	TOSPEED	.00 meters/sec (it has meaning only for geomode #1, it is ignored otherwise)

(NOTE: Queueing Times in mode, Geomode 2, are entered in the runway screen)

Geomode 1 - Takeoff
Geomode 2 - Runway Queue
Geomode 3 - Touch & Go
Geomode 4 - Taxi in/out
Geomode 5 - Aircraft Parking
Geomode 6 - Engine Testing
Geomode 7 - Aircraft Climb
Geomode 8 - Aircraft Approach

Emission rates in kg/hr (per engine)

CO	64.590000
HC	24.990000

AIRCRAFT OPERATIONS

CLIMB AND APPROACH

	CO	HC	NOx
B-727	1.00E+08	6.63E+06	3.55E+08
B-737	1.33E+07	8.85E+05	4.74E+07
B-747	3.49E+07	3.89E+06	1.38E+08
B-757	5.92E+06	7.67E+05	7.73E+07
B 737-300	1.36E+07	4.71E+05	8.52E+07
MD80	2.62E+07	9.87E+06	1.82E+08
BAC111	7.05E+07	2.97E+07	1.16E+08
CESSNA 441	7.99E+05	7.78E+04	2.10E+06
DC10	2.62E+07	2.92E+06	1.04E+08
DC9	8.90E+06	5.90E+05	3.16E+07
LOCKHEED L1011	2.76E+07	9.97E+06	5.38E+07
DASH 7	8.87E+06	1.11E+05	1.62E+07
DCH6	1.90E+07	1.69E+06	1.23E+07
TOTAL CLIMB & APPROACH	355793000	6.757E+07	1.221E+09

TAKEOFFS

	CO	HC	NOx
B-727	4.980E+06	3.450E+05	1.440E+08
B-737	6.640E+05	4.610E+04	1.920E+07
B-747	4.107E+05	1.000E+05	6.010E+07
B-757	1.270E+06	2.440E+05	2.880E+07
B-737 300	1.380E+06	6.280E+04	2.840E+07
MD80	1.900E+06	7.370E+05	7.354E+07
BAC111	4.090E+06	3.540E+06	3.970E+07
CESSNA 441	1.590E+04	1.990E+03	2.560E+05
DC10	3.080E+05	7.540E+04	4.510E+07
DC9	4.420E+05	3.070E+04	1.280E+07
LOCKHEED L1011	2.670E+05	1.380E+06	2.390E+07
DASH 7	2.870E+05	0.000E+00	2.290E+06
DHC6	1.790E+05	0.000E+00	1.350E+06
TOTAL TAKEOFFS	1.619E+07	6.563E+06	4.794E+08

QUEUE

	CO	HC	NOx
B-727	3.980E+08	1.028E+08	3.970E+07
B-737	5.310E+07	1.370E+07	5.290E+06
B-747	2.570E+08	9.970E+07	1.038E+07
B-757	4.360E+07	6.520E+06	4.750E+06
B-737 300	8.080E+07	4.790E+06	1.010E+07
MD80	4.860E+07	1.340E+07	1.380E+07
BAC111	3.780E+08	2.890E+08	2.870E+06
CESSNA 441	6.220E+06	8.020E+06	2.990E+05
DC10	1.930E+08	7.480E+07	7.780E+06
DC9	3.540E+07	9.140E+06	3.530E+06
LOCKHEED L1011	9.640E+07	6.780E+07	3.600E+06
DASH 7	4.080E+07	1.580E+07	4.630E+06
DHC6	5.990E+07	4.700E+07	2.330E+06
TOTAL QUEUES	1690820000	752470000	109059000

TAXI-IN TAXI-OUT

	CO	HC	NOx
B-727	2.390E+08	6.170E+07	2.380E+07
B-737	3.180E+07	8.220E+06	3.170E+06
B-747	1.540E+08	5.980E+07	6.220E+06
B-757	2.620E+07	3.910E+06	2.850E+06
B 737-300	4.840E+07	2.870E+06	6.100E+06
MD80	2.922E+07	8.040E+06	8.330E+06
BAC111	2.260E+08	1.730E+08	1.720E+06
CESSNA 441	3.730E+06	4.810E+06	1.790E+05
DC10	1.610E+08	4.480E+07	4.670E+06
DC9	2.120E+07	5.480E+06	2.110E+06
LOCKHEED L1011	5.780E+07	4.070E+07	2.160E+06
DASH 7	2.450E+07	9.480E+06	2.770E+06
DHC6	3.599E+07	2.820E+07	1.400E+06
TOTAL TAXI IN/OUT	1058840000	451010000	6.548E+07

TOTALS FOR EACH TYPE OF AIRCRAFT

	CO	HC	NOx
B-727	7.420E+08	1.715E+08	5.625E+08
B-737	9.886E+07	2.285E+07	7.506E+07
B-747	4.463E+08	1.635E+08	2.147E+08
B-757	7.699E+07	1.144E+07	1.137E+08
B 737-300	1.442E+08	8.194E+06	1.298E+08
MD80	1.059E+08	3.205E+07	2.777E+08
BAC111	6.786E+08	4.952E+08	1.603E+08
CESSNA 441	1.076E+07	1.291E+07	2.834E+06
DC10	3.805E+08	1.226E+08	1.616E+08
DC9	6.595E+07	1.524E+07	5.004E+07
LOCKHEED L1011	1.821E+08	1.199E+08	8.346E+07
DASH 7	7.446E+07	2.539E+07	2.589E+07
DHC6	1.151E+08	7.689E+07	1.738E+07

	SOx	TSP
ROADWAYS	1.57E+04	1.04E+05
PARKING LOTS	2.16E+03	1.43E+04
TOTAL MOTOR VEHICLES	1.79E+04	1.18E+05
BOILER	5.770E+04	2.880E+05
TRAINING FIRE	2.90E+03	3.71E+05
TANK FARMS	0.00E+00	0.00E+00
CLIMB AND APPROACH	8.726E+07	3.249E+07
TAKEOFFS	2.034E+07	8.534E+06
QUEUES	3.463E+07	1.278E+07
TAXI IN/OUT	2.083E+07	7.656E+06
TOTAL EMISSIONS IN GRAMS	163154320	6.236E+07
TOTAL EMISSIONS IN TONS	179.469752	68.59094
TOTAL EMISSIONS IN TONNES	163.15432	62.3554

EMISSIONS IN METRIC TONS:

	SOx	TSP
MOTOR VEHICLES	0.01786	0.1183
TRAINING FIRE	0.0029	0.371
BOILER	0.058	0.288
TANK FARMS	0	0
CLIMB AND APPROACH	87.263	32.4869
TAKEOFFS	20.3405	8.534
QUEUES	34.6287	12.7825
TAXI IN/OUT	20.8258	7.6564
TOTAL	163.136	62.237

CLIMB AND APPROACH

	SOx	TSP
B-727	2.92E+07	1.20E+07
B-737	3.90E+06	1.60E+06
B-747	8.62E+06	3.18E+06
B-757	3.89E+06	1.30E+05
B 737-300	6.71E+06	8.74E+04
MD80	1.12E+07	3.24E+05
BAC111	7.77E+06	1.01E+07
CESSNA 441	1.93E+05	3.77E+05
DC10	6.46E+06	2.38E+06
DC9	2.59E+06	1.07E+06
LOCKHEED L1011	3.01E+06	0.00E+00
DASH 7	2.11E+06	5.98E+05
DCH6	1.61E+06	6.74E+05
TOTAL CLIMB & APPROACH	8.726E+07	3.249E+07

TAKEOFFS

	SOx	TSP
B-727	7.110E+06	2.670E+06
B-737	9.490E+05	3.560E+05
B-747	2.040E+06	4.750E+05
B-757	9.066E+05	5.160E+04
B-737 300	1.530E+06	2.090E+04
MD80	2.721E+06	1.509E+05
BAC111	1.780E+06	4.079E+06
CESSNA 441	2.090E+04	3.590E+04
DC10	1.530E+06	3.560E+05
DC9	6.320E+05	2.370E+05
LOCKHEED L1011	7.030E+05	0.000E+00
DASH 7	2.390E+05	4.790E+04
DHC6	1.790E+05	5.380E+04
TOTAL TAKEOFFS	2.034E+07	8.534E+06

QUEUE

	SOx	TSP
B-727	1.160E+07	3.590E+06
B-737	1.550E+06	4.790E+05
B-747	3.350E+06	3.990E+06
B-757	1.430E+06	1.990E+04
B-737 300	2.630E+06	5.980E+04
MD80	3.830E+06	7.980E+04
BAC111	3.430E+06	6.380E+05
CESSNA 441	9.970E+04	2.790E+05
DC10	2.510E+06	2.990E+06
DC9	1.038E+06	3.190E+05
LOCKHEED L1011	1.160E+06	0.000E+00
DASH 7	1.110E+06	1.590E+05
DHC6	8.910E+05	1.790E+05
TOTAL QUEUES	3.463E+07	1.278E+07

TAXI-IN TAXI-OUT

	SOx	TSP
B-727	7.000E+06	2.150E+06
B-737	9.340E+05	2.870E+05
B-747	2.010E+06	2.390E+06
B-757	8.620E+05	1.190E+04
B 737-300	1.580E+06	3.590E+04
MD80	2.290E+06	4.790E+04
BAC111	2.060E+06	3.830E+05
CESSNA 441	5.980E+04	1.670E+05
DC10	1.500E+06	1.790E+06
DC9	6.220E+05	1.910E+05
LOCKHEED L1011	7.000E+05	0.000E+00
DASH 7	6.700E+05	9.570E+04
DHC6	5.380E+05	1.070E+05
TOTAL TAXI IN/OUT	2.083E+07	7.656E+06

TOTALS FOR EACH TYPE OF AIRCRAFT

	SOx	TSP
B-727	5.491E+07	2.041E+07
B-737	7.333E+06	2.722E+06
B-747	1.602E+07	1.003E+07
B-757	7.089E+06	2.134E+05
B 737-300	1.245E+07	2.040E+05
MD80	2.004E+07	6.026E+05
BAC111	1.504E+07	1.517E+07
CESSNA 441	3.734E+05	8.589E+05
DC10	1.200E+07	7.516E+06
DC9	4.882E+06	
LOCKHEED L1011	5.573E+06	0.000E+00
DASH 7	4.129E+06	9.006E+05
DHC6	3.218E+06	1.013E+06


```
IMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM
:                 T E M P O R A L   A C T I V I T Y
LMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM
:
:     Temporal name AIRPLANES
:
GDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
:     Hourly factors:
:     0   .13    1   .07    2   .03    3   .01    4   .01    5   .10
:     6   .55    7   .81    8   .82    9   .96    10  .99    11  .93
:     12 1.00    13  .93    14  .74    15  .76    16  .64    17  .88
:     18  .97    19  .88    20  .57    21  .54    22  .50    23  .22
:
:     Daily factors:
:     Sun  .60   Mon  .88   Tue  .88   Wed 1.00
:     Thu  .94   Fri 1.00   Sat  .60
:
:     Monthly factors:
:     Jan  .66   Feb  .58   Mar  .58   Apr  .58   May  .58   Jun  .83
:     Jul  .92   Aug 1.00   Sep  .75   Oct  .58   Nov  .58   Dec  .66
:
HMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM
```

55% activity
midnight to 6:00 am
85.88% 6 thru 2
3 to

```
            O P E R A T I O N A L   A I R C R A F T   S O U R C E S

       TEMPORAL AIRPLANES
  Name  DATA32 B 727 JETS

Runway:
  Location:  Point 1  X1      3075      Y1     1750
             Point 2  X2      3075      Y2     5325
                                                   (Q1X1,Q1Y1) (Q2X1,Q2Y1)
                                                         /            Ç
  Aircraft type   AIRCFT    727                                         Ç Queue
  Takeoffs(peak hour)   PHT    15.00            Queue 1 /               Ç
                      GSEACT 100.00                   /
                                                    Ç-------------------------Ç
                                               (X1,Y1)         Runway        (X2,Y
Queue:
  Time in Mode:                  QTIM   10.00

  End point of queue #1:         Q1X1      3439    Q1Y1      2627
  End point of queue #2:         Q2X1      3439    Q2Y1      4448

   QUENUM   1  (use default)

 Hourly touch and go:            HTGO       .00
```

```
            O P E R A T I O N A L   A I R C R A F T   S O U R C E S

       TEMPORAL AIRPLANES
  Name  DATA32 B 737 JETS

Runway:
  Location:  Point 1  X1      3075      Y1     1750
             Point 2  X2      3075      Y2     5325
                                                   (Q1X1,Q1Y1) (Q2X1,Q2Y1)
                                                         /            Ç
  Aircraft type   AIRCFT    737                                         Ç Que
  Takeoffs(peak hour)   PHT     3.00            Queue 1 /               Ç
                      GSEACT 100.00                   /
                                                    Ç-------------------------Ç
                                               (X1,Y1)         Runway        (X2,
Queue:
  Time in Mode:                  QTIM   10.00

  End point of queue #1:         Q1X1      3439    Q1Y1      2627
  End point of queue #2:         Q2X1      3439    Q2Y1      4448

   QUENUM   1  (use default)

 Hourly touch and go:            HTGO       .00
```

```
            O P E R A T I O N A L   A I R C R A F T   S O U R C E S

       TEMPORAL AIRPLANES
  Name  DATA32 B 747 JETS

Runway:
  Location:  Point 1  X1      3075      Y1     1750
             Point 2  X2      3075      Y2     5325
                                                   (Q1X1,Q1Y1) (Q2X1,Q2Y1)
                                                         /            Ç
  Aircraft type   AIRCFT    747                                         Ç Que
  Takeoffs(peak hour)   PHT     2.00            Queue 1 /               Ç
                      GSEACT 100.00                   /
                                                    Ç--------------------------
                                               (X1,Y1)         Runway        (X
Queue:
  Time in Mode:                  QTIM   10.00

  End point of queue #1:         Q1X1      3439    Q1Y1      2627
  End point of queue #2:         Q2X1      3439    Q2Y1      4448

   QUENUM   1  (use default)

                                 HTGO       .00
```

O P E R A T I O N A L   A I R C R A F T   S O U R C E S

```
    TEMPORAL AIRPLANES
  Name  DATA32 DHC6

Runway:
  Location:   Point 1  X1     3075      Y1     1750
              Point 2  X2     3075      Y2     5325
                                                     (Q1X1,Q1Y1) (Q2X1,Q2Y1)
  Aircraft type    AIRCFT    DHC6                          /              Ç
  Takeoffs(peak hour)   PHT    12.00         Queue 1 /                      Ç Queue
                     GSEACT 100.00                     /                     Ç
                                                      Ç-------------------------Ç
Queue:                                           (X1,Y1)          Runway        (X2,Y
  Time in Mode:                 QTIM  10.00

  End point of queue #1:    Q1X1     3439    Q1Y1    2627
  End point of queue #2:    Q2X1     3439    Q2Y1    4448

   QUENUM  1  (use default)

 Hourly touch and go:         HTGO    .00
```

O P E R A T I O N A L   A I R C R A F T   S O U R C E S

TEMPORAL AIRPLANES
Name DATA32 B 757 JETS

```
Runway:
  Location:  Point 1  X1     3075      Y1    1750
             Point 2  X2     3075      Y2    5325
                                                (Q1X1,Q1Y1) (Q2X1,Q2Y1)
  Aircraft type   AIRCFT   757                           /          Ç
  Takeoffs(peak hour)   PHT    2.00         Queue 1 /                 Ç Queue 2
                     GSEACT 100.00                 /                   Ç
                                                 Ç-------------------------Ç
Queue:                                     (X1,Y1)         Runway        (X2,Y2)
  Time in Mode:                QTIM  10.00

  End point of queue #1:   Q1X1     3439    Q1Y1     2627
  End point of queue #2:   Q2X1     3439    Q2Y1     4448

   QUENUM  1  (use default)

Hourly touch and go:        HTGO     .00
```

O P E R A T I O N A L   A I R C R A F T   S O U R C E S

TEMPORAL AIRPLANES
Name DATA32 B 737-300

```
Runway:
  Location:  Point 1  X1     3075      Y1    1750
             Point 2  X2     3075      Y2    5325
                                                (Q1X1,Q1Y1) (Q2X1,Q2Y1)
  Aircraft type   AIRCFT   737300                        /          Ç
  Takeoffs(peak hour)   PHT    6.00         Queue 1 /                 Ç Queue
                     GSEACT 100.00                 /                   Ç
                                                 Ç-------------------------Ç
Queue:                                     (X1,Y1)         Runway        (X2,Y2
  Time in Mode:                QTIM  10.00

  End point of queue #1:   Q1X1     3439    Q1Y1     2627
  End point of queue #2:   Q2X1     3439    Q2Y1     4448

   QUENUM  1  (use default)

Hourly touch and go:        HTGO     .00
```

O P E R A T I O N A L   A I R C R A F T   S O U R C E S

TEMPORAL AIRPLANES
Name DATA32 MD80

```
Runway:
  Location:  Point 1  X1     3075      Y1    1750
             Point 2  X2     3075      Y2    5325
                                                (Q1X1,Q1Y1) (Q2X1,Q2Y1)
  Aircraft type   AIRCFT   MD80                          /          Ç
  Takeoffs(peak hour)   PHT    8.00         Queue 1 /                 Ç Queue
                     GSEACT 100.00                 /                   Ç
                                                 Ç-------------------------Ç
Queue:                                     (X1,Y1)         Runway        (X2,Y
  Time in Mode:                QTIM  10.00

  End point of queue #1:   Q1X1     3439    Q1Y1     2627
  End point of queue #2:   Q2X1     3439    Q2Y1     4448

   QUENUM  1  (use default)

Hourly touch and go:        HTGO     .00
```

```
          O P E R A T I O N A L   A I R C R A F T   S O U R C E S

       TEMPORAL AIRPLANES
   Name  DATA32 BAC111

 Runway:
   Location:  Point 1  X1     3075      Y1     1750
              Point 2  X2     3075      Y2     5325
                                                 (Q1X1,Q1Y1) (Q2X1,Q2Y1)
    Aircraft type   AIRCFT   BAC111                   /               Ç
    Takeoffs(peak hour)   PHT    8.00        Queue 1 /                 Ç Queue
                       GSEACT 100.00                /                  Ç
                                                  Ç-----------------------Ç
 Queue:                                         (X1,Y1)        Runway      (X2,Y2
   Time in Mode:               QTIM  10.00

    End point of queue #1:   Q1X1     3439   Q1Y1     2627
    End point of queue #2:   Q2X1     3439   Q2Y1     4448

     QUENUM  1  (use default)

  Hourly touch and go:          HTGO     .00
           O P E R A T I O N A L   A I R C R A F T   S O U R C E S

       TEMPORAL AIRPLANES
   Name  DATA32 CESSNA 441

 Runway:
   Location:  Point 1  X1     3075      Y1     1750
              Point 2  X2     3075      Y2     5325
                                                 (Q1X1,Q1Y1) (Q2X1,Q2Y1)
    Aircraft type   AIRCFT   CNA441                   /               Ç
    Takeoffs(peak hour)   PHT    2.00        Queue 1 /                 Ç Queue
                       GSEACT 100.00                /                  Ç
                                                  Ç-----------------------Ç
 Queue:                                         (X1,Y1)        Runway      (X2,Y
   Time in Mode:               QTIM  10.00

    End point of queue #1:   Q1X1     3439   Q1Y1     2627
    End point of queue #2:   Q2X1     3439   Q2Y1     4448

     QUENUM  1  (use default)

  Hourly touch and go:          HTGO     .00
           O P E R A T I O N A L   A I R C R A F T   S O U R C E S

       TEMPORAL AIRPLANES
   Name  DATA32 DC10

 Runway:
   Location:  Point 1  X1     3075      Y1     1750
              Point 2  X2     3075      Y2     5325
                                                 (Q1X1,Q1Y1) (Q2X1,Q2Y1)
    Aircraft type   AIRCFT   DC10                     /               Ç
    Takeoffs(peak hour)   PHT    2.00        Queue 1 /                 Ç Queu
                       GSEACT 100.00                /                  Ç
                                                  Ç-----------------------Ç
 Queue:                                         (X1,Y1)        Runway      (X2,
   Time in Mode:               QTIM  10.00

    End point of queue #1:   Q1X1     3439   Q1Y1     2627
    End point of queue #2:   Q2X1     3439   Q2Y1     4448

     QUENUM  1  (use default)

  Hourly touch and go:          HTGO     .00
```

```
O P E R A T I O N A L   A I R C R A F T   S O U R C E S

   TEMPORAL AIRPLANES
 Name  DATA32 DC9

Runway:
  Location:  Point 1  X1     3075      Y1     1750
             Point 2  X2     3075      Y2     5325
                                                  (Q1X1,Q1Y1) (Q2X1,Q2Y1)
  Aircraft type   AIRCFT   DC9                         /          Ç
  Takeoffs(peak hour)   PHT     2.00           Queue 1 /              Ç Queue 2
                     GSEACT 100.00                    /               Ç
                                                    Ç-------------------------Ç
Queue:                                          (X1,Y1)          Runway      (X2,Y2)
  Time in Mode:                QTIM  10.00

  End point of queue #1:   Q1X1     3439    Q1Y1     2627
  End point of queue #2:   Q2X1     3439    Q2Y1     4448

   QUENUM  1  (use default)

Hourly touch and go:        HTGO     .00
```

```
O P E R A T I O N A L   A I R C R A F T   S O U R C E S

   TEMPORAL AIRPLANES
 Name  DATA32 LOCKHEED L1011

Runway:
  Location:  Point 1  X1     3075      Y1     1750
             Point 2  X2     3075      Y2     5325
                                                  (Q1X1,Q1Y1) (Q2X1,Q2Y1)
  Aircraft type   AIRCFT   L1011                       /          Ç
  Takeoffs(peak hour)   PHT     1.00           Queue 1 /              Ç Queue
                     GSEACT 100.00                    /               Ç
                                                    Ç-------------------------Ç
Queue:                                          (X1,Y1)          Runway      (X2,Y2
  Time in Mode:                QTIM  10.00

  End point of queue #1:   Q1X1     3439    Q1Y1     2627
  End point of queue #2:   Q2X1     3439    Q2Y1     4448

   QUENUM  1  (use default)

Hourly touch and go:        HTGO     .00
```

```
O P E R A T I O N A L   A I R C R A F T   S O U R C E S

   TEMPORAL AIRPLANES
 Name  DATA32 DASH 7

Runway:
  Location:  Point 1  X1     3075      Y1     1750
             Point 2  X2     3075      Y2     5325
                                                  (Q1X1,Q1Y1) (Q2X1,Q2Y1)
  Aircraft type   AIRCFT   DHC7                        /          Ç
  Takeoffs(peak hour)   PHT     8.00           Queue 1 /              Ç Queue
                     GSEACT 100.00                    /               Ç
                                                    Ç-------------------------Ç
Queue:                                          (X1,Y1)          Runway      (X2,Y
  Time in Mode:                QTIM  10.00

  End point of queue #1:   Q1X1     3439    Q1Y1     2627
  End point of queue #2:   Q2X1     3439    Q2Y1     4448

   QUENUM  1  (use default)

Hourly touch and go:        HTGO     .00
```

N A T U R A L   G A S   H E A T I N G   P L A N T

Temporal AIRPLANES

Name WINTER HEATING PLANT

Location X 3500 Y 3125

Building height 10.00 meters
Stack height 30.00 meters   Stack diameter 1.00 meters
Stack gas temperature 200.00 C   Stack gas velocity 20.00 meters/secon

	Size (10^6 BTU/hr)	Notes	Plant class
Plant Class 14	Greater than 100	Utility	13
	10 to 100	Industrial	14
	< 10	Commercial	15
	< 10	Domestic	16

Quantity Burned 6000.00 thousand cubic meters per year

Percent Ash .00   Sulpher Content 4.60 gm/10^3Nm^3

Percent control: CO 0 HC 0 NOx 0 SOx 0 Part 0

S T O R A G E   T A N K S

TEMPORAL AIRPLANES (Note: the TEMPORAL is for filling the tank)

Name DATA32 NORTHWEST

Location X 3750 Y 2250 (m)

Annual Fuel into tank FUEL 148.00 (kl)

Fuel Type FUEL.CD 13

Tank Type TYPE 2 (1 for floating roof, 2 for fixed roof)

% vapor recovery VRI .00 (into tank)
% vapor recovery VRO .00 (from tank into vehicles/tank trucks)

Stack height STK.HI 1.00 (m)

S T O R A G E   T A N K S

TEMPORAL AIRPLANES (Note: the TEMPORAL is for filling the tank)

Name DATA32 UNITED TANK FARM

Location X 3250 Y 2000 (m)

Annual Fuel into tank FUEL 150.00 (kl)

Fuel Type FUEL.CD 13

Tank Type TYPE 2 (1 for floating roof, 2 for fixed roof)

% vapor recovery VRI .00 (into tank)
% vapor recovery VRO .00 (from tank into vehicles/tank trucks)

Stack height STK.HI 1.00 (m)

R O A D W A Y S

Temporal name TEMPORAL AIRPLANES

Roadway name DATA32 NORTH ENTRY DRIVE

Vehicles/hour CAUT 1450.00

Speed (mph) CVAS 40.00

Cold starts (%) CCLD 10.00

End points of road:

point 1	X1	3925	Y1	5100
point 2	X2	3825	Y2	3575

R O A D W A Y S

Temporal name TEMPORAL AIRPLANES

Roadway name DATA32 TWENTY EIGHTH AVENUE SE

Vehicles/hour CAUT 500.00

Speed (mph) CVAS 25.00

Cold starts (%) CCLD 50.00

End points of road:

point 1	X1	3775	Y1	2500
point 2	X2	3775	Y2	2150

R O A D W A Y S

Temporal name TEMPORAL AIRPLANES

Roadway name DATA32 CARGO ROAD

Vehicles/hour CAUT 50.00

Speed (mph) CVAS 25.00

Cold starts (%) CCLD 10.00

End points of road:

point 1	X1	3775	Y1	3600
point 2	X2	3625	Y2	4850

R O A D W A Y S

Temporal name TEMPORAL AIRPLANES

Roadway name DATA32 AROUND TERMINAL

Vehicles/hour CAUT 2365.00

Speed (mph) CVAS 20.00

Cold starts (%) CCLD 50.00

End points of road:

point 1	X1	3500	Y1	3125
point 2	X2	3880	Y2	2875

R O A D W A Y S

Temporal name TEMPORAL AIRPLANES

Roadway name DATA32 AROUND TERMINAL

Vehicles/hour	CAUT	2365.00
Speed (mph)	CVAS	20.00
Cold starts (%)	CCLD	50.00

End points of road:

point 1	X1	3500	Y1	3175
point 2	X2	3880	Y2	3425

V E H I C L E P A R K I N G F A C I L I T I E S

Temporal name TEMPORAL AIRPLANES

Parking facility DATA32 MAIN PARKING

Average distance from gate to parking space AVED 3200 (f

Vehicles entering/hr	VINP	650
Vehicles exiting/hr	VOUT	650
Speed (mph)	CVAS	15.00
Cold starts on exit (%)	CCLD	100.00

Four corners of Lot:	X1	3500	Y1	3025
	X2	3500	Y2	3175
	X3	3750	Y3	3025
	X4	3750	Y4	3175

T R A I N I N G   F I R E S

TEMPORAL AIRPLANES

Site name DATA32 TRAINING FIRE

Location X 2250 Y 2500

Training fire activity:

Fuel code FUEL1 10

Temperature of fire TEMP 200 C

Diameter of fire DIAM1 60.00 (meters)

Quantity of fuel burned QUAN1 1000 (gallons per year)

APPENDIX 4: SEA-TAC AIRPORT'S EMISSION INVENTORY

This appendix contains a print-out of the input to EDMS.

The temporal activity table refers to the percent of the activity, peak activity being 100%, for each time interval (hour, day and month) that Sea-Tac Airport operates at. These values were obtained from Alan Yazvani, of the Sea-Tac planning staff. These temporal factors were used for calculating the annual emission rates from the airport.

The tables labeled "operational aircraft sources" contain information about each type of aircraft that was modeled, the number of takeoffs in each peak hour (this data was obtained from the operations department for April, 1990) the time in queue under worst case conditions, and the endpoints of the runway in the grid coordinates that were used for the study.

The tables labeled "Roadways" contain traffic and grid coordinate information on six sections of roads surrounding the airport or on airport property that were modeled. The "Vehicle Parking Facilities" table provide the input for the only parking lot that was modeled--the main parking area.

The other tables in this appendix show the input for other minor sources: fuel storage tanks, boilers, and training fire.

SEA-TAC AIRPORT EMISSIONS INVENTORY

	CO	HC	NOx
ROADWAYS	3.56E+08	2.58E+07	1.94E+07
PARKING LOTS	1.46E+08	1.14E+07	3.63E+06
TOTAL MOTOR VEHICLES	5.02E+08	3.72E+07	2.30E+07
BOILER	3.360E+06	2.770E+06	1.350E+07
TRAINING FIRE	1.62E+06	9.32E+05	1.20E+04
TANK FARMS	0.00E+00	6.54E+03	0.00E+00
CLIMB AND APPROACH	355793000	6.757E+07	1.221E+09
TAKEOFFS	1.619E+07	6.563E+06	4.794E+08
QUEUES	1690820000	752470000	109059000
TAXI IN/OUT	1058840000	451010000	6.548E+07
TOTAL EMISSIONS IN GRAMS	3628626600	1355723230	1934446000
TOTAL EMISSIONS IN TONS	3991.48926	1491.295553	2127.8906
TOTAL EMISSIONS IN TONNES	3628.6266	1355.72323	1934.446

EMISSIONS IN METRIC TONS:

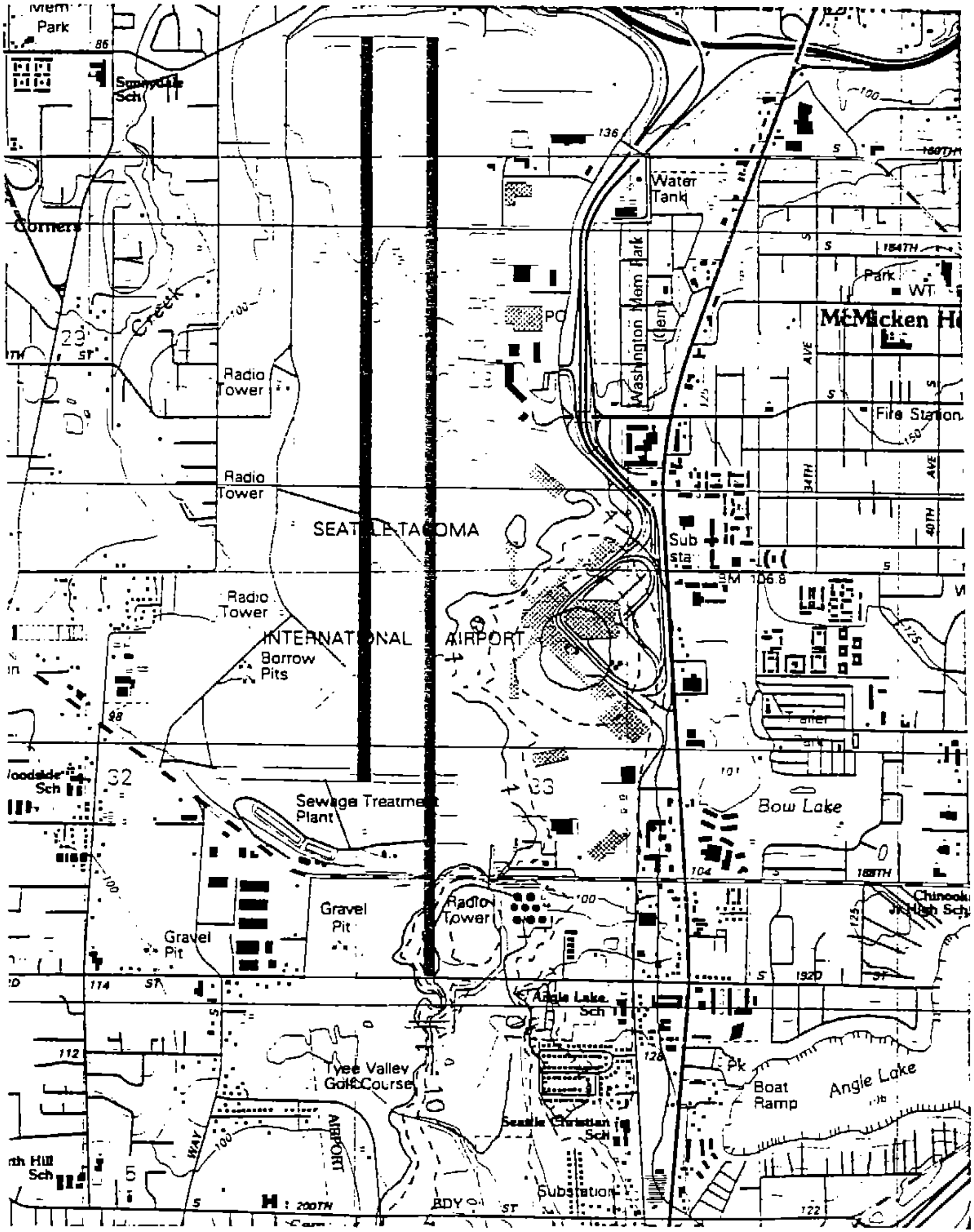
	CO	HC	NOx
MOTOR VEHICLES	502	37.2	23.03
TRAINING FIRE	1.62	0.932	0.012
BOILER	3.360	2.770	13.500
TANK FARMS	0	0.00654	0
CLIMB AND APPROACH	355.793	67.5717	1220.9
TAKEOFFS	16.1936	6.56299	479.436
QUEUES	1690.82	752.47	109.059
TAXI IN/OUT	1058.84	451.01	65.479
TOTAL	3628.627	1318.523	1911.416

Figure 9.

Carbon Monoxide Contours

Wind Direction = 0°

terrain



APPENDIX 5: CONTOUR PLOTS OF PREDICTED CONCENTRATIONS

Figure 12.

Hydrocarbon Contours,
Wind Direction = 0°

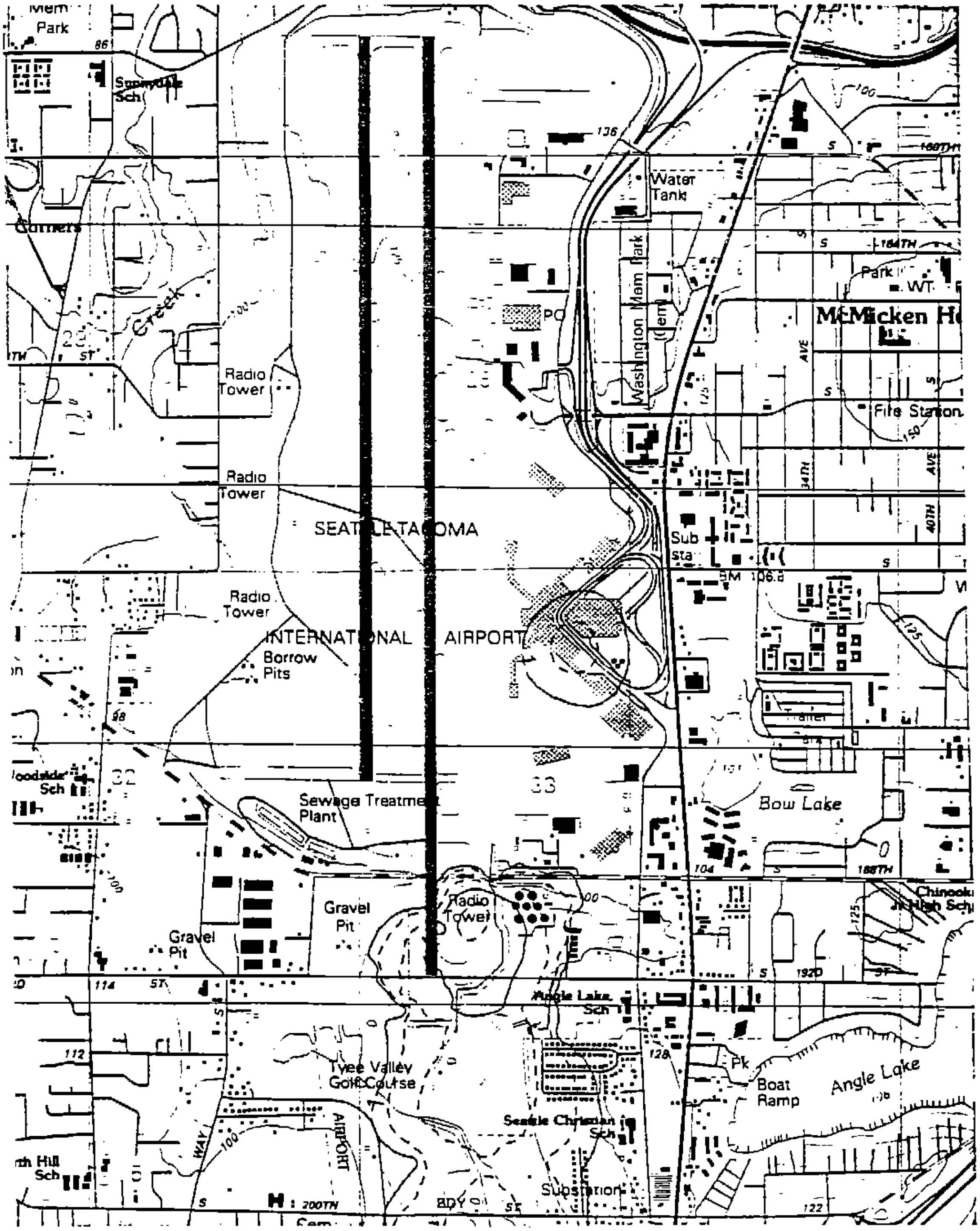


Figure 11.

Carbon Monoxide Contours, Wind Direction = 345°

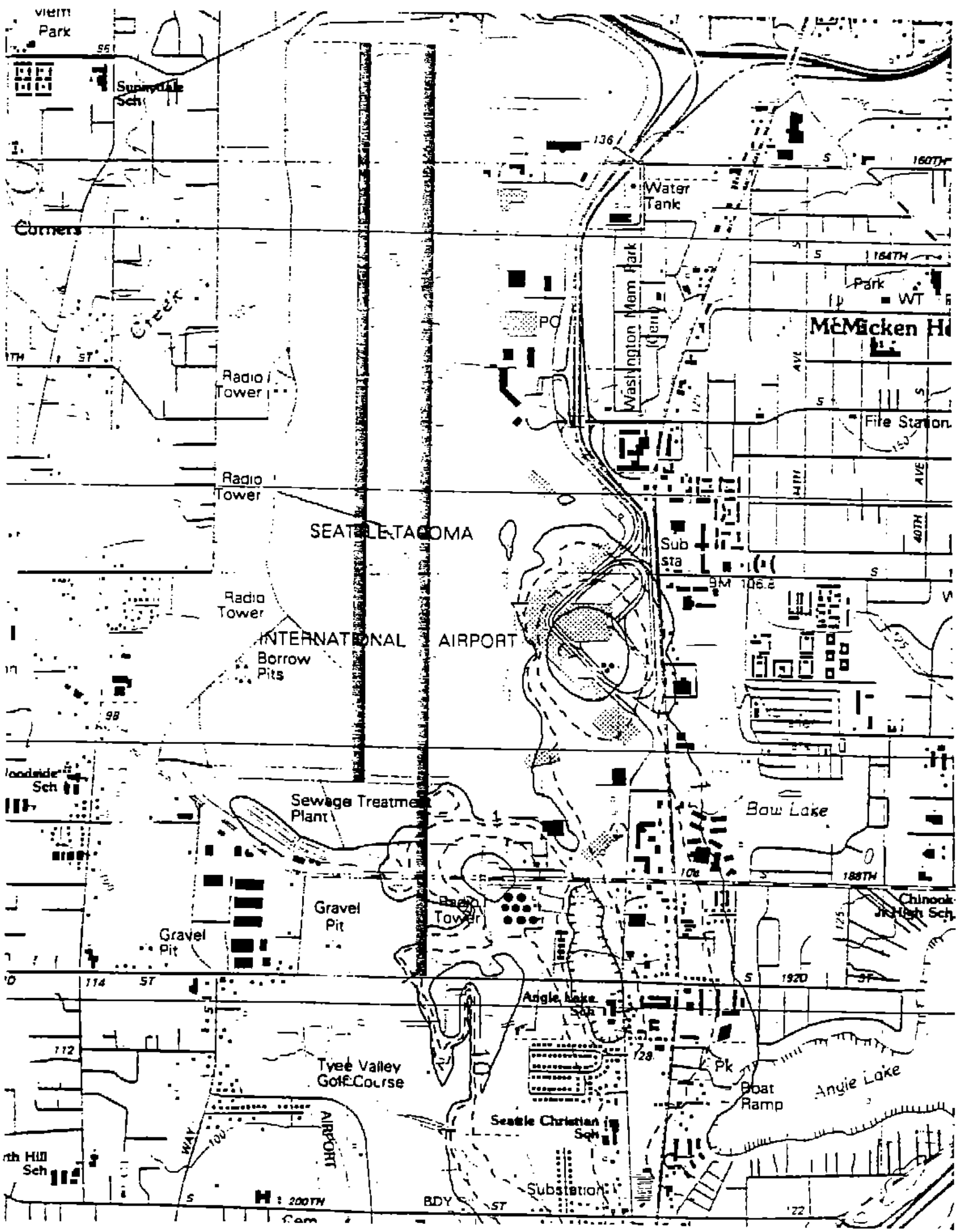


Figure 10.

Carbon Monoxide Contours, Wind Direction = 170°

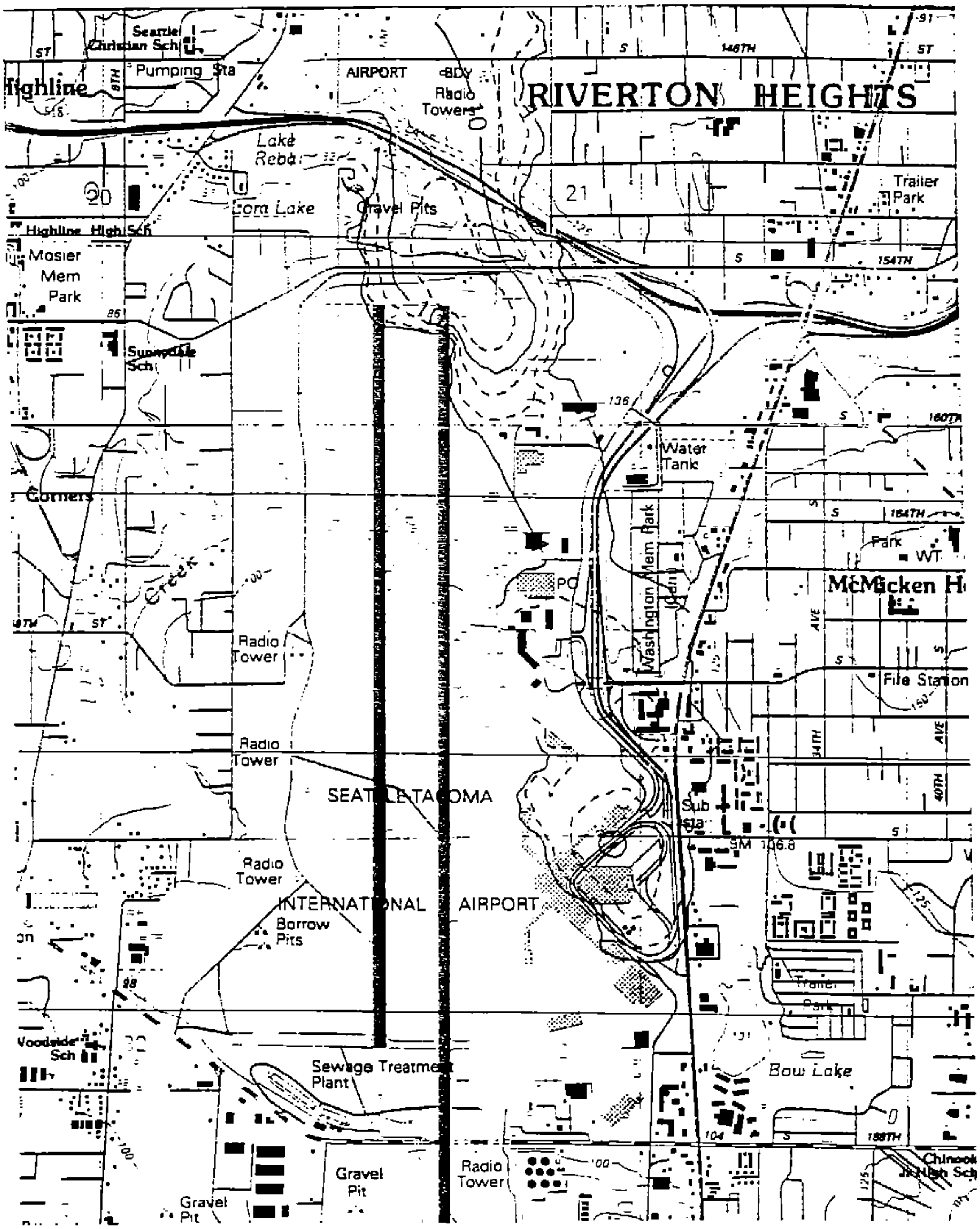


Figure 13.

Hydrocarbon Contours,
Wind Direction = 170°

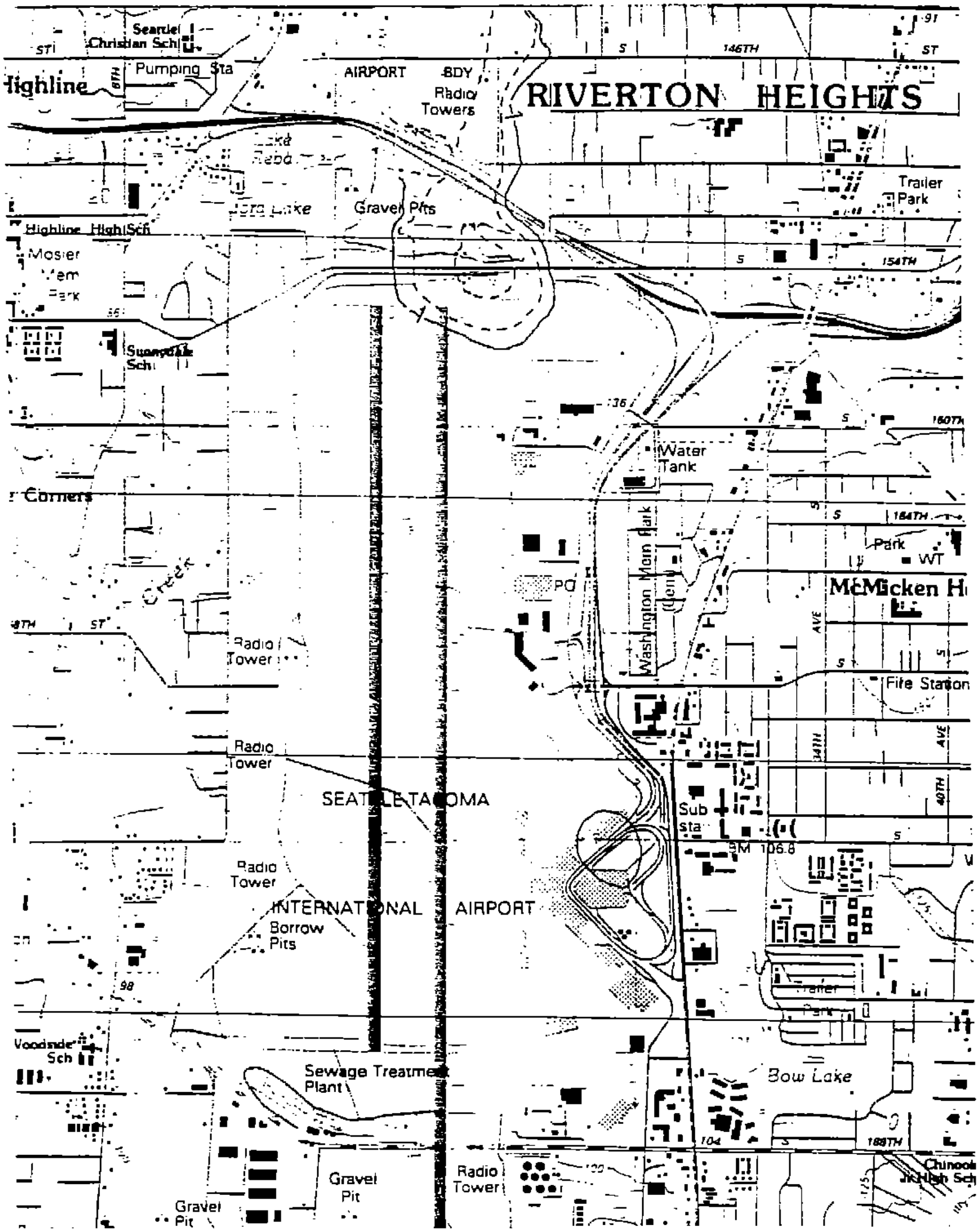


Figure 16.
Nitrogen Dioxide Contours,
Wind Direction = 170°

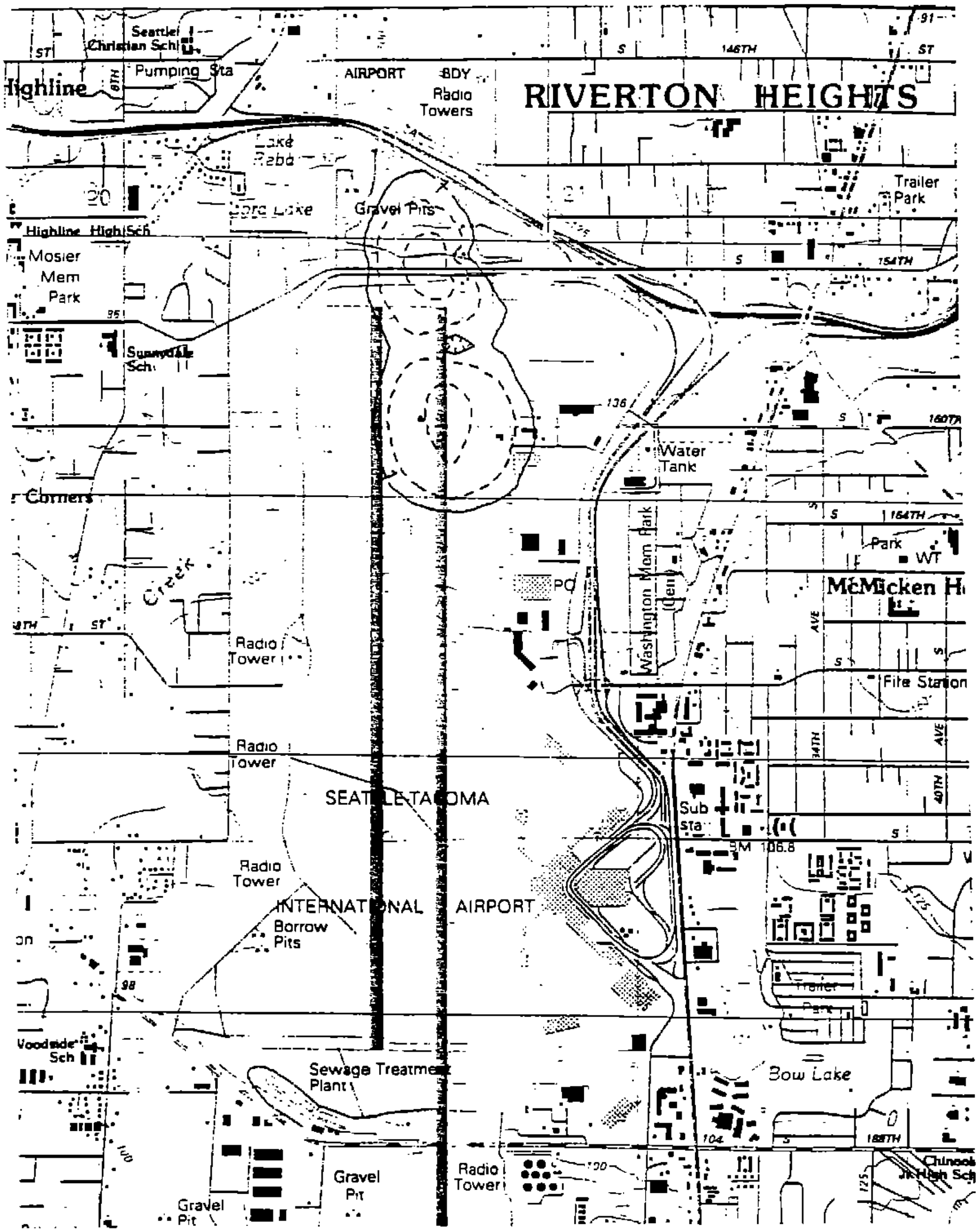


Figure 14.
Hydrocarbon Contours,
Wind Direction = 345°

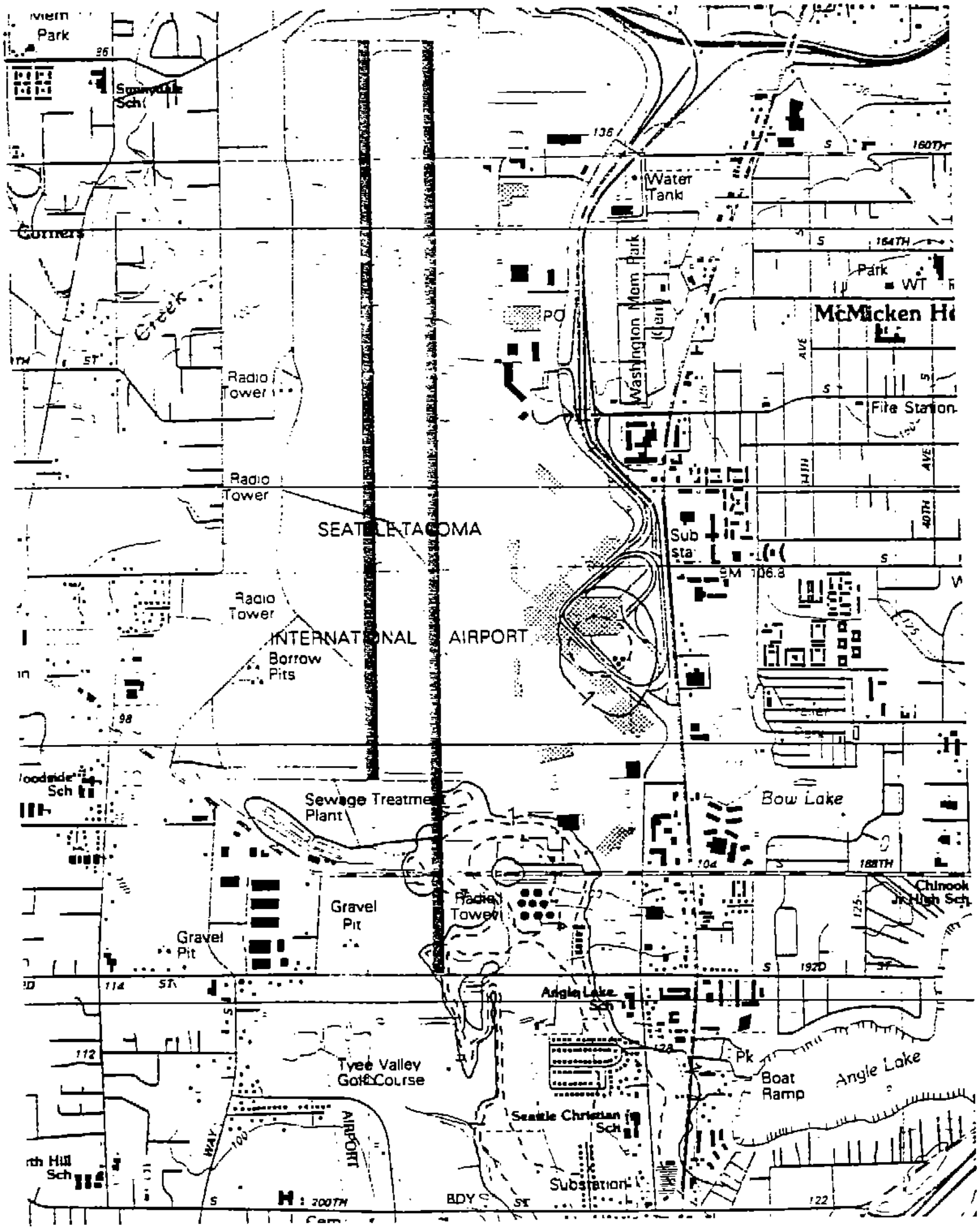


Figure 17.
Nitrogen Dioxide Contours,
Wind Direction = 345°

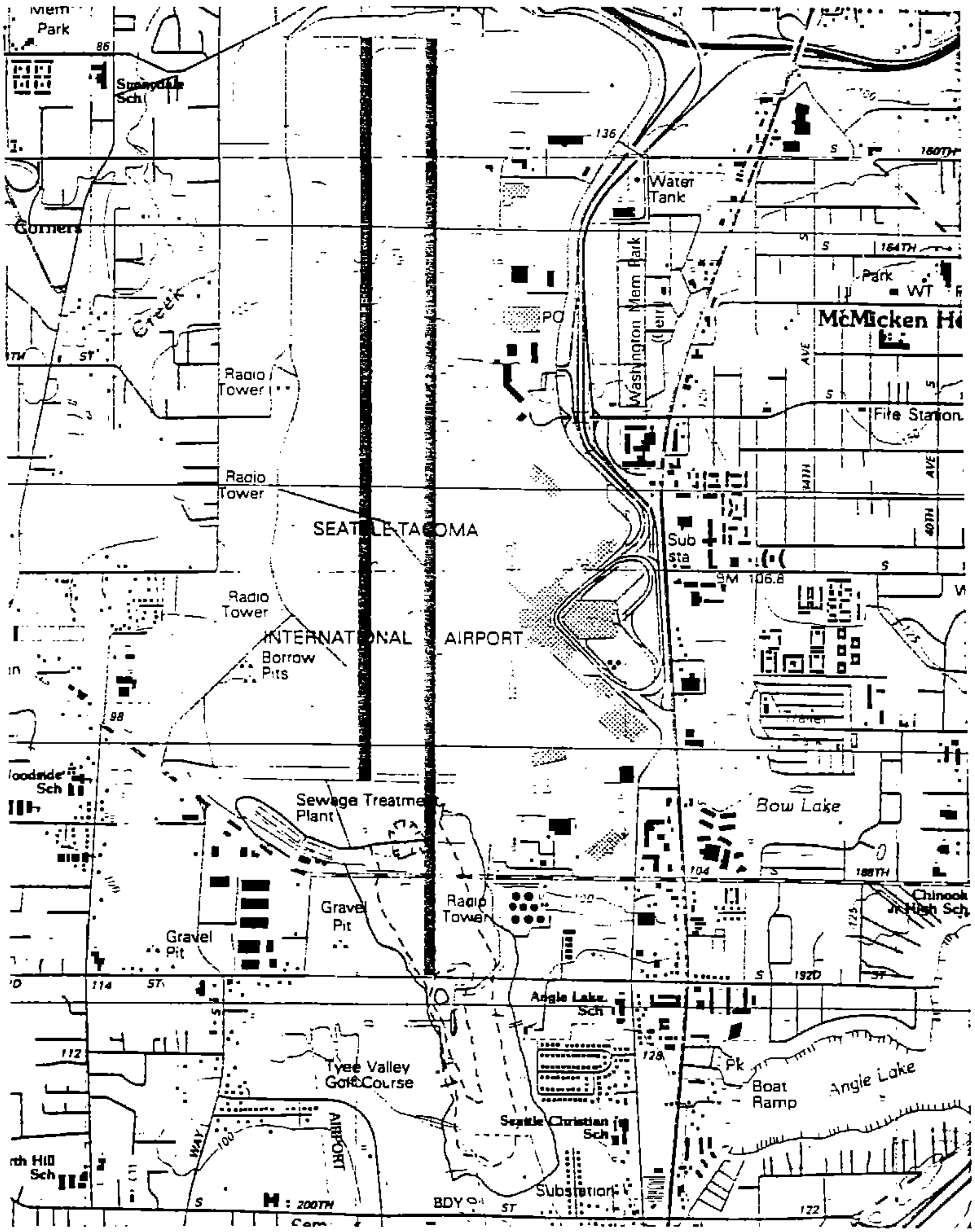


Figure 15.
Nitrogen Dioxide Contours,
Wind Direction = 0°

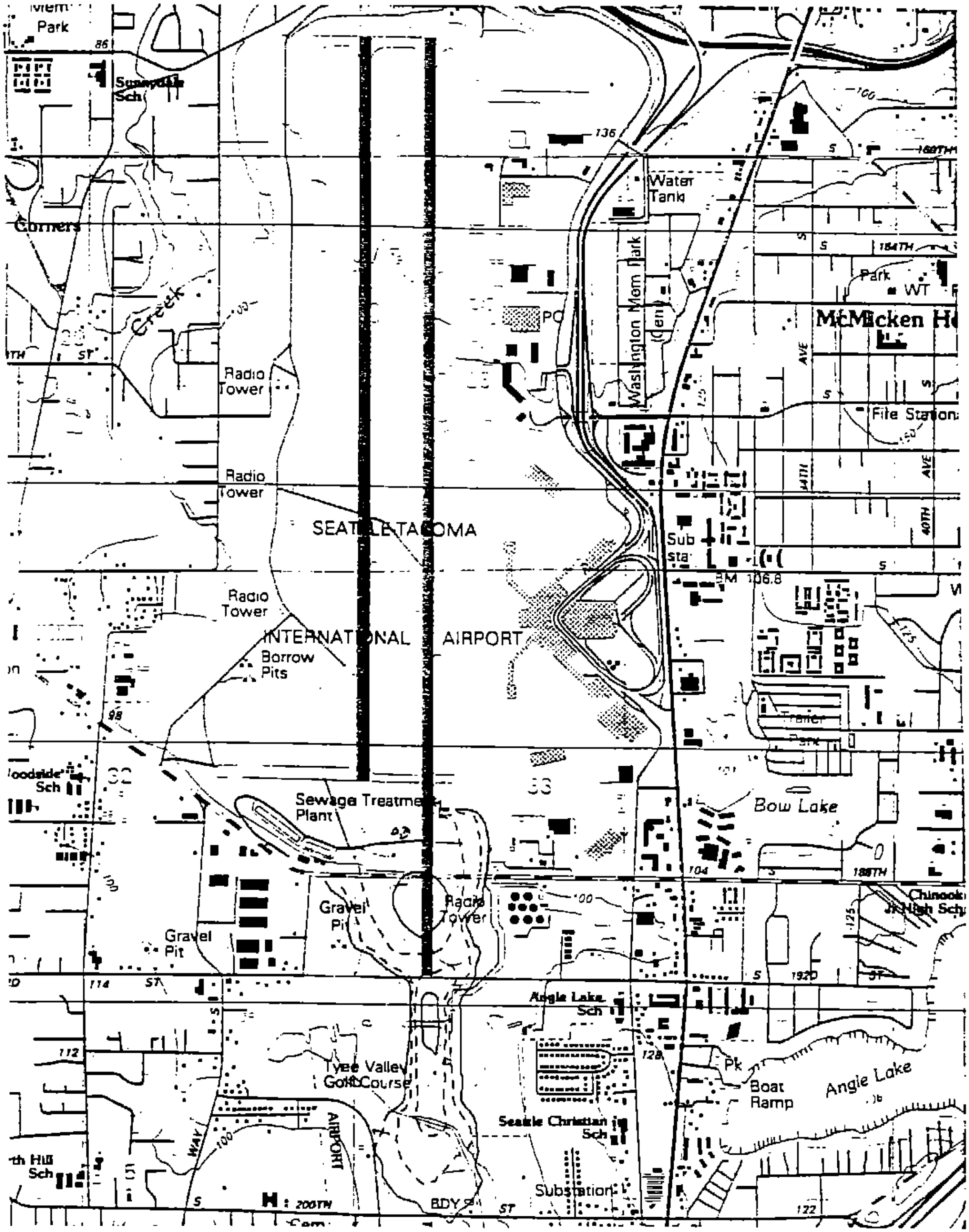


Figure 18.
Sulfur Dioxide Contours,
Wind Direction = 0°

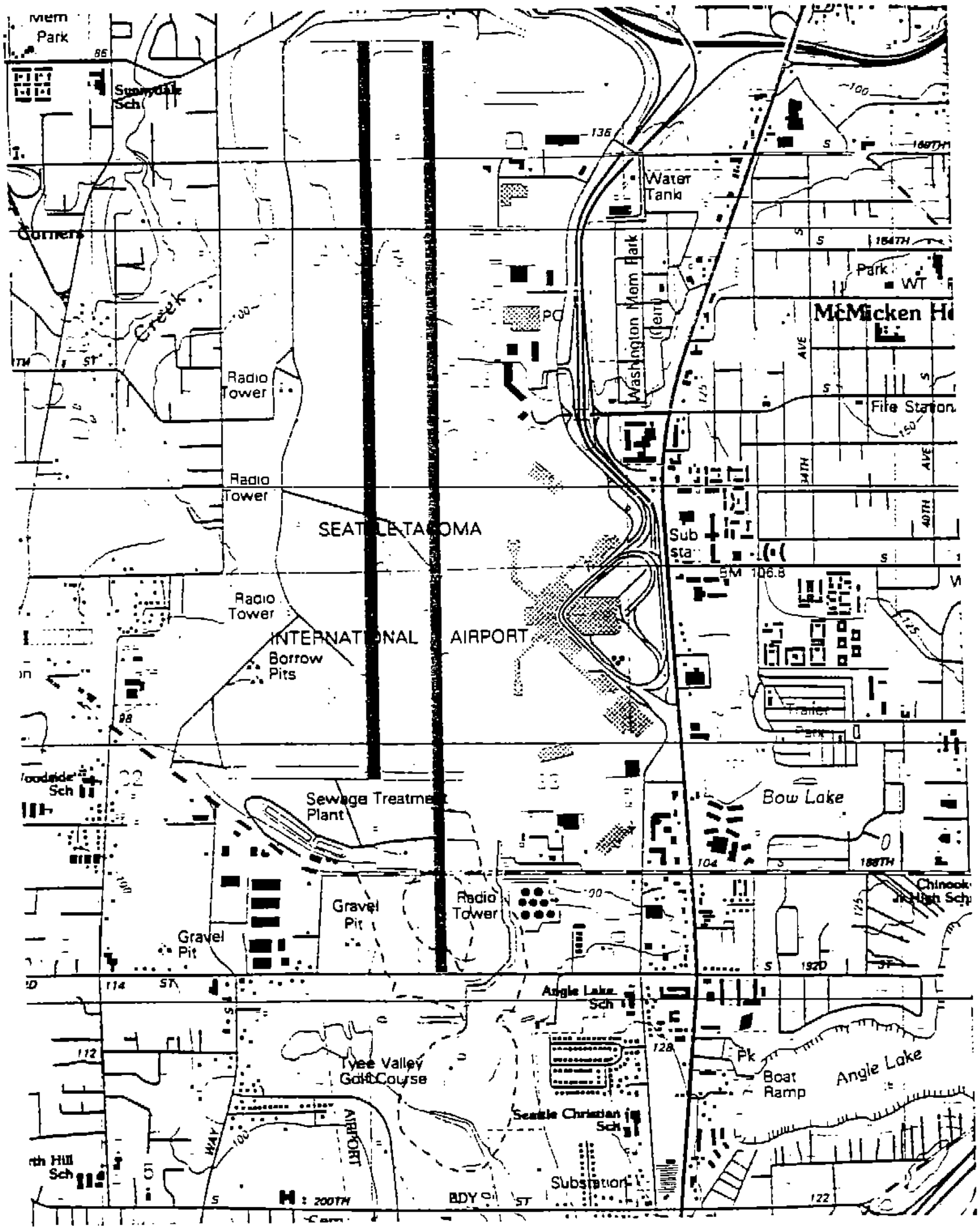


Figure 19.
Sulfur Dioxide Contours,
Wind Direction = 170°

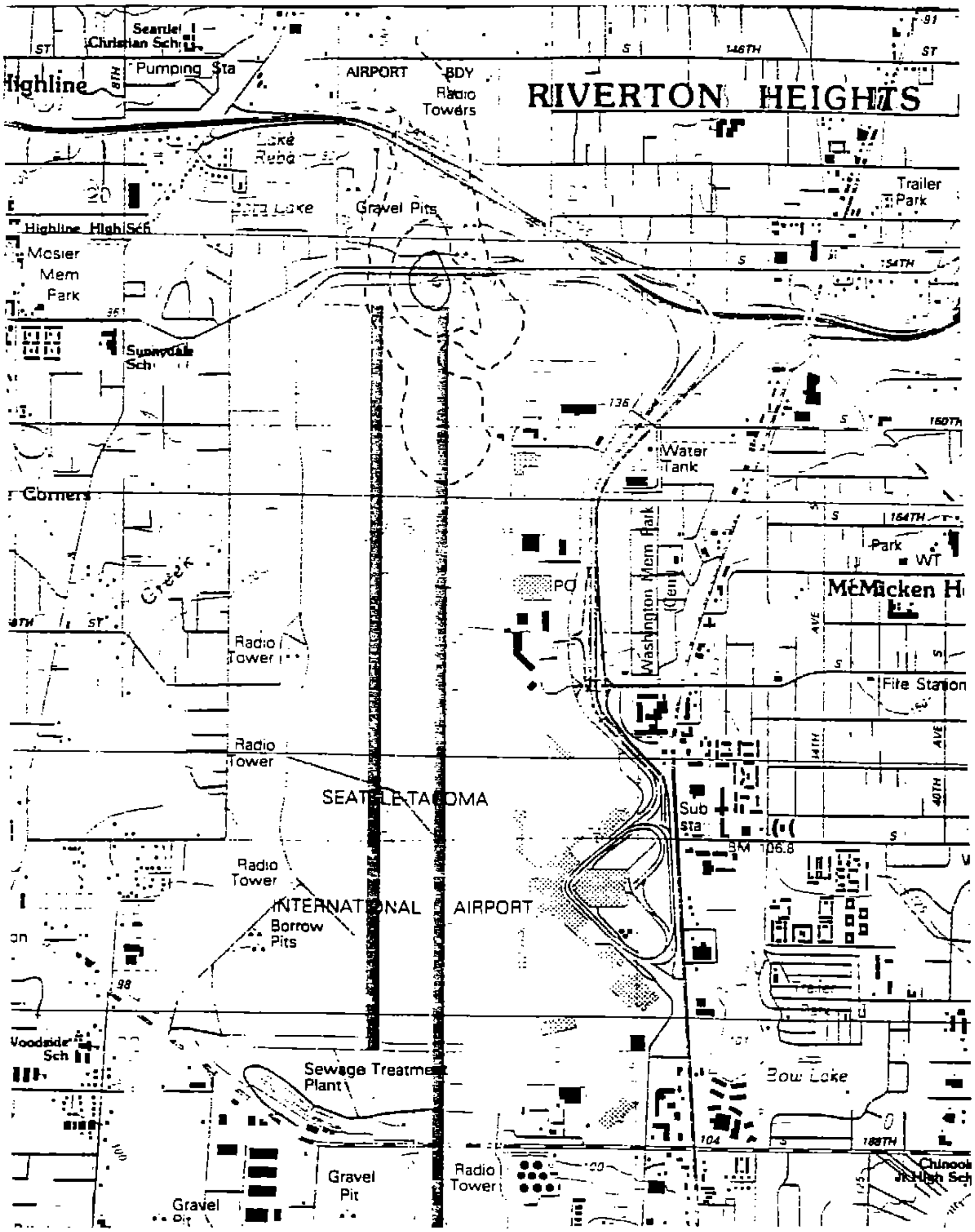


Figure 20.
Sulfur Dioxide Contours,
Wind Direction = 345°

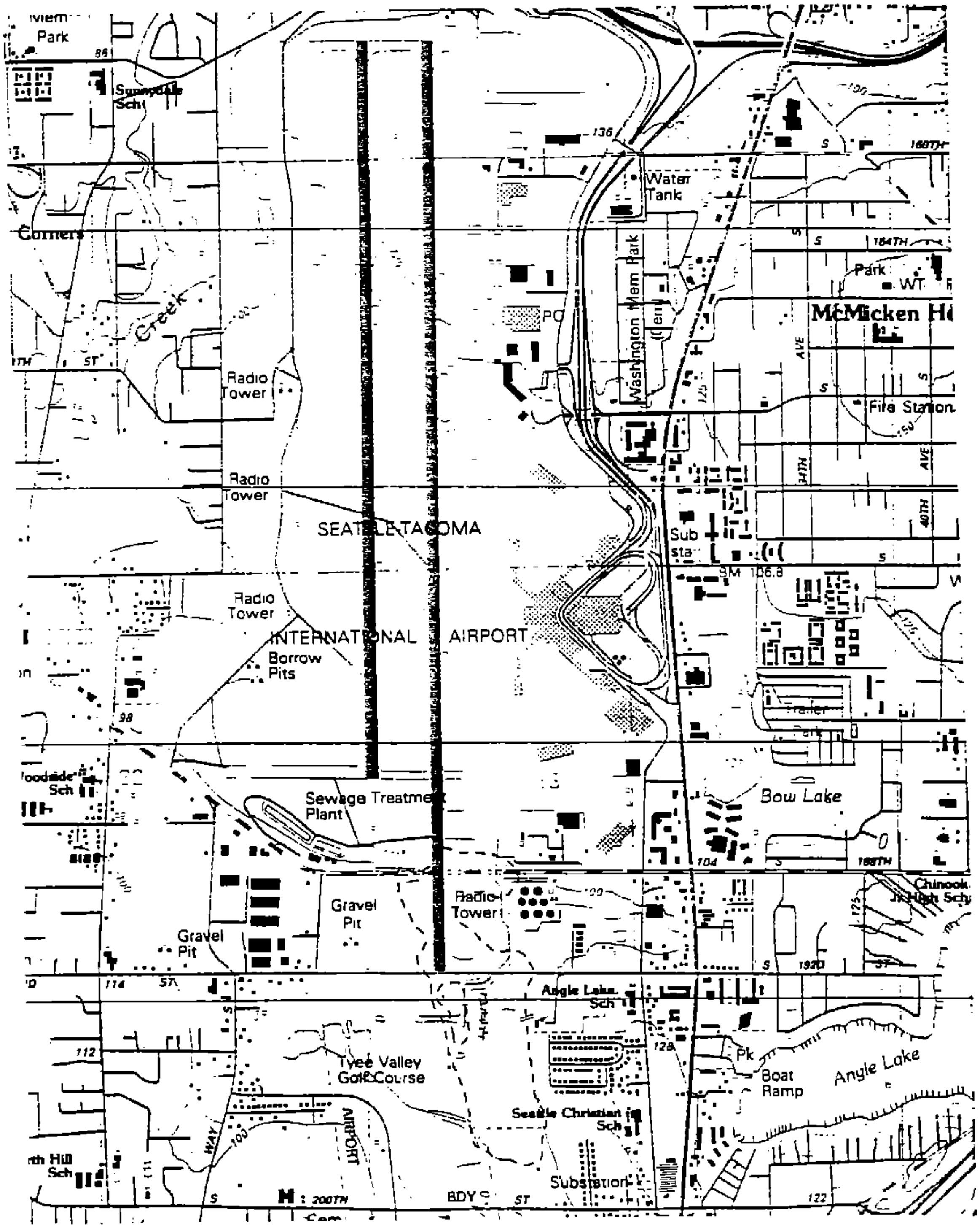


Figure 21.
Fine Particulates (PM10) Contours,
Wind Direction - 0°

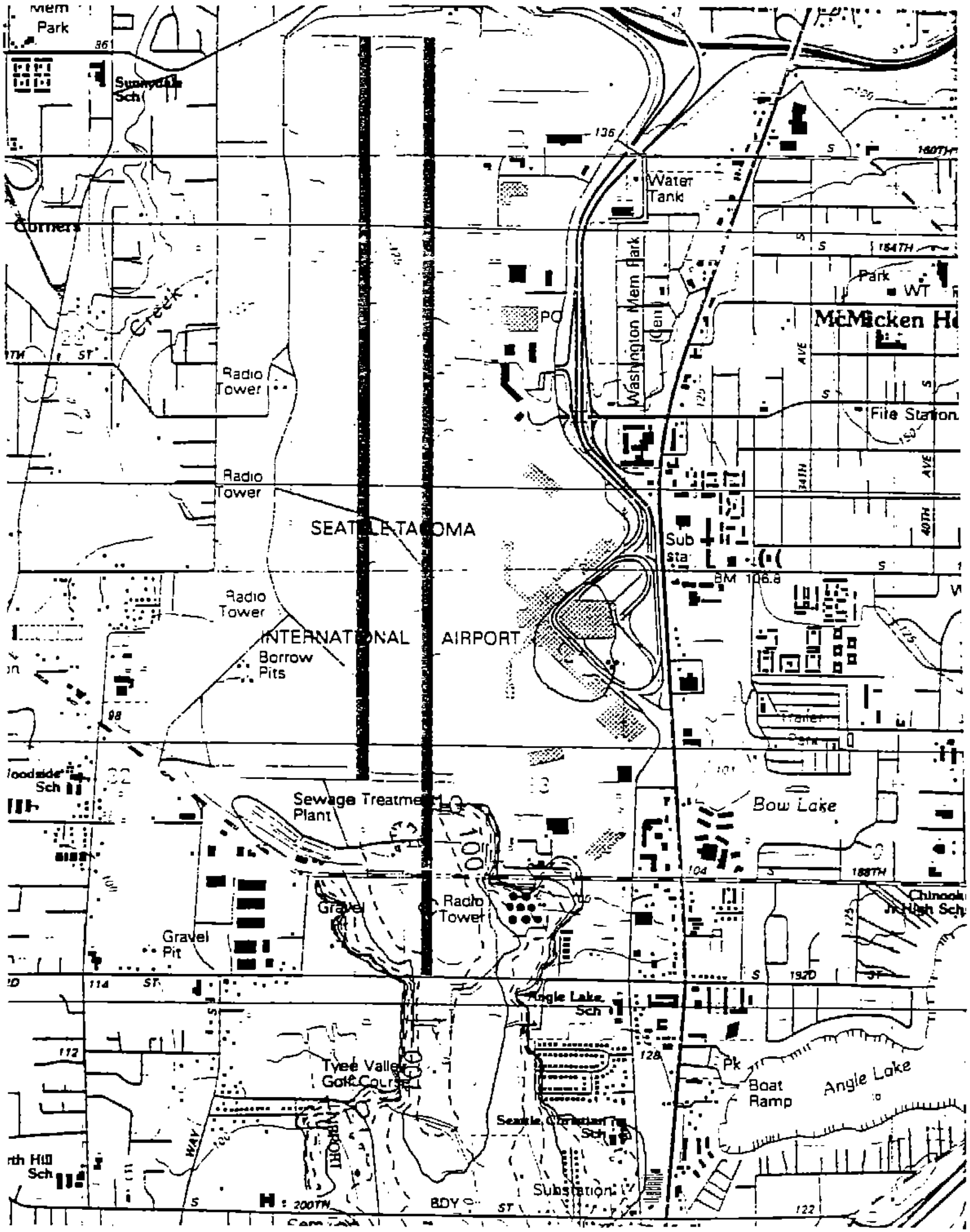


Figure 22.
Fine Particulates (PM10) Contours,
Wind Direction = 170°