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16. ABSTRACT

Introduction:

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The California Division of Highways has two current programs involving measurement of air quality, both making use of instrumented mobile vans. One program, that which is the main subject of this paper, is directed at the provision of an air quality study to serve as input to an environmental impact statement. The other program is one of research to provide knowledge for use in quantifying and mitigating highway impact on air quality. Of the two different measurement systems, the one discussed here is the least sophisticated since its primary purpose is to serve as a tool for routine investigation.

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AIR QUALITY MEASUREMENTS FROM A HIGHWAY PERSPECTIVE

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INTRODUCTION

The modern highway engineer, in addition to his historic responsibilities for planning, designing, building and operating a transportation system, has become increasingly concerned with the amenities surrounding such a system. Foremost among these amenities are safety, aesthetics, and environmental protection. This paper is directed at one small portion of the current highway program for environmental protection, namely that of the measurement of air quality for highway projects.

The California Division of Highways has two current programs involving measurement of air quality, both making use of instrumented mobile vans. One program, that which is the main subject of this paper, is directed at the provision of an air quality study to serve as input to an environmental impact statement. The other program is one of research to provide knowledge for use in quantifying and mitigating highway impact on air quality. Of the two different measurement systems, the one discussed here is the least sophisticated since its primary purpose is to serve as a tool for routine investigation.

BACKGROUND

The highway engineer, in responding to the need for environmental protection, has been motivated by several forces. The first to make an appearance was in the form of a change in public priorities. In certain areas, freeways were no longer welcome neighbors and pressure for environmental protection began to be exerted through neighborhood groups and environmental coalitions appearing at public hearings. The concerns of these groups were eventually expressed in public law, beginning, for all intents and purposes, with the National Environmental Policy Act of 1969. Another Federal law, The 1970 Amendments to the Clean Air Act, and a California law, The California Environmental Quality Act of 1970, followed in quick succession.

As the movement for environmental protection gain momentum, a driving force from within the profession began to make itself felt. This change began with those engineers who welcomed added public responsibility and regarded environmental protection as a logical expansion of a dynamic profession.

Typically, those organizations who were acknowledged leaders in their respective fields were among the first to respond in this fashion.

The professional concern of engineers in the California Division of Highways for protection of the air environment was reflected in the development of techniques and procedures for assessing the air quality impact of new projects. The procedures for the assessment of air quality impact are discussed in a series of manuals (1) published by the Division.

LEGAL REQUIREMENTS FOR ENVIRONMENTAL STUDIES

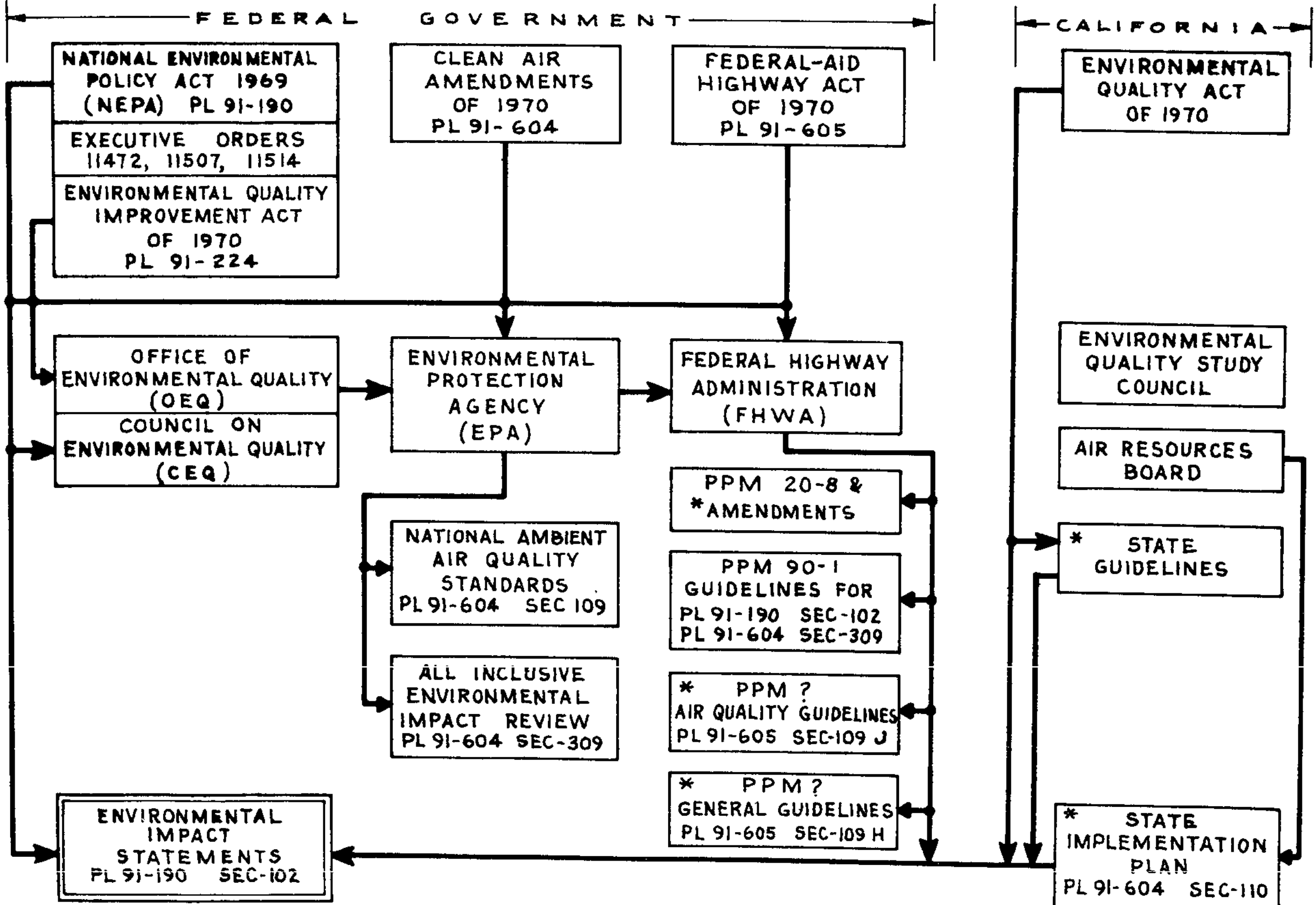
It is important to understand the legal background for environmental studies since public law, in many cases, dictates the manner in which certain aspects of the study must be performed and, in general, dictates the questions which must be answered.

The first major law affecting the work of the Division of Highways with regard to air pollution was the National Environmental Policy Act of 1969. This act created the Council on Environmental Quality. Implementation of this act by the Federal Highway Administration occurred in the form of policy and procedure memorandum (PPM) 90-1. The purpose of this PPM is to provide guidelines to highway departments to assure that the human environment is carefully considered and national environmental goals are met when developing federally financed highway improvements. This PPM reiterates that portion of the law requiring an environmental impact statement for each federally financed project.

Two other important federal laws were enacted in 1970. The first of these, the Clean Air Amendments of 1970, empowered the Environmental Protection Agency (EPA), previously established by executive reorganization, to establish national ambient air quality standards and to require each state to submit a plan providing for implementation, maintenance, and enforcement of such standards in each air quality control region within each state. These plans are termed implementation plans.

The final national law, the Federal Aid Highway Act of 1970, provides for the establishment of general guidelines to assure that possible adverse economic, social, and environmental effects relating to any proposed project on any federal aid system have been fully considered in developing the project. That act also calls for the development of guidelines to assure that highways constructed pursuant to that act are consistent

MAJOR LAWS AND REGULATIONS GOVERNING AIR QUALITY IMPACT STUDIES FOR HIGHWAY PROJECTS



* NOT FINAL AS OF MARCH, 1972

FIGURE 1

with any approved plans for the implementation of any ambient air quality standard or any air quality control medium designated by the Clean Air Act.

On the state level, the Environmental Quality Act of 1970 promotes the maintenance and enhancement of the quality of life. It requires that all state agencies, boards, and commissions shall include in any report on any project they propose to carry out which could have a significant effect on the environment of the state, a detailed environmental statement.

Figure 1 illustrates the general relationship between these laws.

POLLUTANT EFFECTS ON THE AIR ENVIRONMENT

To establish a frame of reference within which the subject of our air quality measurements can be discussed, it is necessary to first talk briefly about the rationale underlying our studies, and to describe the component parts of an air quality study for a highway project.

To properly define an air quality study for a highway line source, a look must be taken at the manner in which the receptors perceive changes in air quality. It is convenient for our purposes to look at these effects on two levels, microscale and mesoscale. The microscale, as the name would imply, defines that area immediately adjacent to the line source where localized pollutant concentrations can reach levels that are injurious to the health of the receptors living there (Figure 2). The mesoscale effect, as would be anticipated, looks at the effect of the project over a much wider area than that of the immediate highway corridor (Figure 3). The primary concern of the mesoscale analysis is the overall effect of the project on downwind ambient air quality. A mesoscale study is quantified in terms of pollutant burden, that is, tons of pollutant per day per unit area of land surface. Pollutant burden is directly related to ambient pollutant concentrations and, while these concentrations may never reach the levels of those found in the microscale situation, they may endure over a sufficiently long period to cause health problems in susceptible individuals.

COMPONENT PARTS OF AN AIR QUALITY STUDY

The essential parts of an air quality study consist of: (1) Source Strength Estimates, (2) Transport and Dispersion Parameters, (3) The Output of Predictive Modeling, (4) Ambient Air Quality Studies. The relationship between these component parts is shown in Figure 4.

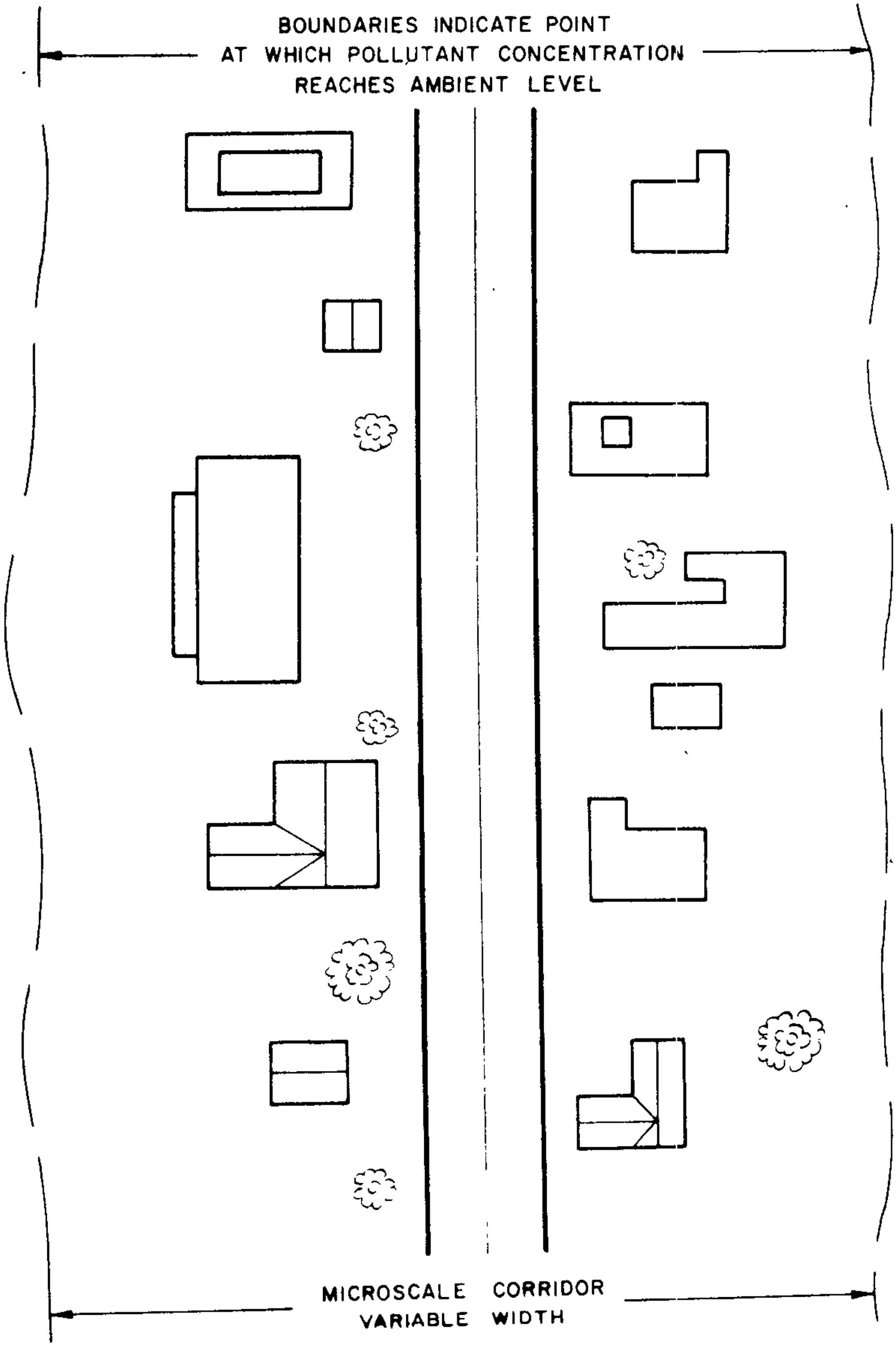


Fig.2 MICROSCALE ANALYSIS

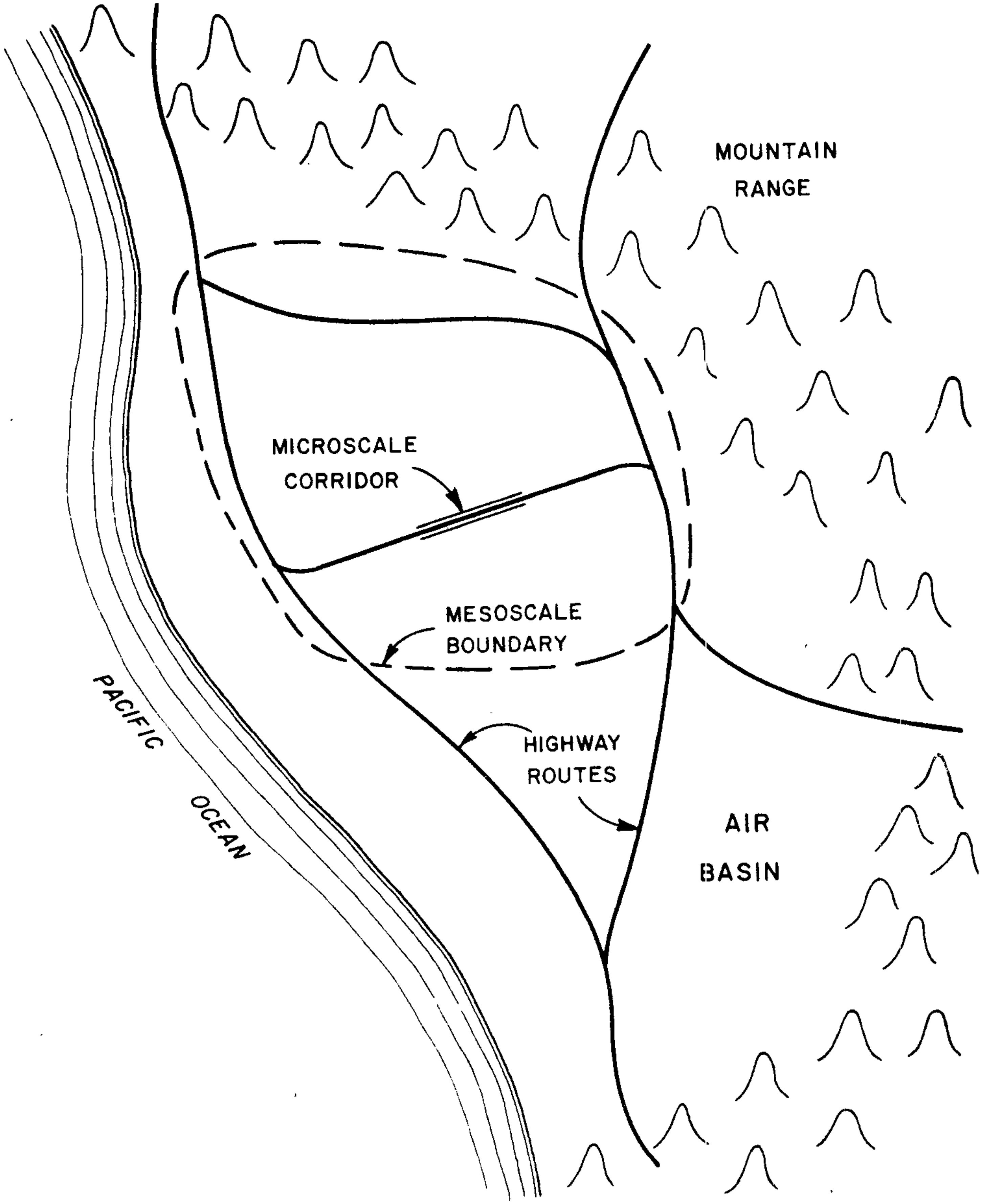
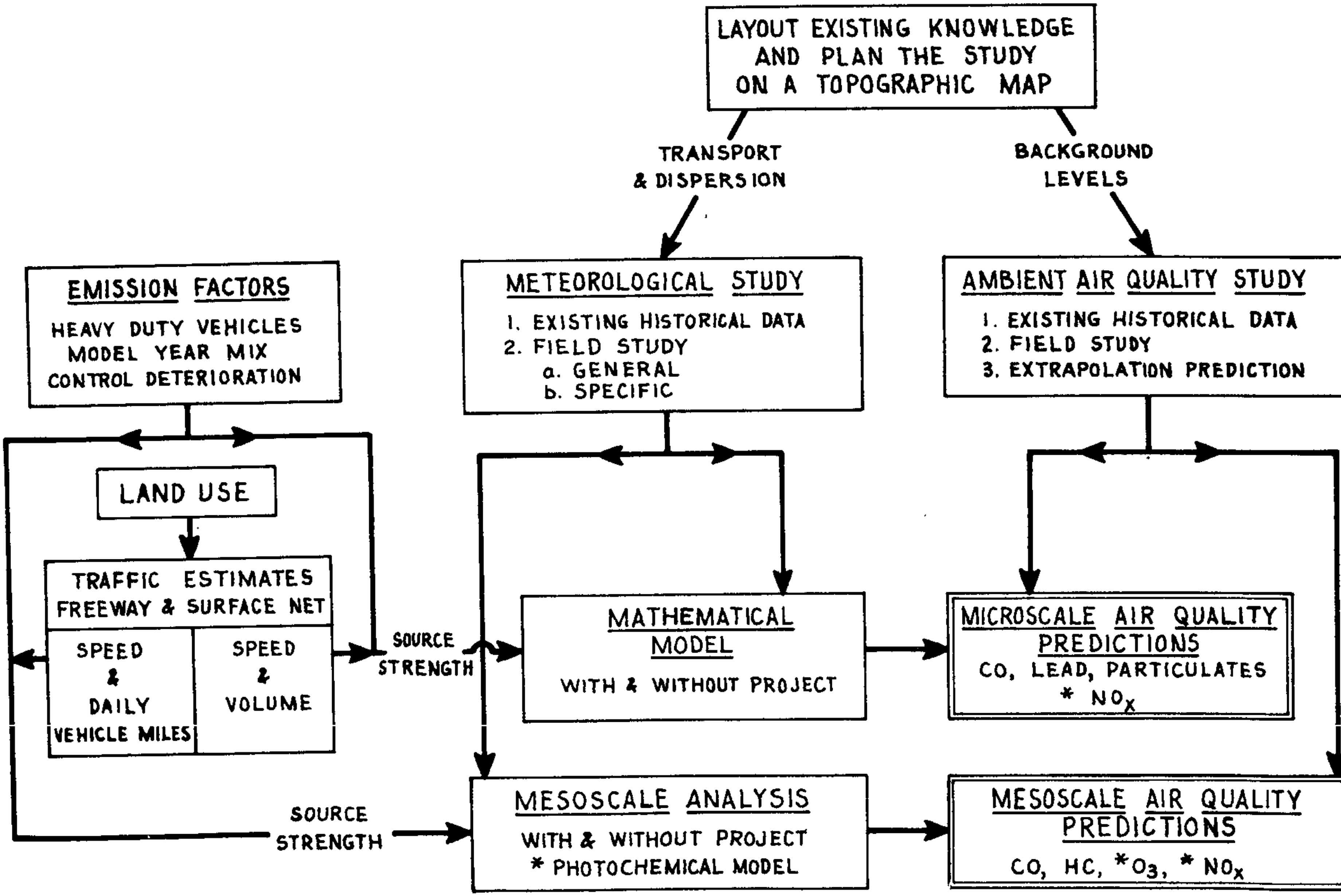


Fig. 3 MESOSCALE ANALYSIS

PROCEDURE FOR ANALYZING HIGHWAY IMPACT ON AIR QUALITY



* TO BE ADDED AT A LATER DATE.

FIGURE 4

The strength of the continuous line source of pollutants emanating from a highway is dependent upon two factors, the first being the volume of pollutants coming from each individual vehicle, and the second being the number of these vehicles on the highway at any given time. The air quality study uses emission factors which vary with:

1) Vehicle model year mix.
2) The percent of heavy-duty vehicles in the traffic stream.
3) Speed of the traffic.
4) Vehicle operating mode (that is, in the simplest sense, whether the vehicle is on the freeway system or on the surface network).

Basically, the model year mix of vehicles composing traffic in California for any particular future year is estimated. The relative emissions for each model year vehicle in the mix, are based on the emission controls which were, or will be, in effect at the time of manufacture. These emissions are weighted, based on the percentage of that model year in the mix, and then averaged to provide an emission factor which can be applied to a traffic estimate. Since the emission control devices can be expected to deteriorate as the vehicle accumulates mileage a deterioration factor is applied to the emission factor.

Traffic data for source strength calculations in the micro-scale area consist of speed and volume information at the point where the analysis is being made. This information must be supplied for the critical hours of the day. The critical hours may be determined either by peak hour traffic or by adverse meteorological conditions.

For the mesoscale, or pollutant burden analysis, total daily mileage and associated average speeds are needed for both freeway traffic and surface traffic.

The transport and dispersion of air pollutants depends upon topography and meteorology. Use is made of historical data from all available sources. The desirable meteorological parameters are wind direction, wind speed, stability for various regimes, inversion heights or mixing depths, and, if data are available, wind streamlines.

There are a few cases where the existing data fully satisfy the data requirements for a project. Normally, however, data are developed for each individual project. This development occurs in two distinct phases. The first step involves the collection of data, using mechanical weather stations at traffic network and the average operating speed at which that mileage is generated. Other aspects of mesoscale analysis include the import of primary and secondary pollutants from distant upwind sources, the export of primary and secondary pollutants generated within the study area to distant downwind receptors, and the examination of the time history of oxidant concentration and the prediction of future trends based on correlation with future pollutant burden estimates.

THE AMBIENT AIR QUALITY SURVEY

The primary purpose of an ambient air quality study is to define the background levels of pollutant concentration in the project area. This not only provides a reference base against which local citizens can compare the future predicted concentrations, but also provides the upwind background concentration which must be added to the predicted concentrations resulting from the highway line source. The second purpose of the ambient air quality survey is to provide validation of the predictive model for the immediate geographic area. A third purpose is to provide a comprehensive aerometric data bank for each highway district. One of the principal uses of such a data bank is the construction of an air quality hazards map. This map serves as an informational aid to the highway planner and indicates areas having higher probabilities of poor air quality based on topography, meteorological considerations, and historical ambient air quality.

The pollutants measured include carbon monoxide, ozone, nitric oxide, nitrogen dioxide, hydrocarbons corrected for methane, total particulates, and lead. The principal pollutant to be measured, however, is carbon monoxide. Carbon monoxide is relatively inert with regard to photochemical reactions, has no apparent principal sink within our scale of interest, and has received a great deal of study relating emissions to vehicle speed and operation. Our studies have shown that carbon monoxide serves as an excellent tracer of automotive emissions, due to the characteristics listed above, and serves as an excellent tool with which to define transport and dispersion in a particular situation. Two other basic pollutants are total particulates and lead. The other gaseous pollutants, although measured and reported during the ambient air quality study, receive far less emphasis than carbon monoxide. The main reason for currently measuring ozone, oxides of nitrogen, and hydrocarbons is only to define existing air quality and provide a data bank for future analysis. Hydrocarbon concentrations are not considered by epidemiologists to constitute a health hazard in themselves. Oxides of nitrogen are not predicted in the microscale due to the lack of suitable emission factors showing the variation of these emissions with respect to speed. Secondary pollutants are not predicted in the microscale since even low wind speeds are usually sufficient to move the reacting pollutant out of the microscale areas before sizable quantities of secondary pollutants can be formed. Recent study, in fact, has shown that ambient ozone within the microscale area is involved in the oxidation of nitric oxide to nitrogen dioxide, thereby reducing the ambient levels of ozone in the immediate vicinity. When suitable emission factors for nitric oxide become available, we will be making predictions of the concentrations of oxides of nitrogen within the microscale.

For the mesoscale, or total burden analysis, we are currently confining our predictions to the two gaseous pollutants, carbon monoxide and hydrocarbons. As in the microscale case, oxides of nitrogen are not predicted due to lack of suitable emission factors. Effects of lead and other particulates are usually limited to the microscale area, since these pollutants, except for some amount in the submicron size range, are acted upon by gravitational forces and are also removed by impaction with surrounding objects. Although particles in the submicron range act much like gaseous pollutants and are probably the ones which cause the most physiological damage, we do not yet have sufficient information, in terms of emission factors, to predict mesoscale concentrations of these particles. Hence, we are not considering them in our current mesoscale analysis.

Due to the lack of a fully validated mathematical model which includes photochemical reactions, we are not predicting the secondary pollutants resulting from these photochemical reactions. Sophisticated models are now becoming available and, as soon as the validation requirements are satisfied, we will be adding this capability to our procedures.

Sampling

The choice of sampling location is dependent upon several considerations. The first consideration is the location of air quality monitoring stations which provide historical data in the project area. If air monitoring stations exist within the project area, samples should be taken immediately adjacent to the air monitoring stations to provide comparative data with which correlation can be made. This correlation compensates for analytical methods and sampling techniques and is essential to make proper use of the historical data. Other samples are taken depending on the variety of homogeneous areas within the vicinity of the proposed highway corridor. These areas can be selected on the basis of land use patterns, common meteorological or topographical features, types of proposed highway designs, and areas where sensitive receptors are located. Sampling may also be indicated in areas where a freeway is located on a fill which crosses a valley and has the possibility of creating a cold air lake during drainage wind regimes. Samples are also taken at any location where air pollution considerations are a special focus of public interest.

Following the selection of locations for the field measurement stations, all the stations along the highway corridor are sampled simultaneously over the same time period to provide the temporal and spatial distribution of pollutant concentrations.

The field measurements are correlated with measurements made at the closest air monitoring station. This correlation (if it exists) should indicate a correspondence between the temporal trends at the air monitoring station and those of the field measurements. Once this correlation is established, along with the correlation of analyzers and sampling techniques, the historical record can be used to extrapolate ambient levels for other periods of the year. This approach can significantly reduce the number of samples required and is used if at all possible.

If no correlation of temporal trends exists between the field measurements and the closest air monitoring station, a more extensive field measurement program is in order. This field measurement program should last at least one year to fully consider seasonal variation in pollutant levels. We do not require field measurements for every day of each month. If a nearby meteorological data source records cloud cover, ceiling height, wind speed and direction, the probability of the surface atmospheric conditions is estimated from in-house computer programs. These estimations serve as a guide to months having similar meteorological conditions and months having worst case and most probable meteorological conditions. During the months which have the greatest potential for air pollution, field measurements should be made daily. During months with more favorable meteorological conditions, it is possible to reduce the number of measurements with the exception of air pollution episodes during which sampling should be done on a daily basis.

The sampling program continues throughout the day beginning before peak morning traffic and ending just after peak evening traffic hours. Special cases may warrant 24-hour monitoring depending on the receptor's location with respect to the highway route. Data are initially summarized for one-hour averaging times with other summaries being made for those averaging times called out in the ambient air quality standards.

desirable locations, to characterize wind speed and direction. Collection of these data might take as long as a year or more. Where possible, inversion heights for the various meteorological regimes are taken simultaneously with the other measurements. The second step involves an examination of the temperature structure and turbulence in the lower atmosphere. This is accomplished by locating a meteorological tower on previously selected sites for short periods under various meteorological regimes. The towers used by the Division of Highways carry two sets of wind speed and direction instruments separated by an interval of approximately 15 meters to examine wind shear. They also carry instrumentation for measuring temperature change over the same interval. The instrumentation is self-contained and capable of operating without support for more than a week at a time.

In any areas where wind flow patterns vary considerably due to topographical influences, it is desirable to obtain meteorological data which will allow construction of wind streamlines. For the microscale situation, these streamlines are constructed with the use of hand-held anemometers and direction indicators. For the mesoscale situation, the use of balloons and theodolites is recommended.

Evaluation of meteorological information will involve the "most probable" meteorological conditions and the "worst case" meteorological conditions. The probabilities of occurrence of these conditions must be estimated. For each of these conditions, a wind rose and stability analysis must be made. These analyses must be correlated with hours of peak traffic flow and any anomolous traffic situation which may give rise to an increase in source strength. Conversely, traffic data must be collected for the "worst case" meteorological conditions. Analyses made in this manner enable the evaluation of the most critical conditions.

Predictive modeling is used to analyze pollutant concentrations in the microscale area. Inputs to this model consist of traffic data, meteorological data, and emission factors. The output from this model is presented in terms of concentrations of the pollutant being analyzed for a particular meteorological regime and a certain traffic condition. To these predictions must be added the ambient concentration of the pollutant in question.

The mesoscale analysis is primarily concerned with the total pollutant burden resulting from changes in the traffic network which accompany the initiation of a new traffic facility. The item of greatest importance in this analysis is the change in the total amount of daily vehicle mileage in the affected

Operational air quality studies are conducted utilizing two sampling methods. The primary method involves the use of Scotchpak bags, capable of containing approximately 7 liters of air, which are filled by a small battery-powered pump. The pump output is adjusted to fill the bag in one hour. The use of a number of these samplers permits the simultaneous acquisition of air quality data over a relatively large area. Air samples taken in this manner are analyzed for carbon monoxide concentration. Analysis is performed using a long path nondispersive infrared analyzer.

The second sampling method for these studies involves the use of a mobile air quality van. These vans are relatively small, but are equipped with a high top to accommodate people of average height. The minivans are equipped with on-board power generation consisting of a 110-volt, 60 Hertz, gasoline-powered generator with a capacity of 2.5 kilowatts. External power outlets are provided for high volume samplers and an external socket and power cord allows connection to an outside power source.

Analysis

Analytical equipment for ambient air quality analysis carried within the minivan includes: a long path nondispersive infrared carbon monoxide analyzer, an ultraviolet absorption ozone analyzer, and a chemiluminescent nitric oxide and nitrogen dioxide analyzer. A high volume air sampler is carried on board the van for placement at some location outside. The van contains separate recorders for each analyzer. Zero and span gases are carried on board for calibration of the carbon monoxide and oxides of nitrogen analyzers. An on-board ozone generator facilitates calibration of the ozone analyzer. The air sample intake is normally maintained about five feet above ground level, although a mast is provided for taking samples at higher elevations.

Meteorological data are acquired during air sampling periods, using wind speed and wind direction sensors mounted on a mast extending about 10 feet above the van. These data are taken on chart recorders for subsequent analysis.

Additions to the current instrumentation aboard these minivans has already been planned. Space has been provided in the instrument rack for a hydrocarbon analyzer with methane correction and a data acquisition system capable of transcribing data from all analyzers and meteorological sensors onto a magnetic tape cassette. This will allow computer analysis of the aerometric data.

RESEARCH

The procedures and equipment which I have just described are those used for making an ambient air quality study for proposed highway projects. As mentioned earlier, the Division is also conducting research projects involving air quality. The sampling and analysis requirements for these projects are substantially different than those used for the operational projects. We are currently constructing two very sophisticated air quality vans for use on these research projects. These vans will have the capability of measuring pollutant concentrations at several points simultaneously and will use flame photometry for measuring sulfur compounds in addition to the other analyzers mentioned.

Meteorological capability will also be greatly expanded in these vans and will include the use of bi-vanes, humidity sensors, and solar radiation sensors. An on-board computer will control both the air sampling system and the acquisition of data fromthe sensors.

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