IMPLEMENTING TRADABLE EMISSIONS PERMITS FOR SULFUR OXIDES EMISSIONS IN THE SOUTH COAST AIR BASIN

VOLUME III

APPENDICES

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CONTENTS

APPENDIX A

LITERATURE REVIEW FOR TRADABLE PERMITS

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One of the most frequently heard criticisms of the current standards-based approach to environmental regulation is that it fails to meet prescribed environmental objectives in a cost-effective manner. If this is in fact true, it would seem incumbent upon those bent on improving the environment to provide alternatives which would be less expensive than the current approach, but also have the possibility of being adopted. This paper examines one candidate which has been suggested as a viable alternative to the existing mode of environmental regulation. The general idea is to set up a market where rights to emit one or several pollutants can be bought and sold. This approach has been referred to by several names including tradable permits, transferable licenses and marketable permits. The principal objective of this essay is to outline the nature of the work which has been completed on tradable permits and, in so doing, point out areas of research which might be of some benefit in assessing both the feasibility and relative merits of a marketable permit scheme.

Before discussing the details involved in the tradable permit approach, it is useful to consider what objectives we should place importance on in designing an environmental policy. At a minimum, it would seem reasonable to design a program which would meet the prescribed environmental quality objectives, or at least allow for meeting objectives in a timely manner. A second desirable feature of an environmental strategy is that it use a minimum amount of resources in achieving its goals, where resources are defined broadly to include both administrative costs and direct expenditures on abatement. If possible, such a policy should not stand in the way of economic progress. Finally, to be more than an intellectual curiosity, the approach should have some possibility of appealing to politicians or regulators who are responsible for developing environmental policy.

The traditional standards approach to regulation is clearly a political favorite, but does not seem to fare well in terms of efficiency. In the case of uniform standards, it is usually possible to achieve significant cost savings by redistributing the burden of cleaning up so that firms for whom it is cheaper will abate more than firms who have very high abatement costs. Even in the case where standards are designed to approximate a least-cost solution, it is quite likely that the regulator will lack the information to identify the solution. In particular, one would expect that several industries possess information on process modifications useful for abatement which are proprietary, and hence, typically not available to the regulator. It would be desirable to develop a mechanism for inducing industry to actively pursue these abatement options when they are cost-effective.

Another more serious flaw of the standards approach is that firms have no reason to abate more than the standard. In the most idyllic of worlds, where standards are treated as a given, firms may have an incentive to search for lower cost alternatives for meeting the standard; however, this will not always be the case since some standards are technology-based. If instead of a standards approach, some pricing mechanism were used to reduce pollution, then, at least in theory, firms would have a continuous incentive to innovate — not only to find lower cost methods of achieving a given standard, but also to search for ways to reduce emissions.

Three general approaches for providing continuous incentives for searching for new pollution abatement methods are taxes, subsidies and marketable permits. The virtues of emissions taxes are well known. If firms are cost minimizers, Baumol and Oates (1975) have shown that imposing such taxes can lead to a cost-minimizing solution. However, taxes are not without their problems. One difficulty is that it is virtually impossible to predict the level of emissions which would result upon imposing a tax. To partially circumvent this problem, some people have suggested that taxes could be adjusted until the desired outcome is attained. There are three basic problems with this suggestion: First, it may be quite expensive for firms to adjust to wide fluctuations in taxes; second, it is unlikely that the regulatory authority would be given that much discretion in adjusting the tax; and third, firms are likely to respond strategically if their response affects how taxes would be adjusted.

A more serious problem with emissions taxes would seem to be their widespread unpopularity among industry. While they confer benefits on the general public, they force firms to foot both the abatement costs and the tax bill. The extent to which firms pay taxes out of profits depends on whether the increase in taxes can be passed along to consumers. Nevertheless, for the case in which total emissions are similar, it is usually in industry's interest to oppose taxes in comparison with standards because the latter avoid the tax.

Providing subsidies for reducing emissions is yet another way to deal with pollution. Subsidies have the advantage that they have met with considerably less political resistance than taxes. In fact, this instrument has been widely used in the construction of municipal sewage treatment plants. Aside from the advantage of political feasiblity, however, subsidies have few good points. Their most serious drawback is that they usually fail to provide an incentive to keep expenditures on abatement down. Like taxes, subsidies also have the problem that the level of resulting emissions is very uncertain.

Marketable permits suffer few of the drawbacks of the other tools discussed thus far while enjoying many if not all of the advantages. The idea was popularized by Dales (1968) who argues that a market approach has the potential to meet environmental quality objectives at the lowest possible cost while allowing for economic growth. Dales envisioned a hypothetical pollution control board specifying the total number of permits, and hence, the overall level of emissions allowed in a given region. Rights of different duration could be bought and sold through the board by anyone who wished to participate. To accommodate growth some permits might be withheld initially. A critical question is whether the idea of marketable permits could ever win favor in the political arena. One potential advantage that permits have over taxes is that they can avoid net payments to the government if they are initially given away rather than auctioned. If permits were given away to industry, then at least some firms might favor marketable permits over the conventional standards approach because of the wealth transfer they would receive in the form of valuable permits.

Dales offers a very general discussion of how a market in tradable permits would work. A more rigorous analysis of the issue is contained in Montgomery (1972), who shows conditions under which tradable permits will be an efficient mechanism for attaining a least-cost solution. Montgomery raises an important problem in defining a permit by drawing a distinction between emissions and ambient pollutant concentrations. Defining permits in terms of emissions may not be the cost-minimizing strategy for achieving a given air quality target. The reason is that the same amount of emissions may have a different effect on ambient air quality if emitted at different locations. If so, charging firms the same price for a "unit" of emissions will typically imply that the marginal cost of improving the level of air quality will differ across firms. This result holds because firms are being charged a uniform price for emissions and not for pollution.

In theory, permits could be defined in terms of ambient air quality at different receptors, but to ensure an efficient solution, this would require the creation of several permit markets in a given air quality region. The extent to which such fine tuning is justified on a purely economic basis is an open question. Initial research indicates that savings could be quite large. However, in my opinion, the likelihood of instituting several markets to deal with a single pollutant in a given airshed is next to nil. Rather than search for the optimum, it would perhaps be more fruitful to consider the effects of a single market with some trading restrictions, or the effects of defining two or three markets within a geographical region.

Applied research on marketable permits has followed two lines of inquiry. The first focuses on problems encountered in market design and the definition of a permit. One difficult problem is what to do in the event the equilibrium price of a permit is much higher than anticipated. Firms could conceivably balk at paying such high prices, or even be put on the verge of bankruptcy, in which case the marketable permit scheme might be terminated. To deal with such a contingency, Roberts and Spence (1976) suggest the use of a mixed system of permits and fees, where the quantity of pollution would be fixed, unless the equilibrium permit price exceeds a certain level. In the latter case, firms would be charged a fee for emissions not accounted for by existing permits. The fee would provide firms with a continuous incentive to reduce emissions until the overall emissions objective was met. The use of such a mixed system makes sense in theory, but in practice it might be difficult to implement because it explicitly raises the issue of taxing, and it may be too complex for the political process to digest. A more workable alternative would be to adjust the level of permits over time by issuing at least some permits of limited duration, and giving the regulatory authority some discretion over the number of permits issued over time.

Another problem which has received little attention in the literature is whether it makes sense to have firms with vastly different degrees of market power participate in the same market. Mar (1971), in designing a system of water rights, suggests using two separate markets — one for large institutions and one for individuals or small institutions. The rationale for this approach is unclear. There are several commodity and stock markets currently in existence which manage to accommodate both large and small investors. If a few firms are expected to dominate a market in tradable permits, then there are two options. One is to abandon the marketable permit approach. The second is to design institutional safeguards which guard against contingencies such as thin markets and cornering. While several authors have recognized the possibility of a market which is not competitive, little effort has been devoted to addressing the issue in a concrete policy application.

The second general approach to analyzing the market for tradable permits is simulation of the equilibrium permit price using mathematical programming techniques. DeLucia (1974) analyzes the case of eight Mohawk river municipalities and concludes that a marketable permit approach is a viable alternative for achieving significant cost savings in water pollution. Even in the case where one of the firms can exert control over market price, DeLucia finds that the effect on the price and distribution of permits is minimal. This result is due to the shape of the treatment cost functions. DeLucia's general systems approach of considering the technical, legal and economic dimensions of the problem represents a quantum leap over previous efforts to demonstrate the viability of a permit scheme. Nevertheless, the analysis is less than convincing on one crucial point — why it is reasonable to assume that municipalities will run their waste treatment facilities in a cost-minimizing mode.

Other studies of permit markets in the early seventies are similar in approach, but narrower in scope. For example, Taylor (1975) uses a linear programming model to appraise a regional market in fertilizer rights aimed at reducing water pollution. Mackintosh (1973) considers a hypothetical air rights market in New Orleans and develops a simulation model to illustrate the effect it has on a local petroleum refinery. He concludes that marketable permits are an attractive alternative for meeting environmental quality objectives.

The early studies which simulate the workings of a market in tradable permits generally define a right in terms of emissions. As noted above, it would be useful to know if significant savings result from defining permits in terms of ambient concentrations. Atkinson and Lewis (1974) attack this problem from a slightly different perspective for the case of airborne particulate matter in the St. Louis Air Quality Region. Using a linear program which minimizes control costs, the authors found that exploiting the difference in contributions to ambient concentrations from different sources can lead to a 50 percent savings over a strategy which treats all emissions alike. While the potential savings are great, according to the model, nine markets (corresponding to the different receptors) would be needed to realize the full cost savings.

The most comprehensive study to date on the feasibility of marketable permits was completed by Anderson et al. (1979). The analysis examines alternative policies for attaining a short-term NO_2 standard in Chicago, and concludes that marketable permits present the most attractive alternative. A calculation similar to the one done by Atkinson and Lewis reveals that cost savings on the order of 90 percent could be obtained by using source-specific charges instead of a uniform emissions tax. Even if charges were based on source categories, the authors estimate savings in the neighborhood of 50 percent. While differential charges may lead to a lower cost solution, it is also quite probable that they would lead to unnecessary regulatory delay resulting from differences of opinion over the appropriate charge. In any event, it is unlikely the political system would accept such a complex pricing scheme.

From the perspective of the policymaker, a serious omission in the analysis by Anderson et al. is that the air quality modeling of NO_2 formation does not incorporate what is currently understood about atmospheric processes. For example, their model does not adequately describe the highly nonlinear chemical conversion processes which lead to NO_2 formation. When coupled with the fact that the pollutant dispersion model is designed primarily for applications involving nonreactive pollutants, their air quality results require careful scrutiny. If further modeling studies are to be performed which may have an impact on policy, they should reflect the current understanding of atmospheric processes as well as a reasoned analysis of the key economic and political questions.

CONCLUSIONS

The U.S. Environmental Protection Agency and state and local environmental regulatory agencies are increasingly being confronted with the harsh reality that the current standards system is not working very well. Not only are critics pointing to the whopping price tags on many projected investments designed to curb pollution, but in some instances, it can also be shown that environmental quality is deteriorating. While the environmental regulatory agencies are hardly to blame for this alleged state of affairs, they are in the unenviable position of having to take the political flak.

As the debate intensifies, it appears that agencies at both the federal and state level are willing to experiment with alternative modes of environmental regulation. In some cases, such as the Connecticut plan, the regulation is designed primarily to ensure that standards will be met.[1] Other tools, such as bubbles and offsets are aimed at both reducing environmental control costs while making marginal strides in the direction of improving environmental quality. The bubble focuses on a single firm with one or several plants with several emissions sources. It is designed to allow the firm to increase emissions beyond the current standard at one location if it makes a greater reduction in emissions somewhere else. Offsets are similar, but typically apply to more than one firm. They allow a firm to add new emissions if it pays for a greater reduction in emissions somewhere else in the same area.[2]

With the stepped-up search for viable alternatives, the time would seem ripe for a detailed evaluation of the feasibility of a tradable permit scheme for a particular pollution problem in a well defined region. A careful comprehensive analysis will require several components drawing on different disciplines. In the case of air pollution, a model needs to be used which links emissions and resulting air quality both spatially and temporally. For an actual application, it is imperative that the model be validated. All past studies which I have seen give scant attention to this issue. This is actually somewhat ironic given the amount of effort devoted to demonstrating the increased gains from exploiting the emissions-air quality relationship. If the model is not validated, there is no way of guessing the errors associated with estimates of potential cost savings.

The air quality model must be linked with abatement cost data to determine the quantity of permits to be issued and the appropriate definition. To be relevant, practical issues such as monitoring, enforcement, and administrative costs must be considered. The study by Anderson et al. (1979) exemplifies the type of work that needs to be done in these areas. The issue of ensuring a competitive market or at least a workable market must be carefully assessed. To date little work has been done which examines how different types of trading rules may serve to promote a viable market. Several authors do not see competition as a problem. For example, Teitenberg (1980), in his survey of the literature, asserts "anti-competitive effects of a TDP [transferable discharge permit] system are not likely to be very important in general."[3] Be that as it may, this is a very real concern to most policymakers which should be given adequate consideration.

The current mode of environmental regulation is rather crude. Loosely, it can be viewed as a give-and-take process where regulators attempt to clamp down tighter on source emissions as new technologies become available. It would be naive to presume that this system will be replaced with a finely tuned complex market mechanism which is cost-effective. It would be more realistic to strive for a system which redirects incentives away from large legal expenditures aimed at fostering regulatory delay, and towards a system which enlists the aid of polluting industries in searching for less expensive ways to meet prescribed environmental quality objectives. To move industry in this direction, it is incumbent upon the researcher to not only outline desirable economic alternatives, but also to outline proposals which will receive the backing of a majority of the participants. Such proposals should be easy to understand and give careful consideration to how the spoils will be distributed.

FOOTNOTES

1. See Clark (1978) for a summary of the Connecticut plan.

2. Payment is not formally required, and sometimes offsets are given away by local or state governments in an attempt to induce firms to locate there. Liroff (1980) provides a more precise definition of these terms along with a discussion of how these policy tools evolved.

3. Teitenberg (1980), p. 414.

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APPENDIX B

MARKETABLE PERMITS: WHAT'S ALL THE FUSS ABOUT?

Robert W. Hahn

ABSTRACT

While the theoretical case for applying market mechanisms to control pollution is persuasive, there are several stumbling blocks which arise in their application. This paper examines some of the key implementation issues which must be addressed in designing a marketable permit scheme. The issues are brought into focus by considering a particular example—the control of sulfur oxides emissions in Los Angeles.

Recently, both state and federal pollution control agencies have begun to direct their attention towards more economical alternatives which would meet environmental objectives.[1] While it has been shown that schemes which offer firms greater choice in selecting abatement alternatives have the potential to significantly reduce the overall cost of meeting prescribed environmental goals, the response of industry, the public and even regulators has been, at best, lukewarm. What might be the cause of this less-than-overwhelming response to new approaches for controlling pollution such as bubbles, offsets or marketable permits? There would appear to be two key reasons for the cool reception. The first results from a lack of familiarity with the new regimes. The "command and control" technique currently employed is a well-seasoned approach which industry, regulators, and the public have dealt with on many occasions. It is possible that, in moving to an incentive-based approach, significant transitional costs would be incurred. A second reason for not adopting such schemes is that distributional issues may take precedence over efficiency considerations for many of the key industrial participants. This paper examines problem of implementation for one particular alternative for dealing with pollution problems—marketable permits. The first part of the essay develops a simple framework for identifying implementation problems and points out several potential problem areas which need to be addressed. The second part of the essay addresses these issues using the specific example of setting up a market for controlling sulfur oxides emissions (SO_x) in a well defined air quality region.

I. DEVELOPING A FRAMEWORK

As a starting point it is useful to construct a situation in which all firms would prefer a marketable permit scheme to a standards regime. The next step is to examine how real world considerations are at variance with the assumptions used to construct the example.

Figure 1 illustrates the relationship between levels of abatement and control cost for a composite variable called "air pollution".

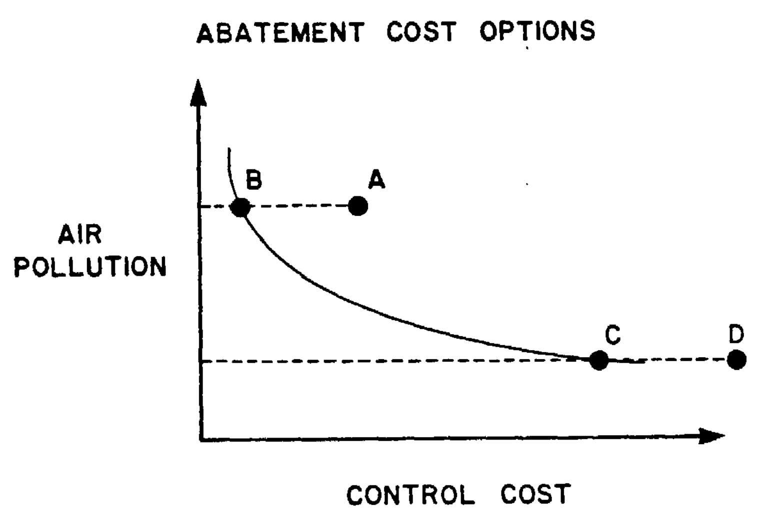

Figure 1

The curve passing through points B and C represents the minimum total cost of achieving a given level of abatement. Because of the difficulties in obtaining information on the nature of the least cost solution, it is typically thought that regulation leaves us at an inefficient point such as A. Since pollution associated with the existing situation usually exceeds the prescribed standard, let point C correspond to the target level of air pollution.

We wish to consider whether it is possible to devise a marketable permit scheme which allows us to move from point A to point C, and which would be preferred by all industrial participants. First consider the simpler problem of moving to a marketable permit scheme at the current level of pollution. This is represented by a move from A to B in the diagram. If transitional and administrative costs could be ignored, then it would be possible to move to a transferable rights scheme by issuing each firm an amount of permits which just equals their current level of emissions. This system of "grandfathering" the rights would be at least as good as the outcome under standards for some firms and unambiguously better for at least one firm (since the move from A to B implies that the overall level of abatement expenditures would be reduced).

The analysis of the situation in which the target air quality standard is more stringent (e.g., moving from A to C) is essentially similar to the argument given above, but requires one further assumption. We must assume that the distribution of rights under the standards approach is known for the level of pollution associated with C. With this assumption, it is sufficient to grandfather the rights in amounts which equal what they would have been under the standards regime. Under such a market scheme, all firms could be made at least as well off as they would be under a standards regime in which the rights to emit are nonnegotiable, since in the latter case, the air quality standard would be reached at a higher cost such as point D.

Two important factors ignored in the above analysis are the implications of uncertainty surrounding the rules to be promulgated by the agency, and the possibility that interested groups could influence the outcome. When these features are considered, the case for convincing industry that it is in their interest to adopt a permit scheme is considerably weakened.

For the case in which the level of air pollution remains unchanged and rights are grandfathered, industry might balk at the marketable permit idea for several reasons. One reason mentioned earlier is that use of a market to reach environmental goals is vastly different from the standards approach. Another possible objection is that grandfathering the rights is unfair because it tends to penalize those groups who have worked hardest to reduce their emissions. Finally, industry might argue that restrictions on trading combined with regulatory delay might lead to a system no better than the present situation, just different.[2]

If a marketable permit system is used to improve air quality over current levels, this introduces additional grounds for objecting to such a system. For example, industry might feel that the pollution associated with points C and D might never be met under a standards approach or that it would take a much longer time to reach the target. In either case, the discounted present value of staying at inefficient point A, with perhaps some chance of moving to inefficient point D in the future, could be less than the cost of immediately moving to C. Decreasing the level of pollution also makes the initial distribution problem that much more difficult, since it is virtually impossible to know how firms would have fared if standards had remained in place.

Movement to a marketable permit scheme also raises significant issues for regulators and the public. The regulatory agency must be capable of making the transition. Resistance to change can be expected. The agency may have to augment its monitoring and enforcement staff to obtain more accurate measurements of emissions which could stand up in court. The economic tradeoff which must be considered is whether the increased administrative costs would be offset by the expected cost savings in abatement.[3] For the market to work, the agency would have to develop trading rules which are comprehensible and allow several firms to participate.

The preceding list of objections might lead to the conclusion that the prospects for adopting this alternative in the near future are bleak. On the contrary, the prospects for adopting this alternative are very good indeed. This is especially true for pollutants which are not heavily regulated. A case in point would be nonaerosol chlorofluorocarbons.[4]

The basic reason for the growing possibility of actually experimenting with marketable permits is the increasingly widespread dissatisfaction among environmentalists, industry and regulators with the existing standards regime--that is, if point A is bad enough, the objections can be overcome. Industry finds the red tape and uncertainty very costly while regulators and environmentalists are dissatisfied with the progress in abating pollution. Since marketable permits are known to possess desirable properties in theory and appear to be workable for several practical applications, experimentation with this approach may be just around the corner. In fact, the offset policy and bubble policy currently being used by the U.S. Environmental Protection Agency are almost identical conceptually to a marketable permit scheme. The bubble policy, as it currently operates, is merely a smaller version of the permit schemes which are envisioned. The offset policy differs from a transferable rights scheme in two respects: first, the firm purchasing an offset must reduce its emissions to the lowest achievable level,[5] and second, the transaction costs in finding offsets and negotiating a price are excessive. A well-organized market could substantially reduce such costs, thus inducing more trading.

The federal experience to date with bubbles, banking and offsets has not been a success for two reasons: uncertainty and regulatory delay. The principal areas of uncertainty concern who has the property rights and for how long. The regulatory delay is primarily caused by the cumbersome State Implementation Plan review process. If an incentive based mechanism is to work effectively, both of these issues must be squarely addressed. By providing firms with some minimum guarantees on the duration for which their rights are negotiable, it is likely that trades would increase significantly. Similarly, if the review process could be expedited and trading rules could be clarified, all involved would benefit. Not surprisingly, the problems which befuddle the current incentive-based approaches could just as easily arise under a marketable permit scheme.

The preceding analysis provides some insights into the implementation problems which can be expected to arise in setting up an artificial market to control emissions. The next section takes a detailed look at one particular pollution problem--sulfur oxides emissions in Los Angeles.

II. A POTENTIAL APPLICATION

To demonstrate the viability of marketable permits without actually implementing the alternative requires selecting a specific pollutant, identifying the key implementation problems, and then designing a market which will address these issues. As an example, the problem of controlling particulate sulfates in the Los Angeles region was selected.[6] This problem was chosen because it appeared to be a likely candidate for marketable permits. The scientific aspects of the problem are well understood. Data on sulfur oxides abatement costs are available or can be constructed for most of the key sources, and monitoring and enforcement problems appear tractable.

The question at hand is whether such a market could actually work. First, the criteria for measuring the success of a market need to be specified. For this specific case we would like to design a market that will meet air quality goals in a more cost-effective manner than the current system of source-specific standards, that will encourage investment in finding new abatement technologies for the future, and that will be legally acceptable and politically feasible. Legal feasibility means that the market must meet the requirements of relevant constitutional and statutory constraints. Political feasibility means that the regulatory agency should be capable of administering the program and that the approach has a reasonable chance of being acceptable enough to industry, the public and regulators that it stands a chance of being enacted by political officials.

To meet air quality goals requires a good technical understanding of the problem. The particulate sulfate problem in Los Angeles is caused primarily by the combustion of sulfur-bearing energy products. Particulate sulfates are an important concern because they tend to reduce visibility, acidify rainwater, and may also have harmful health effects. The conversion of sulfur oxides emissions to sulfates in Los Angeles can be thought of as proceeding in three stages. First, sulfur enters the air basin. Virtually, all of the sulfur which man uses in the Los Angeles area enters in a barrel of crude oil. Second, when oil products are refined or burned, some of the sulfur contained in them is converted to SO_2 and SO_3 which is released to the atmosphere. Finally, the SO_x compounds react to form sulfates through a series of atmospheric chemical processes. Cass (1978) has shown that the relation between sulfur oxides emissions and sulfate air quality in Los Angeles is approximately linear and, in addition, can be modeled as if it were largely independent of the level of other key pollutants. Given a sulfate air quality objective, it will be possible to use an environmental model to compute the corresponding level of permissible emissions.[7]

The current approach towards controlling sulfur oxides emissions relies on standards and an offset policy. New sources of pollution must trade off the uncontrolled portion of their emissions by effecting further reductions at existing sources in the Los Angeles Basin. The owner of an existing source is thus vested with a valuable property right which can be sold in whole or in part to new source owners. The owner also has the option of holding onto his current abatement possibilities to facilitate subsequent expansion.

The offset policy is one limited form of a market in transferable licenses to emit air pollutants. Its principal drawbacks are that the costs of negotiation are excessive and the number of trades which can be made by new sources are limited. Negotiation costs are high because new entrants must first identify existing sources of pollution where emissions reductions are feasible, then try to estimate a reasonable charge for the offset, and finally perhaps have to purchase the entire business operations of some polluter. Purchases of offsets by new firms are limited by the requirement that new firms must reduce emissions to the lowest achievable level before being allowed to enter the offset market. Presumably, in a full-blown marketable permit scheme, all specific source by source restrictions on burning sulfur would be lifted. This would tend to increase the number of mutually beneficial trades. In addition, the market obviates the need for bilateral bargaining, which is cumbersome and unnecessary. By conveying a uniform price for a right to pollute, the market also ensures that rights will go to the highest bidder, and the marginal value of a right owned by a firm will approximate the market price.

While the market in licenses can attain a least cost solution, this cannot be assumed. In constructing a market in sulfur oxides emissions licenses for Los Angeles, care has to be taken to ensure that a few firms will not be able to dominate. Table 1 gives some indication of the relative market shares of sulfur oxides emissions in 1973 and projected shares for 1980 under a low natural gas scenario.

TABLE 1

Past and Projected "Market Shares" for Sulfur Oxides Emissions by Source Type for the South Coast Air Basin

1973 Emissions		1980s Projection - low natural gas scenario and 1977 emissions control regulations	
Source Type	% of Total Emissions[b]	Source Type	% of Total Emissions[b]
Utility	28	Utility	31
Mobile Sources	16	Mobile Sources	27
Utility	11	Utility	10
Oil Company	8	Oil Company	4
Steel Company	7	Coke Calcining Company	4
Oil Company	3	Oil Company	3
Coke Calcining Company	3	Steel Company	3
Oil Company	3	Oil Company	3
Oil Company	2	Oil Company	2
Oil Company	2	Oil Company	2

[a]These figures are based on sources located within the 1974 definition of geographic boundaries of the South Coast Air Basin (which was subsequently revised).

[b]Emissions are rounded to the nearest percent.

Source: Based on author's calculations from data used to compile Cass (1978) and Cass (1979).

The low natural gas scenario is essentially a worst case because the absence of natural gas means that fuel with higher sulfur content will be burned. If this pattern of emissions is accurate, the electric utilities can be expected to account for the largest share of emissions. Note that mobile sources account for more than one-fourth of the total in the 1980s scenario. To force all mobile sources to participate in the market would, needless to say, be quite expensive.

Fortunately, it may be possible to transfer this responsibility to local oil companies since they make the gasoline, diesel oil, jet fuel, and bunker fuel burned by mobile sources.

While a transition to a market in tradable licenses will almost certainly imply different market shares from those presented above, the electric utilities can still be expected to have the largest share of the market. This presents some difficulties because even if the utilities act as cost minimizers their interaction with the public utilities commission rate-setting process might provide incentives towards investing in licenses which differ from more conventional privately-held firms. The problem of predicting utility behavior in a license market is currently being investigated by examining how other durable assets, such as real estate, are treated, and by observing utility behavior under the current system of offsets and banking.

Given that competition in such a market is not a foregone conclusion, it is important to ask what happens if some of the safeguards don't work and some of the firms successfully manipulate the price of a license. While this would certainly affect the distribution of income and should be avoided if possible, it by no means renders the system a complete failure. In fact, so long as the market provides greater flexibility for firms wishing to locate in Los Angeles while maintaining the current level of air quality, this will be a big step forward over current policy.

Some critics fear the market may not have a sufficient number of trades to be competitive. In the jargon of the economist, this is the problem of "thin" markets. The extreme case of a thin market is when no trading occurs. From a practical point of view, this lack of trading would be a concern even if firms in the area were at an equilibrium which minimized aggregate abatement costs. The concern stems from the observation that new firms wishing to enter the area would receive little information on the cost of entry. The solution to this problem is to devise a system which will give potential entrants a price signal when the market becomes too thin. One alternative whose properties are currently being investigated, is to have existing firms put a small percentage of their permits up for sale. Anyone wishing to bid on these licenses, including existing participants, would be encouraged to do so. Under such a scheme, new entrants would have a better idea of the cost of emitting sulfur oxides in Los Angeles.

While questions of efficiency are important, distributional issues must also be addressed if the market is to become a politically viable entity. One important concern in moving to a market to control sulfur oxides air pollutants is the transitional costs which firms will face. Some firms or industries may be forced to shut down. For example, if a firm competes in a national market and faces an elastic demand for its product, it may be the case that the costs of entering a license market could force it to move to another area where environmental regulations are less costly. Estimates of the likelihood of firm closings obtained so far indicate that plant closure will not be a problem in this specific case.[8] If the policy maker wishes to avoid plant closings, this issue can be addressed through a suitable initial distribution of licenses.

To gain some perspective on the distribution problem, it is useful to have a qualitative estimate of the size of the "pie." Preliminary estimates of the total annual value of emissions (i.e., the price of a license multiplied by the quantity issued) are in the neighborhood of 200 million dollars per year.[9] Assuming there are roughly 10 million people in the South Coast Air Basin implies that each person could receive 20 dollars per year if the licenses were auctioned and the proceeds were distributed to the public. Some critics have argued that the magnitude of the potential wealth transfers involved does not bode well for marketable permits in the political arena. While problems with distribution can be viewed as a barrier to implementation, there is an alternative view that control over the distribution of permits makes it that much more likely that a politically acceptable solution can be found.

What is really at issue here is who will be given the property rights to the air, and for how long. It is quite likely that a large part of the resistance to emissions tax proposals is related to the realization that under most taxation schemes, emissions rights will revert back to the public domain.[10] This is, in essence, the nature of the excess burden or double taxation argument which states that it is unfair for industry to have to pay the tax and pay to clean up as well. The alleged inequity of the excess burden can be directly addressed in marketable permit scheme. In the extreme case, all licenses could be distributed to industry if that were deemed fair or necessary to enlist industrys' cooperation. Alternatively, some of the proceeds could go directly to the public or could be used to finance administrative costs. The basic point is that adopting a marketable permits approach provides a great deal of flexibility in addressing distributional issues.

The final question which needs to be addressed is whether the infrastructure exists to handle a marketable permits scheme. There is currently a nominal emissions fee system in place for the South Coast Air Basin. Each firm is required to complete a form analogous to an income tax form which gives annual emissions for air contaminants which are subject to the fee. The principal purpose of the fee system is to cover a part of the operating cost of the South Coast Air Quality Management District (AQMD). For example, during the 1980-81 fiscal year, fees can be expected to cover about 30 percent of the projected 20 million dollar budget.[11] Sulfur oxides emissions are one of five air pollutants which come under the fee system. The charge for emitting a ton of sulfur oxides is $21.[12] This can be compared with a license price which is estimated to be in the neighborhood of $1,000 per ton for the case in which sulfur oxides emissions remain at their present levels. Though the AQMD currently handles all disputes over emissions fees within the agency, when the price of emissions increases by one or two orders of magnitude, it is quite likely that the courts will play some role in settling disputes.

The problem is to figure out how to minimize the role of the courts. One way is by carefully defining a license in terms which can be monitored. Two obvious choices are to define a license in terms of a short-term maximum emissions rate such as a pound per hour, or in terms of a cumulative measure of emissions over a longer time interval. For the case of sulfur oxides emissions it would probably be preferable to define a license in terms of cumulative emissions over a time interval such as a week or a month, but the problem is that integrated stack monitors do not exist which would provide the necessary information to demonstrate that a violation had actually occurred. On the other hand, the technology for determining whether a source has violated a short-term maximum emission rate does exist. This can be accomplished by a team of 4 or 5 technicians performing a source test.

The monitoring and enforcement of a marketable permit scheme to control sulfur oxides emissions is well within the grasp of the AQMD. It is a relatively straightforward manner to monitor cumulative emissions for utilities and the majority of industrial sources who do not use any abatement equipment for reducing sulfur oxides emissions. The only information that is required to estimate emissions is the quantity of fuel burned and the sulfur content of the fuel. For those sources who do not route all of the sulfur input into the air, the task is less straightforward. The major sources in this category include the oil refiners, coke calciners, glass manufacturers and steel manufacturers. There are two basic approaches which can be used to monitor stack emissions. One is the source test performed by technicians. The second is to install monitoring equipment which indicates the concentration of sulfur within a small area in the stack. Unfortunately, without some estimate of the flow rate, it is impossible to know the cumulative emissions. While the use of stack monitors for measuring SO_x is still in its infancy and the estimates are not always reliable, they may be used as a continuous check to determine when a firm's emissions appear to be exceeding its permits.

There are currently about 20 stack monitors in place and 100 are expected to be in place by the end of the year in the South Coast Air Basin.[13] One possibility for enforcing the SO_x permit scheme is to sample firms at random to see if they are in violation. This random sampling approach could be augmented by a program which uses the information provided by the continuous monitoring system installed in many of the larger sources.

It is likely that the current monitoring and enforcement staff, which has a little less than 200 members, would have to be increased if a SO_x marketable permit scheme were implemented. The size of the required increase is not certain, and depends on an assessment of how well the current system works. By all accounts of people interviewed, both in and outside the AQMD, the system for monitoring SO_x emissions works well now, so I feel that, at most, it would cost the agency an additional million dollars annually to monitor.[14] This amount is easily offset by the expected cost saving to be derived from using marketable permits.

There are some legal problems which need to be addressed in the implementation phase. For example, it is not clear whether under current law the AQMD can penalize violators by fining them in accord with the severity of the violation. It would be desirable to have a system of fines which could be administratively imposed, again, to minimize the role of the courts. In addition, the question of who should be given the burden of proof needs to be addressed. The current reporting system for emissions is analogous to federal income tax reporting with the polluter responsible for substantiating his claims when the AQMD estimates differ with those submitted by the polluter.

The exact form of the fine raises some interesting issues. First, consider the objectives in designing a penalty system. The basic objective is to provide firms with a strong incentive to play by the rules so the air quality target will be met. But, how strong an incentive? Clearly, if the penalties were made high enough and there were some probability of getting caught, all firms would play by the rules. There is a question, however, both from a legal and an administrative perspective, as to how high you can make the penalties and still have them be workable. If the penalties far exceed the estimated damages, the courts are not likely to uphold them and the regulators might be reluctant to impose them. Such might be the case if all violations were to be punished by closing down the plant. Thus, in addition to providing an incentive for firms not to exceed their allowed emissions, a penalty scheme should be enforceable.

There are no magic formulas for determining a penalty scheme. The basic theoretical approach is to try to maximize the difference between social benefits and social costs. Operationally, this is not very helpful. If the firm's violation is viewed as marginal, then a less grandiose objective might be to equate the firm's marginal benefit from the violation with the marginal cost to society of allowing such a violation. The firm's marginal benefit can be estimated by members of the firm, but, in all likelihood, is not public information. The marginal physical damage to society of such a violation is anybody's guess, but can usefully be separated into two components: the probability of getting caught, p, given that a firm is in violation, and the damage due to a violation, D, which is detected. We shall then define the expected marginal physical damage to society of a violation D, which is detected as (D/p). The problem is to operationalize this notion by defining physical damages more precisely and converting them to monetary damages.

Quantification of damages is always difficult. For illustrative purposes suppose that damages are a function, f, of the size of the difference between monitored emissions and permits currently held by the firm. Call this difference x so that damages are represented by $D=f(x)$. Let F be the size of the fine in dollars and let ℓ be the price of a marketable permit. Equation (1) represents a preliminary attempt to link the fine to damages, the probability of getting caught when in violation and the existing price for polluting, ℓ.

$$F = \frac{f(x)\ell}{p} \tag{1}$$

The numerator of equation (1) represents an estimate of the monetary value of damages. Dividing through by p gives a measure of expected damages. Thus, the firm is supposed to compare its expected marginal benefits with expected damages.

Though there is nothing wrong with equation (1) conceptually, it suffers from one serious flaw. Such a penalty system can be circumvented by driving the price of a permit to zero. This situation could easily arise if a sufficiently large number of firms chose not to participate in the market. Equation (1) is easily modified to deal with this issue. Let 'a' be a parameter set by the regulator which could reflect the expected market price of a permit if all firms were to participate in the market. This gives rise to equation (2) which captures the spirit of (1), but does not fall prey to manipulation as easily.

$$F = \frac{f(x)\ \mathrm{Max}(a,\ell)}{p} \tag{2}$$

In Equation (2), "Max" denotes the maximum of a and ℓ. Thus, at a minimum, a firm caught in violation would have to pay $f(x)a/p$.

The nature of the damage function, f(x), needs to be spelled out. If the objective is to keep firms close to their permit levels, then it makes sense to increase the marginal cost when the size of the violation increases. This is easily accomplished by letting $f(x) = Kx^n$ where K is an arbitrary constant and n exceeds unity. Substitution into (2) yields:

$$F = \frac{Kx^n \, Max(a,\ell)}{p} \qquad (3)$$

Equation (3) is offered merely as one possibility for designing a penalty scheme. It has the virtue that it is simple, and all the parameters can be estimated, at least roughly. Furthermore, it crudely relates benefits to costs, and also would appear to be consistent with the postulated objectives for a penalty system.

The point of going through this exercise of designing a fee was to demonstrate a general approach to the problem as well as noting some of the difficulties in moving from theory to practice. The above formulation is simplistic. It assumes away many of the measurement problems. For example, there is obviously some uncertainty in measuring x. Nevertheless, it is our belief that source tests are sufficiently accurate to warrant a penalty design which assesses fines which are commensurate with the size of the violation. Another problem is that p is really an endogenous variable, which depends on the penalty scheme actually adopted, making it difficult to estimate before implementation begins. In addition, the probability of detection may vary with the size of the violation.

The detailed design of a penalty system will require further distinctions not made here. For example, firms who report violations should be subject to less severe penalties than firms who do not. In the above model, p could be set equal to unity for firms reporting violations. In actuality, firms caught cheating on their reported emissions could be subject to other civil or criminal sanctions, similar to those imposed by the Internal Revenue Service.

The first objective in designing a penalty scheme was to induce firms not to exceed the allowable level of emissions most of the time. However, it was recognized that there may be unforeseen circumstances, such as an equipment failure, when a firm might violate its emission limit for a short time. Just as it is important to identify extenuating circumstances for the individual firm, it is also important to identify situations where a marketable permit scheme may be inappropriate. For the case of SO_x emissions in Los Angeles, these are two types of uncertainty which can be expected to strain the system. The first is the unpredictability of the natural gas supply. The permit scheme can handle this uncertainty in two ways: either by forcing industry to deal with this uncertainty or providing some relief in the form of issuing temporary permits should a crisis situation arise. The second major area of uncertainty is the problem of air pollution episodes which require dramatic action on the part of all participants. Because such events are very difficult to predict in advance, the best way of handling these situations is probably to suspend the permit system and invoke tighter regulations during these brief periods.

The preceding discussion indicates that it will be possible to design a market in tradable SO_x emission licenses for Los Angeles. Monitoring and enforcement capabilities currently exist, but will probably have to be expanded. A fee system needs to be worked out in detail which will induce firms not to exceed their allowed level of emissions. In addition, the problem of obtaining revenues to administer the market must be addressed. One simple solution is to set a nominal fee on SO_x emissions analogous to the 21 dollar/ton fee which is applied now. Such a fee could be expected to lower the permit price by the discounted value of the fee.

III. CONCLUSIONS

In a world not beset by uncertainty, but befuddled by pollution problems, it was possible to construct an example in which marketable permits were preferable to standards. In the real world in which we live, the comparison is less straightforward. There are transitional costs in moving to a new system. Not all firms will necessarily be winners in moving to a permit scheme. It is possible that firms may face higher abatement costs than under standards for the simple reason that the air quality goals may be reached more quickly.

Despite these objections, there appears to be an increasing willingness on the part of all groups to experiment with new kinds of environmental regulation. This enthusiasm is derived, in part, from the observation that the command and control approach is not working for many problems. It is burdensome administratively, and even though industry can sometimes foster delays in enacting regulations, the attendant uncertainties can be very expensive for firms who have long-term planning horizons. It might be the case that coalitions can be formed which are willing to consider alternatives such as marketable permits which can provide greater certainty.

If regulatory agencies decide to experiment with marketable permits, it is of paramount importance that some assurances be placed on the minimum duration of a permit. In addition, trading rules need to be spelled out clearly. If environmental agencies adopt a marketable permits approach and change the rules capriciously, they run the risk of losing support for a tool which can be a most-effective means of controlling pollution problems.

The importance of selecting the right problem cannot be overemphasized. It is helpful to have an understanding of the relationship between emissions and pollution so the target can be attained without having to iterate frequently. A monitoring and enforcement capability is imperative. Many environmental regulatory agencies currently do not have the resources or the expertise to successfully monitor and implement a marketable permit scheme. The final element necessary to assess the viability of the marketable permit alternative is an estimate of what it will cost industry to clean up the problem. This information can be used to identify implementation problems and design a market which will address these issues.

FOOTNOTES

1. Krier and Bell (1980) provide an insightful discussion on the relationship between some of the new approaches being proposed such as bubbles, offsets and marketable permits, and the traditional approaches to environmental regulation.

2. A summary of industrys' skeptical perspective on the bubble policy which supports this view is contained in Environment Reporter (1980).

3. Both the study by MATHTECH and the study by Rand indicate that expected cost savings are much greater than any expected increase in administrative costs.

4. This is the subject of the Rand study prepared for the U.S. Environmental Protection Agency.

5. U.S. Environmental Protection Agency (1980), p. 8.

6. The Los Angeles region refers to the South Coast Air Basin and a part of Ventura County. The current definition of the South Coast Air Basin includes all of Orange County, the majority of Los Angeles County and parts of San Bernardino and Riverside County. See Air Report (1980) for a more precise definition.

7. See Cass (1978) for a description of the model and the validation procedure.

8. There are two possible exceptions to this conclusion--a large steel manufacturer which may close down before the system could get underway, and the glass manufacturers who account for less than 1% of current emissions, but have very high abatement costs. It appears that both of these problems could easily be handled through a distribution scheme that is politically acceptable.

9. These calculations will be spelled out in more detail in Chapter 3 of Hahn (1981).

10. This point may need further clarification for readers with a legal perspective on the issue. In a legal sense, it may be true that the public has a claim on such rights. The point made here is that regardless of who has the claim, industry is, de facto, exercising the right whenever it spews forth emissions which are sanctioned by law.

11. Based on interview with Eric Lemke (1980).

12. Small emitters as defined in Rule 301 of the Rules and Regulations are exempted. SO_x is measured in equivalent tons of SO_2.

13. Based on interview with Eric Lemke (1980).

14. This upper bound estimate is based on the assumption that up to 25 or 30 more technicians might need to be hired.

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APPENDIX C

MARKET POWER AND TRANSFERABLE PROPERTY RIGHTS*

Robert W. Hahn

ABSTRACT

The appeal of using markets as a means of allocating scarce resources stems in large part from the assumption that a market will approximate the competitive ideal. When competition is not a foregone conclusion, the question naturally arises as to how a firm might manipulate the market to its own advantage. This paper analyzes the issue of market power in the context of markets for transferable property rights. First, a model is developed which explains how a single firm with market power might exercise its influence. This is followed by an examination of the model in the context of a particular policy problem--the control of particulate sulfates in the Los Angeles region.

1. Introduction

The idea of implementing a market to ration a given quantity of resources is by no means novel. Working examples include markets for taxi medallions and liquor licenses. Suggested applications for the use of a market approach abound in the economics literature, especially in the fields of air and water pollution.[1] Why has the idea of setting up a market in transferable property rights received so much attention? One key reason, and the reason which motivates this paper, is that such markets have the potential to achieve a given objective in a cost-effective manner. Whether this potential is realized depends, among other things, on the design of the market and the extent to which individual firms can exert a significant influence on the market.

The purpose of this paper will be to explore how the initial distribution of property rights can lead to inefficiencies. Section 2 develops the basic model for the case in which one firm can influence the market. Section 3 considers a potential application of the model. The results of the theoretical analysis are then compared with the conventional wisdom and directions for future research are discussed in Section 4.

For analytical purposes, firms are divided into two categories. A firm will be said to have market power if it realizes it has an influence on price. A firm will not have market power if it acts as a price taker. The question for analysis, then, is how a single firm with market power might influence the market by affecting the price at which a commodity sells. More precisely, this essay examines how the pricing strategy of a firm with market power varies with changes in the initial distribution of property rights.

In the static models developed below, all transactions take place at a single price. Restricting the model in this way permits analysis of a range of inefficient outcomes. This is in contrast to the approach taken by Coase (1960) in his seminal article, who does not restrict the bargaining space and, consequently, emphasizes the range of efficient outcomes that can result, irrespective of the initial endowment of property rights.

The principal result is that the degree of inefficiency observed in the market is systematically related to the distribution of permits. For the case of one firm with market power, the results have some intuitive appeal. If a firm with market power would elect to buy permits in a competitive market (i.e., where all firms act as if they were price takers), then it follows a strategy resembling that of a monopsonist. If it would choose to sell permits in a competitive market, then the firm with market power follows a strategy resembling that of a monopolist. These results are formalized in the next section.

2. The Basic Model

A critical assumption underlying the competitive model is that firms act as if they were price takers. In the model developed below, it will be assumed that all firms except one are price takers. The basic question to be answered is how (and whether) the equilibrium price and quantities will vary as a function of the initial distribution of permits among firms.

Consider the case of m firms with firm 1 designated as the firm with market power. A total of L permits are distributed to the firms, with the ith firm receiving Q_i^o permits. Firms are allowed to trade permits in a market which lasts for one period. The number of permits which the ith firm has after trading will be denoted by Q_i. All firms except the market power firm are assumed to have downward sloping inverse demand functions for permits of the form $P_i(Q_i)$ over the region [0,L]. P_i represents firm i's willingness to pay. All trades in the market are constrained to take place at a single equilibrium price, P. For concreteness, we shall consider the case of a classical pollution externality. All price-taking firms attempt to minimize the sum of abatement costs and permit costs. For the case of pollution, the assumption of downward sloping demand curves is equivalent to the assumption that marginal abatement costs are increasing. Let $C_i(Q_i)$ be the abatement cost associated with emitting Q_i units. Marginal abatement costs, $-C_i'$, are assumed to be positive and increasing, which implies $C_i' < 0$ and $C_i'' > 0$ for i = 2,...,m. Price takers solve the following optimization problem:

$$\underset{Q_i}{\text{Minimize}} \quad C_i(Q_i) + P(Q_i - Q_i^o) \qquad (i=2,\ldots,m). \qquad (1)$$

The first order condition for an interior solution is:

$$C_i'(Q_i) + P = 0. \qquad (2)$$

This merely says that price takers will adjust the quantity used, Q_i, until the marginal abatement cost equals the equilibrium price, P.[2] Equation (2) implicitly defines a demand function $Q_i(P)$ which is downward sloping on [0,L] for i=2,...,m. Furthermore, note that the number of permits the ith price-taking firm will use is <u>independent</u> of its initial allocation of permits.

The analysis of the firm with market power is less straightforward. Begin by defining an abatement cost function $C_1(Q_1)$ where $C_1' < 0$ and $C_1'' > 0$. This says that the firm with market power faces increasing marginal abatement costs. Firm 1 has the power to pick a price which will minimize its expenditure on abatement costs and permits subject to the constraint that the market clears. Formally, the problem is to:

$$\underset{P}{\text{Minimize}} \quad C_1(Q_1) + P(Q_1 - Q_1^o) \qquad (3)$$

$$\text{Subject to: } Q_1 = L - \sum_{i=2}^{m} Q_i(P).$$

Substituting the constraint into the objective function and differentiating yield the following first-order condition for an interior minimum:

$$(-C_1' - P)\sum_{i=2}^{m} Q_i' + (L - \sum_{i=2}^{m} Q_i(P) - Q_1^o) = 0. \qquad (4)$$

Equation (4) reveals that the only case in which the marginal cost of abatement, $-C_1'$, will equal the equilibrium price is when firm 1's distribution of permits just equals the amount it chooses to use. In effect, this says that the only way to achieve a cost-effective solution, where marginal abatement costs are equal for all firms, is to pick an initial distribution of permits for firm 1 which coincides with the cost-minimizing solution.

This gives rise to the following result:

Proposition 1: Suppose there is one firm with market power. If it does not receive an amount of permits equal to the number which it elects to use, then the total expenditure on abatement will exceed the cost-minimizing solution.

The key point to be gleaned from the analysis is that the distribution of permits matters, with regard not only to equity considerations but also to cost. Traditional models of such markets view problems of permit distribution as being strictly an equity issue.[3] With the introduction of market power, it was shown that the distribution of permits may also impinge on efficiency considerations.

The next logical question to explore is how the market equilibrium will vary as a function of firm 1's initial distribution of permits. Doing the necessary comparative statics yields:

$$\left.\frac{\partial P}{\partial Q_1^o}\right|_{L=\text{constant}} = \frac{1}{(-C_1' - P)\sum_{i=2}^{m} Q_i'' + \sum_{i=2}^{m} Q_i'^2 C_i'' - 2\sum_{i=2}^{m} Q_i'} \qquad (5)$$

The expression for the denominator is the second order condition for the cost minimization and will be positive if the second-order sufficiency condition for a minimum obtains. For example, in the case of linear demand curves (i.e., $Q_i'' = 0$), the expression will be positive. Thus, for the case when a regular interior minimum exists, a transfer of permits from any of the price takers to the firm with market power will result in an increase in the equilibrium price. An immediate corollary to this result is that the number of permits that the firm with market power uses will increase as its initial allocation of permits is increased. Formally, the problem is to show $(\partial Q_1/\partial Q_1^o) > 0$. By the chain rule,

$$\frac{\partial Q_1}{Q_1^o} = \left(\frac{\partial Q_1}{\partial P}\right)\left(\frac{\partial P}{\partial Q_1^o}\right) . \qquad (6)$$

It suffices to show $(\partial Q_1/\partial P)$ is positive. By direct substitution for Q_i,

$$\frac{\partial O_1}{\partial P} = \frac{\partial (L - \sum_{i=2}^{m} Q_i\ (P))}{\partial P} \qquad (7)$$

The expression on the right-hand side of (7) equals $-\sum_{i=2}^{m} Q_i'(P)$, which is positive, because demand curves are presumed to be negatively sloped.

One question which arises in this model is whether there is any systematic relationship between the distribution of permits to the firm with market power and the degree of inefficiency. If inefficiency is measured by the extent to which abatement costs exceed the minimum required to reach a stated target, then it is possible to show the following result:

> Proposition 2: Let Q_1^* denote the distribution of permits for the case when permit distribution equals permit use for the firm with market power. Then inefficiency increases both as Q_1^o increases above Q_1^* and as Q_1^o decreases below Q_1^*.

The proposition is verified by determining how total cost, TC, varies as a function of Q_1^o.

The efficient solution is derived from the following minimization:

$$\underset{Q_1,\ldots,Q_m}{\text{Minimize}} \quad TC = C_1(Q_1) + \sum_{i=2}^{m} C_i(Q_i) \tag{8}$$

$$\text{Subject to:} \quad Q_1 + \sum_{i=2}^{m} Q_i = L.$$

First order conditions imply:

$$-C_i'(Q_i) = P_i(Q_i) = P. \qquad (i=2,\ldots,m) \tag{9}$$

Differentiation of total cost with respect to Q_1^o yields:

$$\frac{\partial TC}{\partial Q_1^o} = C_1' \frac{\partial Q_1}{\partial Q_1^o} + \sum_{i=2}^{m} C_i' \frac{\partial Q_i}{\partial Q_1^o}$$

$$= C_1' \sum_{i=2}^{m} \frac{\partial Q_i}{\partial Q_1^o} + \sum_{i=2}^{m} C_i' \frac{\partial Q_i}{\partial Q_1^o}$$

$$= \sum_{i=2}^{m} (C_i' - C_1') \frac{\partial Q_i}{\partial Q_1^o} \quad . \tag{10}$$

The above expression can be simplified by noting:

$$\frac{\partial Q_i}{\partial Q_1^o} = - \frac{\partial P}{\partial Q_1^o} \Big/ C_i'' \quad . \tag{11}$$

Equation (11) is obtained by differentiating (9) with respect to Q_1^o. Substituting equation (11) into (10) yields:

$$\frac{\partial TC}{\partial Q_1^o} = - \frac{\partial P}{\partial Q_1^o} \sum_{i=2}^{m} \frac{(C_i' - C_1')}{C_i''}$$

$$= - \frac{\partial P}{\partial Q_1^o} \sum_{i=2}^{m} \frac{(-P - C_1')}{C_i''} = \frac{\partial P}{\partial Q_1^o} (P + C_1') \sum_{i=2}^{m} \frac{1}{C_i''} \tag{12}$$

Equation (12) implies:

$$\frac{\partial TC}{\partial Q_1^o} > (<)\ 0 \text{ as } (P + C_1') > (<)\ 0. \tag{13}$$

Combining (13) with equation (4) yields the result that total cost achieves a minimum at Q_1^* and will increase as the permit distribution deviates from Q_1^* in either direction.

In addition to determining how inefficiency varies with the initial distribution of permits, it is also of some interest to know when the level of inefficiency can be related to observable variables such as the quantity of permits which are exchanged. If there is a single firm with market power and this firm is known, then placing restrictions on the demand for permits by price takers yields the following result:

> Proposition 3: The degree of inefficiency will increase as the amount the firm with market power decides to buy or sell increases, provided the demand for permits by price takers is linear.

To see this result, first note that any price not equal to the competitive equilibrium price will cause efficiency losses. Second, note that as the deviation between the competitive equilibrium and the observed price increases, the degree of inefficiency increases. This result follows immediately from the assumption that all firms face increasing marginal abatement costs. It remains to be shown that trading increases as the size of the deviation between the actual price and the competitive equilibrium price increases.

The size of the deviation between the actual price and the competitive price is governed by the initial distribution of permits to the firm with market power, Q_1^o. The amount of net buying, $(Q_1 - Q_1^o)$, is also governed by Q_1^o. At the competitive equilibrium, the firm with market power does not trade — $Q_1 = Q_1^o$ — and a competitive price, P^*, will prevail. The deviation between the actual price and the competitive price, $(P-P^*)$, is an increasing function of Q_1^o. To see this, it suffices to show $\partial P/\partial Q_1^o > 0$ (since P^* is constant). The assumption of linear demand implies $Q_i'' = 0$ for all price takers. Inspection of equation (5) reveals $\partial P/\partial Q_1^o > 0$ for this case. This implies that the absolute deviation in prices increases as Q_1^o rises above Q_1^*, and as Q_1^o falls below Q_1^o.

If it can be shown that selling increases as Q_1^o rises above Q_1^* and buying increases as Q_1^o falls below Q_1^o, then Proposition 3 will have been verified. For then, increases in selling and increases in buying will be associated with larger absolute price deviations and hence, higher degrees of inefficiency. Formally, the problem is to show $\partial(Q_1 - Q_1^o)/\partial Q_1^o < 0$. The relationship between net buying and permit distribution is derived below:

$$\frac{\partial(Q_1 - Q_1^o)}{\partial Q_1^o} = \frac{\partial Q_1}{\partial Q_1^o} - 1$$

$$\frac{-\sum_{i=2}^{m} Q_i'}{\sum_{i=2}^{m} Q_i'^2 C_i'' - 2\sum_{i=2}^{m} Q_i'} - 1 < 0 \qquad (14)$$

The second equality is based on substitution of equations (5) through (7). Based on the signs of Q_i' and C_i'', it follows that $\partial Q_1/\partial Q_1^o < 1$ for this case, which immediately yields the desired result.[4]

Other analysts have considered the possibility of market power, but generally restrict themselves to a special case. For example, Ackerman et al. (1974) consider the problem for a specific hypothetical case, but do not deal explicitly with the effect of permit distribution.[5] DeLucia (1974) considers a numerical example in a simulation of a water rights market in which the rights are auctioned. The firm with market power plays the role of a monopsonist, restricting its demand for permits in an effort to keep the permit price low. The situation analyzed by DeLucia corresponds to the case when the firm with market power receives no permits initially.

While concern that a firm or group of firms can influence such a market has been expressed, relatively little thought appears to have been given to exactly what is meant by market power and how to devise institutions which would yield a desirable set of outcomes. The simple model developed above reveals two essential points. First, just because a firm may have a large share of the permits, this does not necessarily mean it can influence the outcome in the permit market. Second, if a firm does have market power in the permit market, its effect on price (assuming there is one firm with market power) varies with its excess demand for permits. That is to say, once the potential for market power has been ascertained, it is a flow — excess demand of the firm with market power — which determines the equilibrium.

The importance of the flow has immediate implications for market design. In particular, with full knowledge of demand functions, a central authority could effectively pick the quantity of permits it wanted the market power firm to use through a suitable initial allocation. The limits to the discretion of the authority would be dictated by two extreme cases: pure monopsony in which all permits are distributed to the price takers, and pure monopoly in which all permits are distributed to the firm with market power.

Of course, the more realistic situation is one in which the authority has, at most, only a crude estimate of the demand functions.

In this case the basic model can be applied to assess the possibilities for exerting market influence. The sensitivity of the results could be checked by varying the demand functions and the initial distribution of permits. This would allow the policymaker to determine if the type of market influence considered here is likely to pose a problem in a given application.

3. A Potential Application

In order to apply the basic model described in Section 2, it is necessary to develop an operational test for identifying a firm with market power. How this might be done is beyond the scope of this paper. In the application discussed below, the firm holding the largest share of permits under a competitive market simulation is designated as the market power firm.

To demonstrate how the basic model can be applied, the problem of controlling particulate sulfates in the Los Angeles region was selected. This problem was chosen because it appeared to be a likely candidate for a transferable property rights scheme, and because the problem of market power could conceivably arise. Market simulations based on the assumption that firms are price takers indicate that the largest emitter of sulfur oxides, an electric utility, could account for as much as half of the total emissions, and an even higher proportion of emissions for which abatement technologies are known--i.e., controllable emissions.[6]

The extent of market power will in general, vary with the level of allowable emissions, the shape of the marginal abatement cost schedule for the market power firm, and the marginal abatement costs faced by all other firms. For this particular example, a permit will be defined as the right to emit one ton of sulfur oxides emissions per day for one day. Based on this definition, Figure 1 shows the marginal costs of abatement for the firm designated as the market power firm.[7] Two curves are drawn in Figure 1, a discrete step function (based on the data in Hahn (1981b)), and a continuous approximation which has the following functional form:

$$-C_1' = 88{,}300\ Q_1^{-.866} \qquad (15)$$

Actually, for the case of the market power firm, a continuous approximation is probably more reasonable because the abatement strategy under consideration is the desulfurization of fuel oil or the purchase of lower sulfur residual fuel oil.

A similar graph for all other firms is shown in Figure 2 which illustrates the derived demand for permits at any given price. The continuous approximation to the discrete case takes the following form:

$$\sum_{i=2}^{m} Q_i(P) = 73 + 154{,}000/P. \qquad (16)$$

The demand curve is based on some discrete technologies such as scrubbers as well as some continuous abatement strategies such as the one mentioned above. The continuous approximation will be used for purposes of illustration. Note that the particular form used in (16)

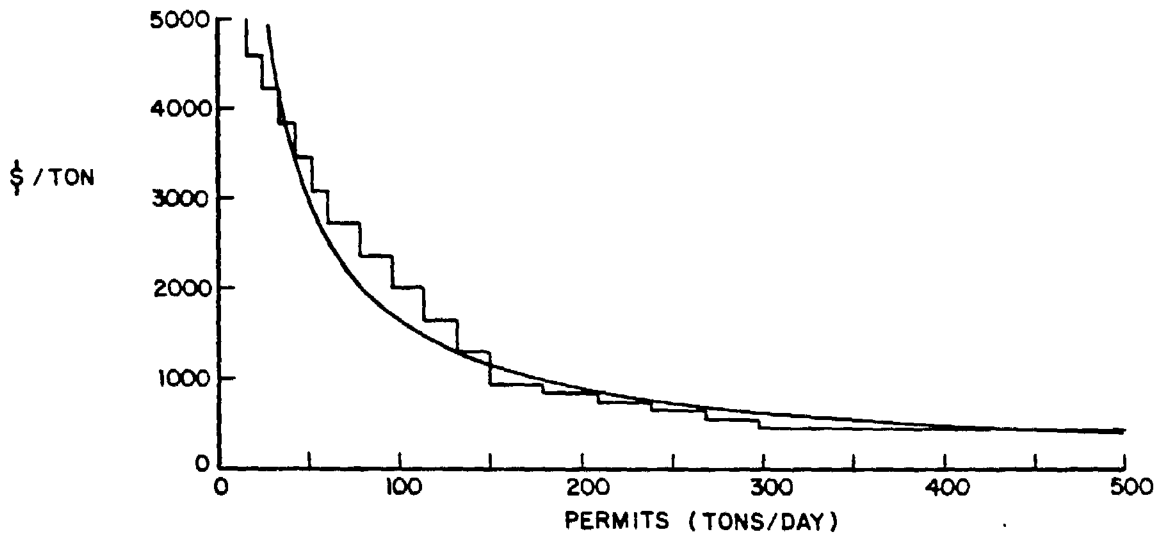

FIGURE 1

Marginal Abatement Costs for Market Power Firm

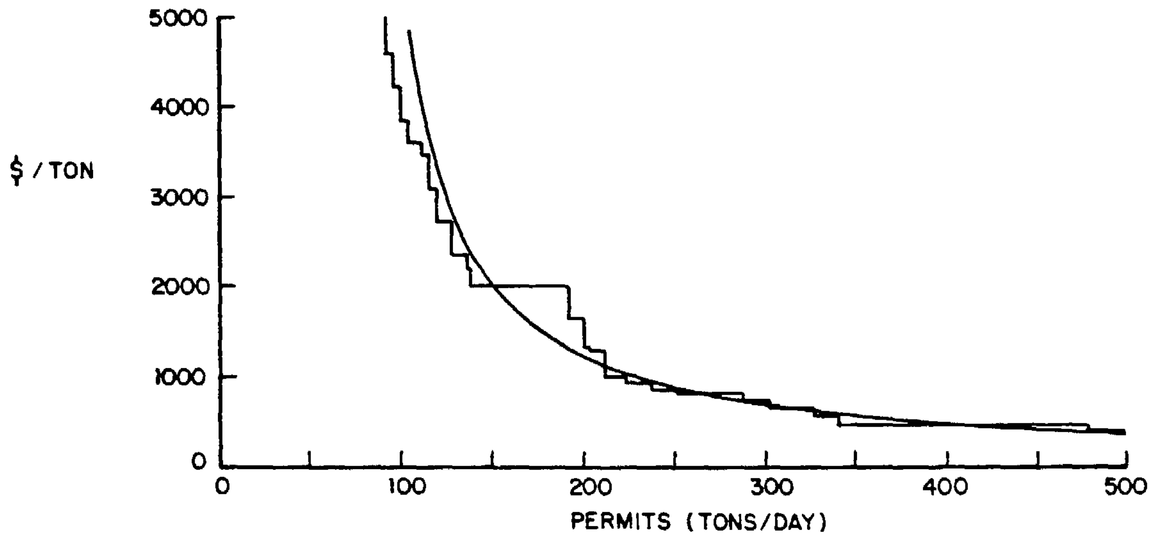

FIGURE 2

Derived Demand for Permits by All Other Firms implies that emissions by others will be at least 73 tons per day for all positive permit prices.

To compute how the initial distribution of permits affects prices, quantities and overall abatement, it is first necessary to select a value for the total number of permits. In this example the parameter L was set equal to 149 tons/day, an amount which will ensure that both state and federal standards related to sulfur oxides emissions and particulate sulfates will be met. Having chosen a value for L, it is possible to examine how permit use varies with initial distribution by substituting equations (15) and (16) into equation (4) and solving. The graphical solution to the problem is shown in Figure 3. Note that Q_1 increases as a function of Q_1^o until a corner solution is approached. This point corresponds to a permit distribution where all other firms receive an amount of permits that just equals their uncontrollable emissions. If all other firms receive an amount of permits that falls short of their uncontrollable emissions, then the relationship between Q_1 and Q_1^o is not unique. In this latter case, the market power firm can reap infinite rewards by exploiting the perfectly inelastic part of the demand curve.[8]

Prices vary widely as a function of the initial distribution of permits. The monopsony price is approximately 3200 dollars/ton while the competitive price, associated with $Q_1^o = 36$, is about 3900 dollars/ton.[9] When all other firms receive permits corresponding to their uncontrollable emissions, the price of a permit jumps to approximately 21,000 dollars/ton. The monopoly price, i.e., when

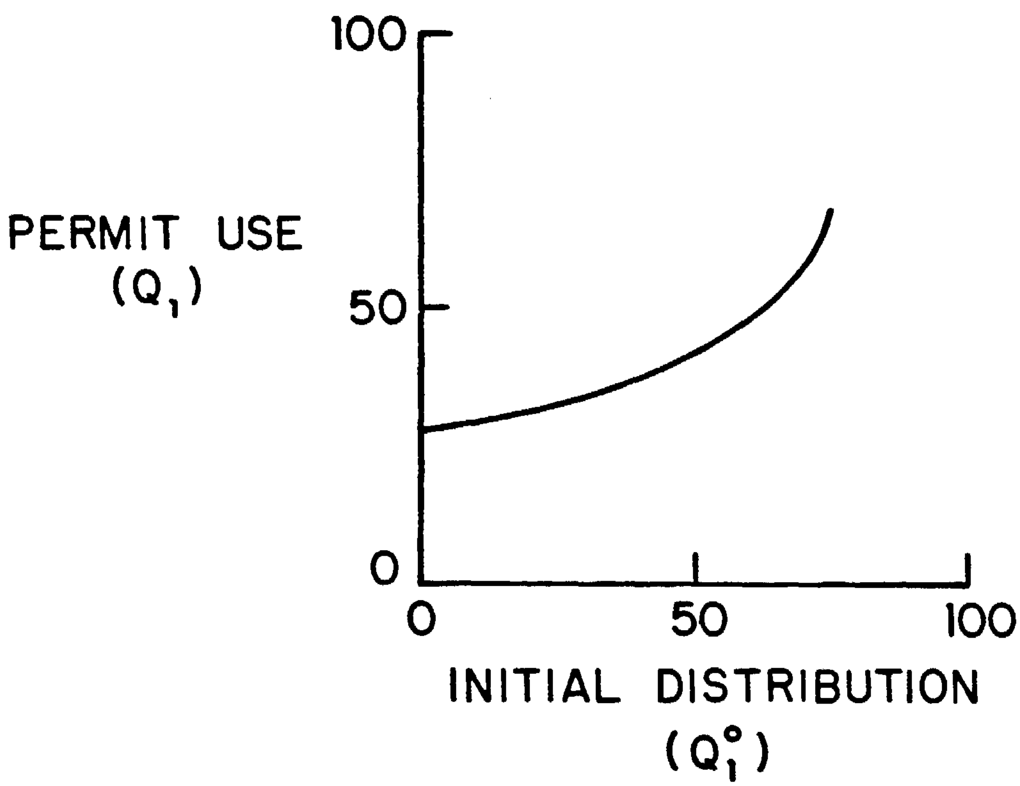

FIGURE 3

Permit Use vs. Permit Distribution--Market Power

$Q_1^o = L$, is not well defined both in theory and in practice—in theory, because (16) is a hyperbola with an asymptote, and in practice, because of insufficient information on the value of firms and possible technologies that might be available for controlling so-called uncontrollable emissions.

Given permit use as a function of the initial distribution of permits, it is then possible to estimate the total annual costs of abatement by integrating equations (15) and (16). The relationship between total annual abatement expenditures and the initial distribution of permits is shown in Figure 4. Note that abatement expenditures remain relatively constant (in the neighborhood of 490 million dollars annually) until the market power firm is able to exert some monopoly power when it receives permits in excess of 60 tons/day or so.

If the primary objective in setting up a market is to minimize total abatement costs, Figure 4 indicates that the policymaker should try to avoid a situation where the firm with market power can act as a monopolist. However, because of the uncertainty associated with the cost data, it makes sense to try to minimize the likelihood that a firm or group of firms will be able to induce a price-quantity equilibrium which departs from the competitive result in either direction. Alernatives for dealing with this issue are discussed in Hahn and Noll (1982). The theory developed in this paper indicates that the expected excess demand of each firm may be a critical variable over which the policymaker can exercise control.

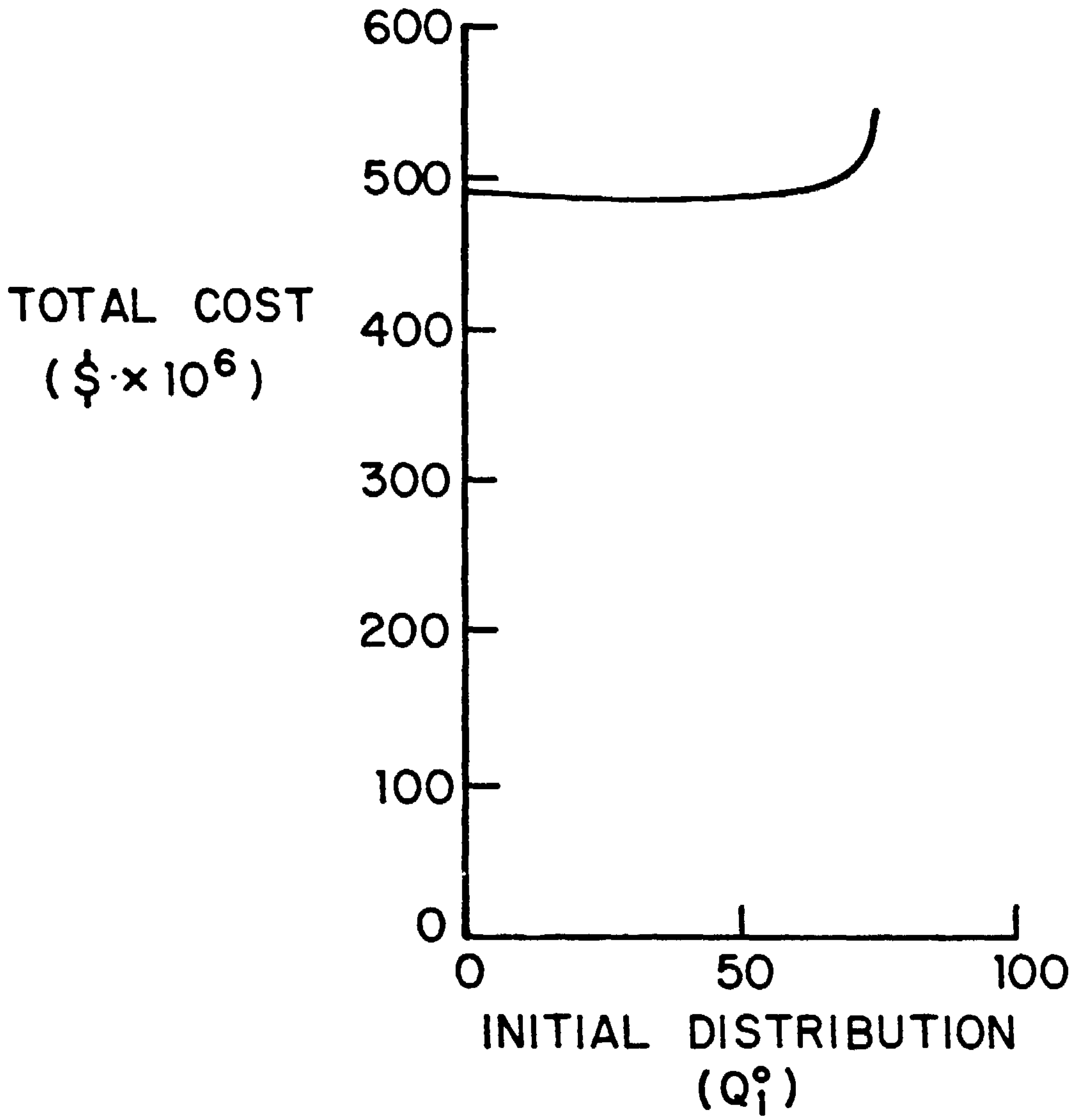

FIGURE 4

Total Annual Abatement Cost vs. Initial Distribution

4. Conclusions

The formal analysis in sections 2 and 3 indicates the range of potential outcomes that might arise when firms can exert rather specific types of influence in markets which ration a fixed supply of intermediate or final goods. There are clearly other strategies which large firms might pursue, particularly when the market is just getting under way. For example, it is quite likely that the total number of permits issued and the pattern of distribution could be affected by the behavior of such firms. In the case of pollution rights, some firms might refuse to play the game if they do not care for the new set of rules. Such actions are difficult to model explicitly, which is why the focus here has been on the potential for gain within a well-defined set of rules. Even within this setting, further research is warranted.

One avenue for further research would be to extend the basic model to the case where two or more firms have market power. Hahn (1981a) has examined this issue for the case of two firms with market power. The result on cost minimization and permit distribution (Proposition 1) was shown to generalize. A second potentially fruitful area of research would be to extend the model to more than one period along the lines of Stokey (1981), who considers a durable goods monopolist. Finally, it might be useful to test the theory of the basic model in a small-group expermental setting and determine when, and under what types of institutions, it is supported.

The key result obtained here, that it is the pattern of excess demands that ultimately determines the extent to which any firm can influence the market, does not appear to be widely recognized. One reason is that many people feel that manipulation of such markets will not be a problem. For example, Teitenberg (1980), in surveying the literature on air rights markets, expresses the view that "the anti-competitive effects of a TDP [transferable discharge permit] system are not likely to be very important in general."[10] For several applications such as the one considered by DeLucia (1974) and the one considered by Hahn (1981a), the assumption that the market will approximate the competitive solution would appear to depend critically on how the institutions are designed. Because there is a very real possibility that several markets in transferable property rights could be subject to different kinds of systematic manipulation, there is a need to further explore the ramifications of such problems in theory and applications.

Footnotes

* I would like to thank Jim Quirk, Roger Noll and Jennifer Reinganum for providing useful input to this effort. Any remaining errors are solely the responsibility of the author.

1. Teitenberg (1980) provides a comprehensive survey of the application of marketable permits to the control of stationary source air pollution. A general list of references to potential applications in air and water pollution is provided in the study by Anderson et al. (1979).

2. The assumption of increasing marginal abatement costs implies that the firm attains a regular minimum in solving the problem (6.1).

3. The analysis by Montgomery (1972) is one such example. In this analysis, firms are assumed to be price takers. For the case of one pollutant, one market and a linear relationship between source emissions and environmental quality, Montgomery finds that the distribution of permits will have no effect on achieving the target in a cost-effective manner.

4. Proposition 3 will also hold if $(Q_1 - Q_1^o) \geq (\leq)\ 0$ and $Q_i''' \geq (\leq)\ 0$.

5. See Ackerman et al. (1974), p. 279.

6. A more detailed discussion of the market power question can be found in Hahn (1981a), and Hahn and Noll (1982).

7. Further assumptions underlying the development of this data, such as the availability of natural gas, are discussed in Hahn (1981a).

8. In practice, such rewards would be limited by the decision of other firms to shut down operations.

9. All prices and costs are given in 1977 dollars.

10. Teitenberg (1980), p. 414.

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APPENDIX D

DESIGNING A MARKET IN TRANSFERABLE PROPERTY RIGHTS: A REVIEW OF THE EXPERIMENTAL EVIDENCE

Robert W. Hahn

A basic theme of the economics literature in the field of environmental regulation is that competition will work wonders. If firms can be induced to minimize pollution costs in the same way they naturally try to minimize the costs of using other inputs in the production process, the hope is that prescribed levels of environmental quality can be met using fewer resources than are employed currently. Whether or not this hope becomes a reality depends crucially on how the market or "institution" for controlling pollution is designed.

This paper reviews the available evidence on designing markets in transferable property rights. The first section offers a set of characteristics that we would like an institution to exhibit. The second section reviews the evidence on the design of institutions for dealing with related problems. The third section concludes with a brief discussion of one possible market design that looks promising.

1. Objectives

One of the critical problems in current trading schemes aimed at controlling pollution is that relatively little trading is taking place. One reason for this may be that the property right is not well defined. A second reason is that there may be a great deal of uncertainty about a "reasonable" price for the commodity. A consequence of the lack of trading is that information on prices is not readily available to participants in the market and potential entrants. This has the effect of raising the transactions costs associated with trading between parties. Indeed, this may be one of the reasons that, to date, more trades has occurred within individual firms than between firms.[1]

If a market is to be effective in promoting trading, it is important that a price signal be established at the outset. However, establishing a price signal is not, in itself, sufficient to warrant establishing a market. It is also necessary that the price be close to the competitive equilibrium so that the potential gains from efficiency can be reaped.

In establishing a market, issues of practicality also need to be addressed. One critical issue is the problem of potential wealth transfers. It is important that the institution under consideration be able to address questions of equity that are likely to arise.

To summarize, there are three basic objectives that will be considered in the initial design of an institution:

1. Establishing a price signal;
2. Approximating the least-cost solution over time;
3. Allowing for equity considerations.

This list is not meant to be exhaustive. Other issues such as the speed at which the price signal converges to an equilibrium and the robustness of the institution will need to be considered before informed policy recommendations can be developed.

2. The Evidence

Fortunately, there has been a large body of work devoted to the examination of how subjects actually behave under different institutions. This section reviews the empirical evidence which is pertinent to the design of a market in transferable property rights with the objectives set forth in Section 1. Before undertaking this task, it is useful to summarize the state of existing theory on the subject.

In theory, it is generally accepted that instruments such as taxes and marketable permits will lead to a cost-minimizing solution provided firms act as if they were price takers. A formal statement of the conditions under which the result holds is given by Baumol and Oates (1975). However, if firms do not act as if they were price takers, problems can arise. Implications of relaxing the price-taking assumption in the context of markets for transferable property rights have been explored by Hahn (1981).

While theory may be helpful as a guide in predicting behavior, it often arrives at different conclusions depending on the assumptions which are employed. Moreover, most theory in economics fails to provide a reasonable prediction of how markets will actually arrive at a particular equilibrium. Thus, it is useful to explore the workings of particular market institutions in practice.

There are two basic approaches that economists usually take in studying market phenomena. One is to examine historical data on the operation of markets which are similar to the institutions under consideration. In this regard, the study by Vivian and Hall (1981) and the recent study by the General Accounting Office (1982) provide useful information on attempts to move from command and control regulation to a market based approach in the field of air pollution. Unfortunately, however, one of the principal findings of both these studies is that, at present, such markets are not working very well. This leaves the task of trying to design an institution that might remedy some of the problems which have arisen.

The second approach that is taken to studying market phenomena is to examine institutions in a controlled experimental setting. In this approach, human subjects participate in an experiment with well defined rules and payoffs. Subjects are paid in cash. Smith (1976) provides the theoretical basis for this approach. Laboratory experiments attempt to capture the essence of the institution under study. Of necessity, they tend to simplify reality. Nonetheless, they can provide a useful check on the workings of different institutions. For if an institution does not meet its prescribed objectives in a simplified setting, it can hardly be expected to perform well in more complicated environments.

The experimental literature reveals important insights for designing a tradable permits scheme. The contributions fall into three areas: testing the theory of externalities, testing the theory of derived demand and identifying institutions which may be susceptible to manipulation.

Plott (1977) has tested the theory of externalities in the context of using both taxes and marketable permits. A key finding was that markets behave in accord with the competitive model. Applying a tax reduced the equilibrium price and quantity while using a marketable permit approach had a similar effect. Both markets exhibited high levels of efficiency.

The above study by Plott and another study conducted by Plott and Uhl (1981) provide a test of the theory of derived demand. In the externalities study, the transferable rights experiment is conducted with a primary market and a secondary market for licenses. Agents desiring to own units in the primary market must also cover themselves in the license market. In the study by Plott and Uhl, the authors examine how middlemen between buyers and sellers affect the equilibrium that is achieved. The middlemen may be viewed as entrepreneurs who operate in a market for inputs as well as a market for outputs. This theory is relevant to the case of marketable permits because pollution can be viewed as an input to the production process. The demand for any input is based on the demand for the product it produces, and in that sense it is a derived demand. Both studies found that the prices and quantities converged to the results predicted by the competitive model.

The preceding experiments lend support to the view that externalities such as pollution can be controlled using market mechanisms. However, the specific structure of the market needs to be considered. The above results were based on the use of a double-oral auction similar to the one used on the New York Stock Exchange. It will be useful to know the type of situations where the market is likely to perform poorly. This question is very relevant to several potential markets in transferable discharge permits because of problems with market thinness and market concentration. The key results on market power are summarized below.

- o Experiments involving one seller and five buyers do not achieve the monopoly equilibrium; however, in some cases the competitive equilibrium is achieved (Smith (1981)).
- o Groups that conspire often make less than competitive profits. Prices and quantities do not seem to converge to the monopoly, monopsony or the competitive equilibrium (Smith (1981)).
- o In some markets, buyers can post bids on a take-it-or-leave-it basis. Smith (1981) has examined this institution for one seller and five buyers. He found that this institution can serve to limit monopoly power, but at the expense of achieving the competitive equilibrium.
- o Plott (1981) examined the posted pricing institution and found that, in general, it can induce higher prices.

The above findings on market power reveal two essential points. The first is that there are situations -- in this case with one buyers and five sellers -- that the market does not reach the competitive equilibrium. The second point is that the choice of institutions may be crucial in determining the type of equilibrium that is reached.

3. Market Design Issues

Having reviewed the relevant theory and experimental literature we are now in a position to address the problem of designing a market in transferable property rights for the particular problem at hand -- the control of sulfur oxides emissions in the Los Angeles airshed. Recall that the basic objectives are to design a market that will elicit a price signal, induce efficient abatement decisions and satisfy considerations of equity. One approach to the problem might be to distribute the permits to firms in some prescribed manner (e.g., grandfathering) and let them trade the permits as they see fit. The basic problem with this approach is that there is no guarantee that a quick price signal will be generated because firms might be hesitant to trade. A second problem with this approach is that grandfathering of permits could result in a situation where one firm would be the principal purchaser of permits while most remaining firms would be sellers of permits.

Hahn and Noll (1982) suggest one possible approach for dealing with these problems. Initially, each firm would receive a provisional allocation of permits, presumably based on considerations of equity. All sources would be required to offer their entire allocation for sale. An auction would then be held, where firms would report their demand curve for permits. The sum of the demand curves would be used to calculate the market-clearing price for a permit, and the final allocation of permits to firms. Firms would make a gross payment to the state equal to the market price times their final allocation, and would receive a gross revenue from the state equal to the market price times their initial allocation. This auction mechanism ensures that the proceeds from the auction are completely redistributed to the participants so that the net financial effect on all firms taken together is zero.

The idea of returning some or all of the proceeds of an auction to the participants in the auction has been tried in several settings. For example, Plott (1977) uses a lump-sum transfer in testing the tax mechanism in his externalities paper. What is new, to our knowledge, is the proposed mechanism for redistributing revenues. This is why some further experimentation is in order.

Whether such an auction will work in practice remains to be seen. However, there is some reason to be optimistic. For example, Miller and Plott (1980) examined a multiple unit first price auction and found that the result converged to the competitive equilibrium and was demand revealing. However, the Miller and Plott result did not use provisional allocations. Further research will be necessary to determine if the use of provisional allocations induces firms to manipulate the market.

4. The Experimental Design

To test the properties of an auction that returns the proceeds to the buyers, a small group experiment was designed that captures its essential features. The instructions to the subjects are included at the end of this paper, and provide a complete explanation of how it works. In this experiment, subjects are given a list of possible equilibrium prices, and are asked to write down the quantity demanded of a fictitious commodity at each price. The fictitious commodity is then redeemable from the experimenters according to a schedule of payoffs that is provided to the subject. By varying the schedule of payoffs, different market structures can be created. This enables the experimenter to test the conditions under which the experimental institution produces a competitive equilibrium.

The experimental institution differs from one that would be used in practice in only one major detail. In the real world, participants in the auction would write down their demand curves (e.g., price and quantity pairs of their own choosing), not only quantities on a schedule of predetermined alternative prices. The reason for this design change is that instructing subjects in how to express demand functions — that is, how price and quantity vary together -- is considerably more difficult and time consuming than the procedure followed in the experiment. Although there is no reason to believe that this change in the procedures would affect the outcome of the institution, it is conceivable that it might: strange things do occasionally emerge in experimental markets that lead experimenters to revise their definitions of equivalent institutional forms.

The experiment described in the instructions has been tested in pilot trials, with payoffs structured to produce both monopsonistic and competitive outcomes. In the former case, four subjects were used, but one accounted for more than eighty-five percent of the market and was the only net buyer of permits. This did not produce the competitive result, but a price that was considerably below it. The experiment was discontinued after six rounds and there was no price convergence.

In the second pilot, eight subjects participated in an experiment which lasted ten periods. Each subject received the same redemption value schedule. The horizontal aggregation of these schedules is shown in Figure 1 along with the vertical supply constraint. The competitive equilibrium price was 500. The only parameter which differed across subjects was the initial allocation. Four subjects received an initial allocation of 100 units and four received 150 units. By design, the total initial holdings of 1000 just equaled the quantity for sale in each period.

The results of the auction are summarized in Figure 2 and Table 1. Figure 2 shows the equilibrium time path of prices. Price is equal to the competitive equilibrium in seven of the ten periods. In periods 5 and 6, price falls below the competitive equilibrium. This fall is largely a result of the decision of one subject to submit purchase commitments of zero over a range of prices.

Table 1 provides a measure of the efficiency of the auction. The measure used is the total earnings divided by the total possible earnings. The ratio is constrained to be greater than or equal to zero and less than or equal to one. It would equal one in the case that all subjects truthfully reveal their demand. Table 1 reveals that the efficiencies are greater than or equal to .89 in all periods.

These preliminary results are encouraging. In future experiments, we plan to test the robustness of the institution by varying demands and initial allocations, and by using the actual data from the estimation of the derived demand for sulfur oxides emissions in the Los Angeles airshed.

TABLE 1

EFFICIENCY RESULTS

Period:	1	2	3	4	5	6	7	8	9	10
Efficiency	.90[a]	1.00	1.00	.98	.89	.89	.99	1.00	1.00	1.00

[a]Figures rounded to nearest hundreth.

Figure 1

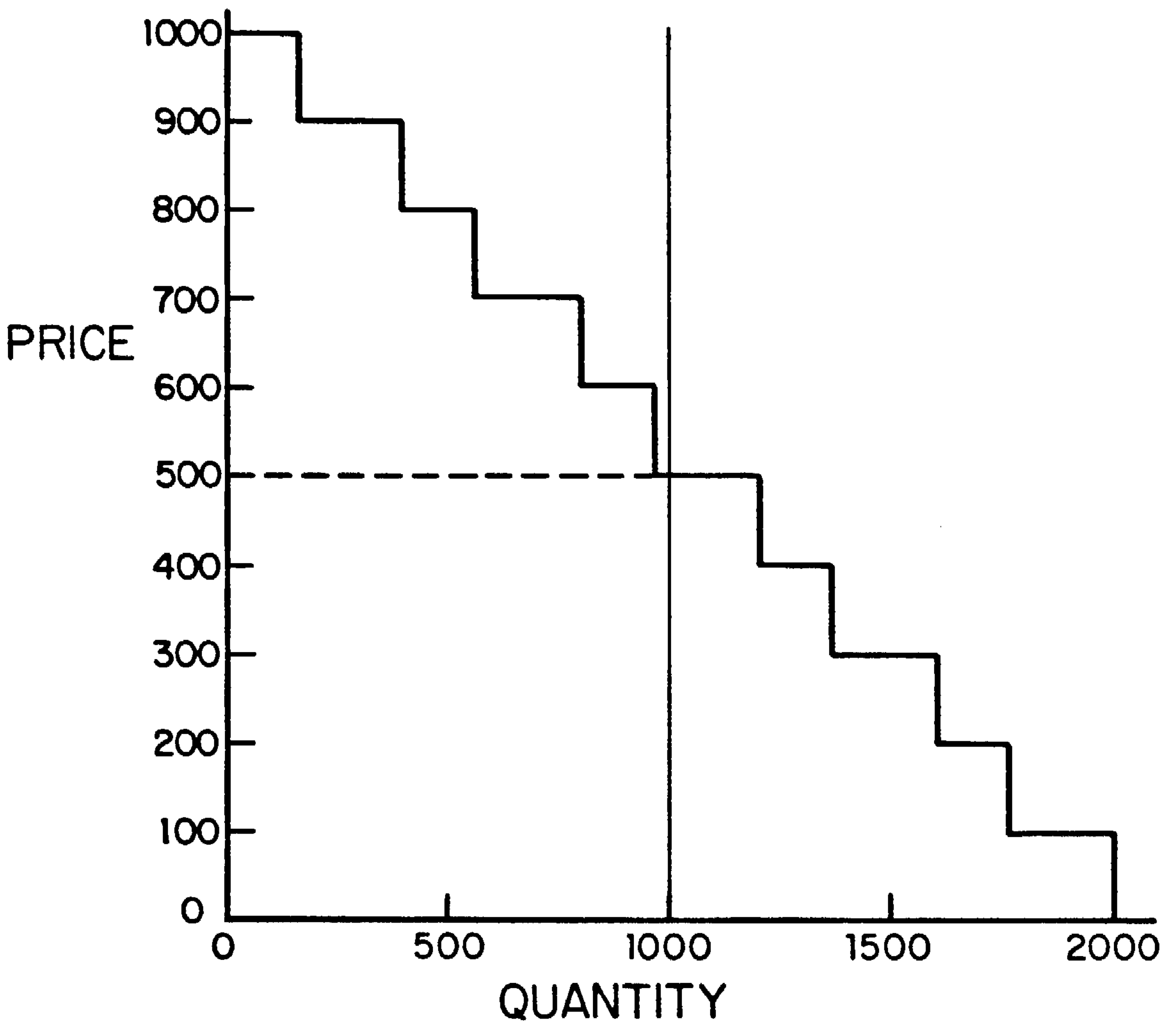
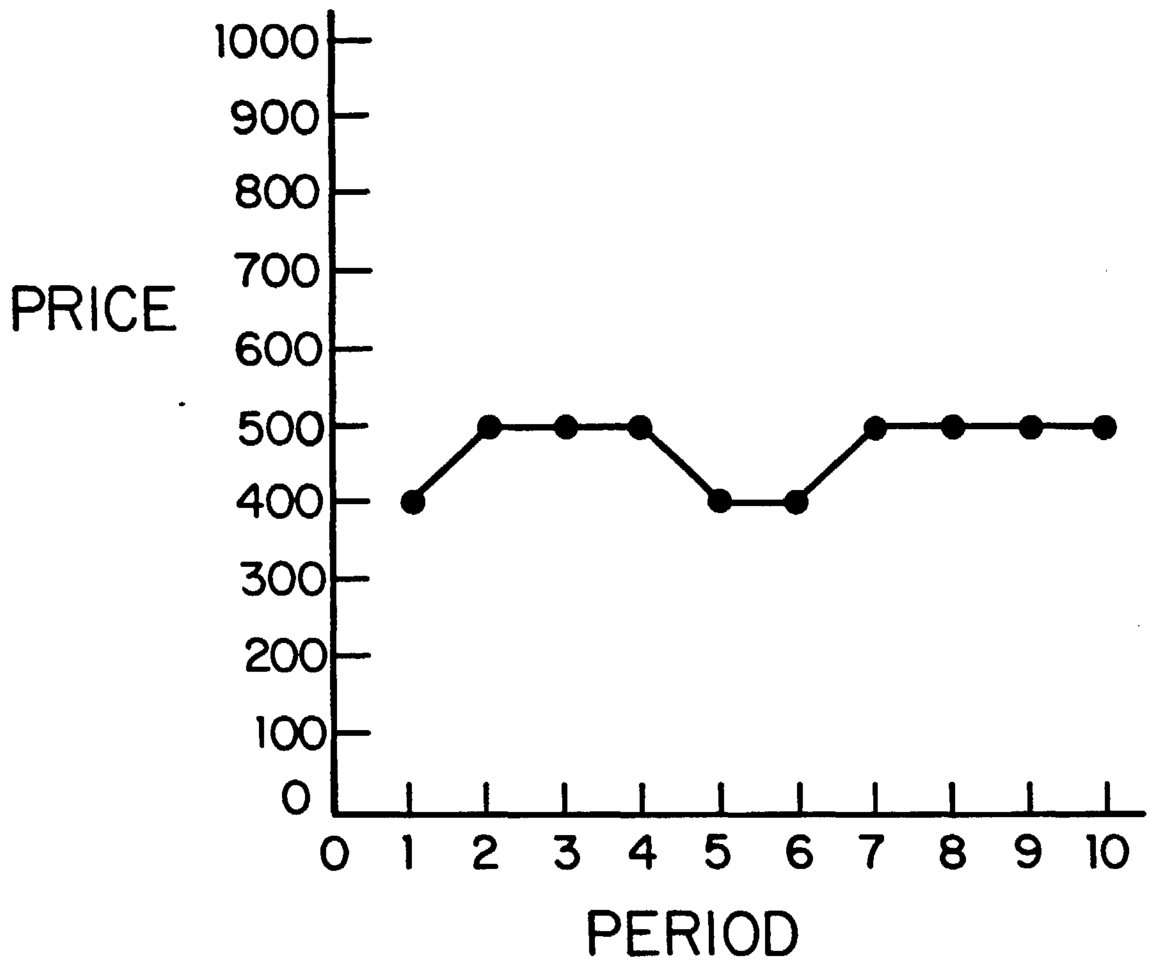

1000
900
800
700
PRICE
600
500
400
300
200
100
0
0
500
1000
1500
2000
QUANTITY

Figure 2

Equilibrium Time Path of Prices



FOOTNOTES

1. Current issues faced in the trading of air pollution emission reduction credits are spelled out clearly in the recent GAO report (1982). One approach to dealing with the problem of insufficient trading has been suggested by Foster and Weiss (1981).

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INSTRUCTIONS

GENERAL

This is an experiment in the operation of markets. Various research foundations, government agencies and corporations have provided funds for this research. The instructions are simple, and if you follow them carefully and make good decisions, you can earn a considerable amount of money. Your earnings in the experiment will be paid to you in cash at the end of the experiment.

In this experiment you will be given the opportunity to earn money in two ways. First, you will be given the opportunity to purchase a product that is redeemable in cash at the end of the experiment. Second, you will be given an initial holding of the same product which also will be redeemed in cash. The market will be repeated several times in a sequence of trading periods.

Your earnings will be calculated on the basis of your personal information sheets. The sheets may differ among the participants in the experiment. Your sheet contains your own personal, private information. <u>You must not reveal this information to anyone</u>.

YOUR PROFITS

During each trading period you can earn profits from your participation. These profits will be the sum of the following: your earnings from purchases and your income from selling your initial holdings. That is:

Profits = Earnings from Purchases + Sales of Initial Holdings

Each of the sources of profits is described below.

<u>Earnings from Purchases</u>

During each trading period you may make commitments to buy an amount of the product at each of several possible final prices. How you make these purchasing commitments is described below. The earnings from each purchase (which are yours to keep) are the difference between the redemption value and the purchase price of the purchased unit. In each period all of the units that you purchase will have the same price, but they may have different redemption values. For each unit that you purchase, your net earnings will be calculated as:

Earnings = Redemption Value - Purchase Price.

Your total earnings for a trading period will be the sum of the net earnings for all units that you purchase.

Table 1 shows the redemption value of your units for each period. To see how Table 1 is used, consider the illustrative case shown on the board. The first unit purchased can be redeemed for $3; the second unit and the third unit can be redeemed for $2 each; and the fourth unit for $1.

Suppose that you buy two units at a price of $1.50. Your earnings are:

Earnings from 1st unit = 3.00 - 1.50 = $1.50
Earnings from 2nd unit = 2.00 - 1.50 = $ .50
Total earnings = $1.50 + $ .50 = $2.00

Sales of Initial Holdings

You will also receive an initial holding of the product that is being sold in the market. At the end of each trading period, your initial holding will be redeemed for cash. Each unit of the initial holding will be redeemed at the final market price of the product. For example, if your initial holding were three units and the final market price for the product were $1.50, your sales of initial holdings at the end of the period would be 3 x 1.50 = $4.50. Your initial holdings for each trading period are shown in Row (1) of Table 2.

Recording Your Profits

Table 2 is for recording your profits and your transactions in the market. When the final price and your purchase commitment are determined, write them on Row (2) and Row (3) of Table 2.

The blanks on the table will help you record your profits. Table 3 will assist you in determining your earnings from purchases for various combinations of market price and quantity purchased. At the end of the period record your earnings from purchases on Row (4) of Table 1.

To compute your sales of initial holdings, multiply your initial holding shown in Row (1) by the price of a unit in Row (2). This figure is entered on Row (5). Profits are computed by adding Row (4) and Row (5). This figure is then entered on Row (6).

MARKET OPERATIONS

The market in which you will participate will be operated as follows. At the beginning of the trading period, the total amount of the product that is being offered for sale will be announced. The amount sold will exactly equal the total initial holdings of all of the participants in the market. Each participant, as described below, will submit commitments to purchase amounts of the product at each of several possible final prices. On the basis of these commitments, a final price will be calculated. This will be the lowest possible price at which the purchase commitments of all the participants exactly equal the amount being offered for sale. Each participant will then receive a quantity of the product equal to the amount he or she committed to buy at that price. The profits of all the participants will then be calculated.

At the end of the last trading period you will present your personal record forms to the experimenter. Your personal profit calculations will be verified, and you will be paid in cash the profits that you have earned.

You are not to reveal your bids or profits to any other buyer, nor are you to talk to other buyers during the experiment. Are there any questions?

Table 1

Redemption Values, Buyer No. ______

Redemption Values for <u>ALL</u> Trading Periods

Units	Redemption Value (in $\$2.4 \times 10^{-5}$)/unit
1-20	1000/unit
21-50	900
51-70	800
71-100	700
101-120	600
121-150	500
151-170	400
171-200	300
201-220	200
221-250	100

Table 1

Redemption Values, Buyer No. _______

Redemption Values for ALL Trading Periods

Units	Redemption Value (in \$1.8 x 10^{-5})/unit
1-20	1000/unit
21-50	900
51-70	800
71-100	700
101-120	600
121-150	500
151-170	400
171-200	300
201-220	200
221-250	100

TABLE 2

Market Record, Buyer No. 8

	TRADING PERIOD NUMBER	1	2	3	4	5	6	7	8	9	10		
1	INITIAL HOLDINGS	150	150	150	150	150	150	150	150	150	150		
2	FINAL PRICE												
3	QUANTITY PURCHASED												
4	EARNINGS FROM PURCHASES												
5	SALES OF INITIAL HOLDINGS												
6	PROFITS ($\$1.8x10^{-5}$)												

Name____________________ Social Security No.____________

Address____________________________

Total Payment________________________

TABLE 3

Earnings from Purchases for Selected Prices and Quantities, Buyer No. 1-8

PRICES \ NUMBER OF UNITS	20	50	70	100	120	150	170	200	220	250		
1000	0											
900	2000	2000	0									
800	4000	7000	7000	4000	0							
700	6000	12000	14000	14000	12000	6000	0					
600	8000	17000	21000	24000	24000	21000	17000	8000	0			
500	10000	22000	28000	34000	36000	36000	34000	28000	22000	10000		
400	12000	27000	35000	44000	48000	51000	51000	48000	44000	35000		
300	14000	32000	42000	54000	60000	66000	68000	68000	66000	60000		
200	16000	37000	49000	64000	72000	81000	85000	88000	88000	85000		
100	18000	42000	56000	74000	84000	96000	102000	108000	110000	110000		

TABLE 2

Market Record, Buyer No. 1

TRADING PERIOD NUMBER		1	2	3	4	5	6	7	8	9	10		
1	INITIAL HOLDINGS	100	100	100	100	100	100	100	100	100	100		
2	FINAL PRICE												
3	QUANTITY PURCHASED												
4	EARNINGS FROM PURCHASES												
5	SALES OF INITIAL HOLDINGS												
6	PROFITS ($\$2.4 \times 10^{-5}$)												

Name____________________ Social Security No.____________

Address______________________________

Total Payment________________________

TABLE 4

Commitment Sheet* Buyer No. _____

TRADING PERIOD NUMBER / PRICES	1	2	3	4	5	6	7	8	9	10		
1000												
900												
800												
700												
600												
500												
400												
300												
200												
100												

*You may only bid for units at the prices stated on the Commitment Sheet.

TABLE 5

Total Profits* for
Selected Prices and Quantities, Buyer No. 1-4

PRICES \ NUMBER OF UNITS	20	50	70	100	120	150	170	200	220	250		
1000	100000	97000	93000	84000	76000	61000	49000	28000	12000			
900	92000	92000	90000	84000	78000	66000	56000	38000	24000	0		
800	84000	87000	87000	84000	80000	71000	63000	48000	36000	15000		
700	76000	82000	84000	84000	82000	76000	70000	58000	48000	30000		
600	68000	77000	81000	84000	84000	81000	77000	68000	60000	45000		
500	60000	72000	78000	84000	86000	86000	84000	78000	72000	60000		
400	52000	67000	75000	84000	88000	91000	91000	88000	84000	75000		
300	44000	62000	72000	84000	90000	96000	98000	98000	96000	90000		
200	36000	57000	69000	84000	92000	101000	105000	108000	108000	105000		
100	28000	52000	66000	84000	94000	106000	112000	118000	120000	120000		

*Total Profits = Earnings from Purchases + Sales of Initial Holdings. Cells that are left blank correspond to profits that are less than zero.

APPENDIX E

THE SULFUR OXIDES EMISSIONS POTENTIAL OF THE SOUTH COAST AIR BASIN IN THE EARLY 1980s

Glen R. Cass

E1.1 Introduction

This appendix provides an estimate of the potential for sulfur oxides emissions from sources located in the central portion of the South Coast Air Basin in the early 1980s. That inventory will serve as the base case against which emission control strategies for improving sulfate air quality in that airshed will be tested.

The approach taken here is not to try to predict the actual SO_x emission rate for a particular future year. The actual level of sulfur oxides emissions in the Los Angeles area in any given year is a strong function of the level of natural gas supply. When natural gas is plentiful, most stationary combustion sources burn gas rather than sulfur-bearing fuel oil, and SO_x emissions are relatively low. Conversely, in years with a poor natural gas supply, several hundred additional tons per day of SO_2 are emitted from residual and distillate oil combustion. Natural gas supplies have been observed to fluctuate widely in response to Federal regulations that are beyond the control of state and local pollution abatement authorities. Hence the actual level of SO_x emissions in any particular year is not readily forecast, and any abatement plan that is inflexible to the point of requiring a firm emissions forecast is liable to fail dramatically.

Instead, the approach taken here is to develop a spatially and temporally resolved inventory of the potential for sulfur oxides emissions as they would occur under conditions of low natural gas supply. This inventory forms a realistic estimate of the upper limit on SO_x emissions in Los Angeles in the early 1980s. From this base case, emissions rates that would prevail in the presence of any arbitrary level of natural gas supply can be quickly constructed by attenuating the SO_x emissions from fuel burning sources in proportion to the additional gas supply contemplated.

Computations in this appendix will proceed under the assumption that fuel combustion trends and SO_x emissions control practices apparent in 1977 were continued unaltered into the future. As should be surmised from the above discussion, we do not expect that this, in fact, will occur. In particular, additional sulfur oxides emissions control measures are under active consideration at the present time (South Coast Air Quality Management District, 1978a). Some of these control measures undoubtedly will be adopted while others will be modified as the public hearing and review processes proceed. Instead of trying to anticipate the eventual outcome of that debate, we will attempt to adopt a format for emissions projection which will permit an easy cross-reference between this study and other concurrent efforts.

A basic starting point will be taken which is similar to that assumed by the South Coast Air Quality Management District (1978a) emissions forecast. New emission control measures agreed upon or adopted prior to January 1978 will be assumed to be implemented in future years. Emissions from all other sources not affected by recent changes in regulations will be projected into the early 1980s assuming that trends apparent in 1977 remain unchanged into the near future.

E1.2 Methodology

Appendix A2 of the study by Cass (1978) presented a spatially and temporally resolved SO_x emissions inventory for the central portion of the South Coast Air Basin during each month of the years 1972, 1973, and 1974. That emissions inventory was projected into early 1980s, while maintaining nearly the same organization of sources into groups of like equipment. Major point sources and dispersed area-wide sources of sulfur oxides were assigned to appropriate locations within the 50-by-50 mile square grid shown in Figure E1.1. Major equipment items located beyond that grid system were itemized separately, while small off-grid area sources were neglected as before.

A base case level of natural gas supply to Southern California was selected, based on an analysis of utility system forecasts and other stated assumptions. Then electricity generation plans were obtained on a unit-by-unit basis from major electric utilities in the air basin. Fuel use needed to generate those quantities of electrcity were computed. From that fuel use estimate, electric utility SO_x emissions estimates were derived.

A forecast of total thermal energy consumption by refinery and industrial fuel burners next was made on a spatially resolved basis for the early 1980 s. Then the natural gas supply forecast was used to estimate the level of fuel oil and refinery gas consumption required to meet that industrial energy demand under conditions of low natural gas supply. SO_x emissions were then computed from fuel use as before.

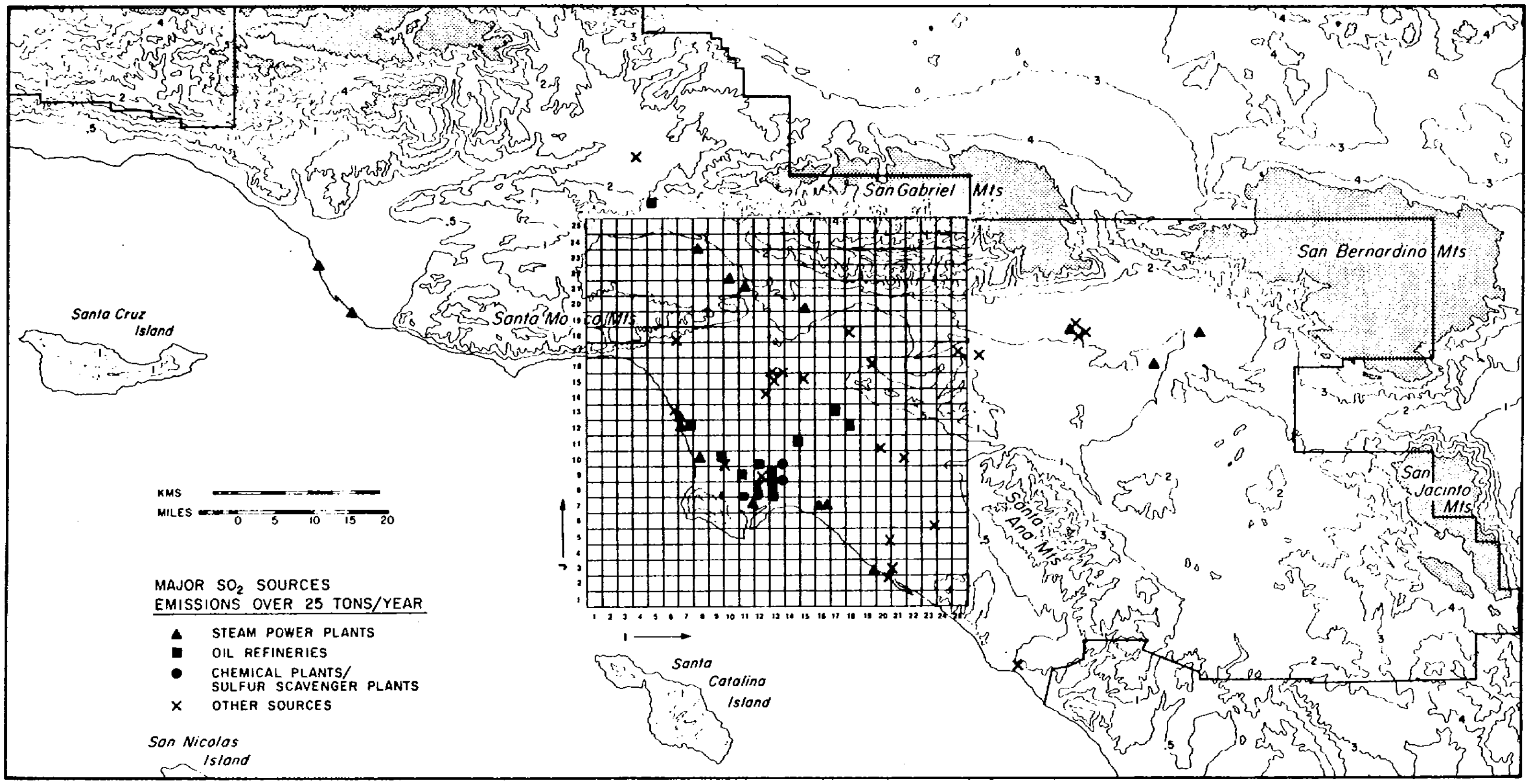

Figure E1.1

The Central Portion of the South Coast Air Basin Showing the Grid System Used

Industrial process SO_x emissions estimates for the early 1980s were obtained by personal interview with South Coast Air Quality Management District engineers. An equipment list compiled from the historical emissions inventory of Appendix A2 of the study by Cass (1978) was used as a check list for this interview procedure. Each item of equipment emitting over 25 tons of SO_x annually was reviewed to determine if it was still in operation, if its emissions were expected to be impacted by regulations or consent agreements adopted prior to January 1978, or if an improved estimate of future emissions could be made.

Finally, mobile source emissions data were updated. A freeway and surface street traffic growth survey was used to forecast 1980 traffic volumes on a spatially resolved basis. Then highway traffic was subdivided into catalyst-equipped and non catalyst-equipped gasoline-fueled vehicles, plus diesel trucks and buses. Fuel combustion estimates for railroads, ships, and aircraft were projected to the early 1980's based upon conversations with transportation industry personnel.

Thirty-six consecutive monthly emissions estimates were made for each source type of interest for each month of three test years. These three years of projected emissions data will later be matched with three different years of meteorological data so that a range of air quality possibilities can be examined using the air quality simulation model of Chapters 3 and 5 of the study by Cass (1978). Meteorological data taken from the years 1972 through 1974 form an attractive set of test conditions. Those years contain two instances of typical weather conditions leading to high summer sulfates and low winter sulfates (as in 1973 and 1974), plus one counter example yielding high winter sulfates with low summer sulfates (as in 1972). In order to capture the interplay between weather conditions and fuel use, the seasonal variation in energy consumption observed in those years was factored into the following emissions projections when appropriate.

E1.3 The Anticipated Level of Natural Gas Supply

The principal source of sulfur oxides emissions in the United States is from the combustion of sulfur bearing fossil fuels (U. S. Environmental Protection Agency, 1974). Historically, the cornerstone of the South Coast Air Basin sulfur oxides emission control strategy has rested on desulfurization of refinery gas, plus provision of a high level of natural gas supply to industry and electric utilities. Low sulfur oil was to be used only in the event that cleaner burning gaseous fuels became unavailable. This policy of promoting gaseous fuel use was so successful that in 1970, only about 21% of Los Angeles County SO_x emissions were derived from stationary source fuel combustion (Southern California Air Pollution Control District, 1976).

Since about the year 1970, natural gas deliveries to Southern California have steadily declined under the combined effects of interstate natural gas price regulations imposed by the Federal government, plus regulation-aggrevated declines in both gas exploration and new gas reserve accumulation. While the amount of energy needed to run the economy of the South Coast Air Basin might be projected from data given in the energy and sulfur balance portion of the study by Cass (1978; Appendix A3), emissions of sulfur oxides cannot be forecast without knowing the combination of gas and oil that will be available to meet that energy requirement. In order to address that issue with reasonable accuracy, reliable information must exist on whether the natural gas supply will continue to deteriorate or will improve.

Forecasts of future natural gas deliveries to southern California customers are prepared annually by the utility systems serving California (for example, see the 1977 California Gas Report). The Pacific Lighting Companies act as the largest purchasing agent for natural gas sold in southern California, and as such should be in the best position to know their distribution capabilities, customers' requests for service, and the supply of gas available to them from producer's around the world (including LNG). If they cannot forecast their own level of natural gas purchase more than a year or so in advance, then it would be unwise for us to place much faith in our ability to second guess their behavior more than a few years hence under the assumption that trends apparent in 1977 continued into the future.[1]

Figure E1.2 provides a comparison of forecast natural gas deliveries to southern California[2] prepared by California utilities at three

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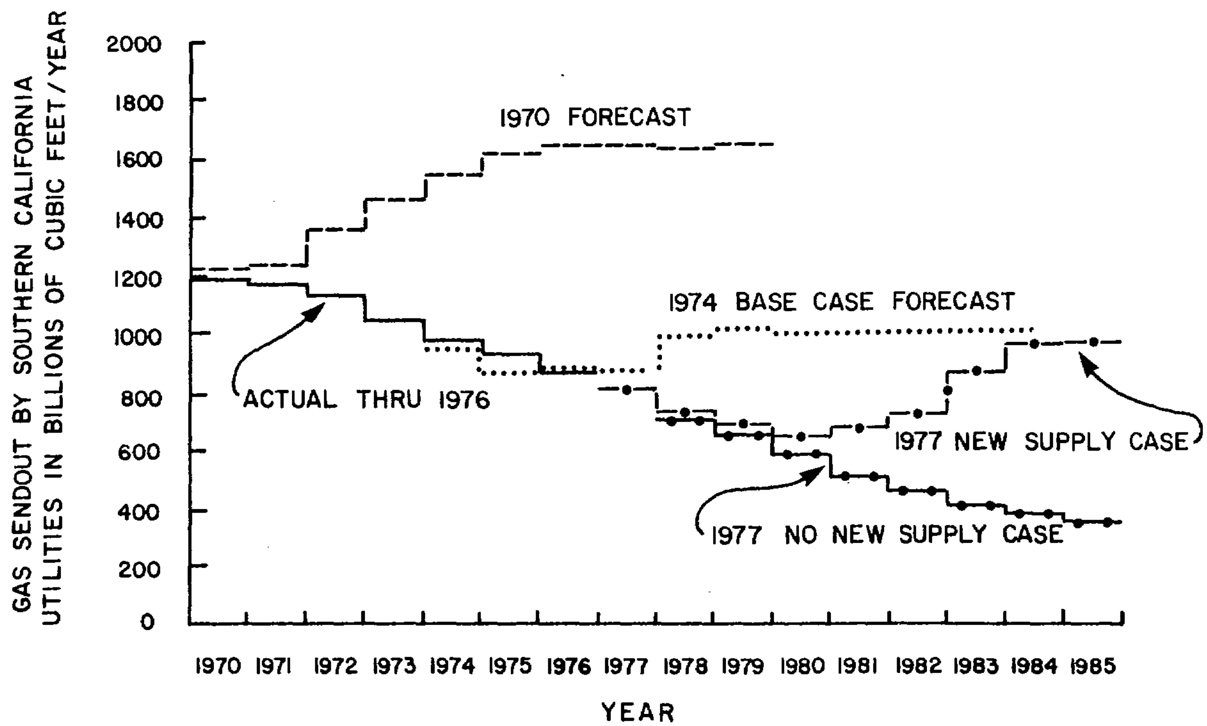
[1]This problem is distinct from our ability to assess the <u>opportunities</u> for natural gas supply. While we might be able to make rather strong statements about what gas supplies could be made available in future years, we might not be able to forecast what will happen if events are left to unfold along their present course.

[2]Not the South Coast Air Basin, but rather all of California south of the Pacific Gas and Electric service area.

SOUTHERN CALIFORNIA NATURAL GAS SUPPLY FORECASTS

COMPARISON OF UTILITY INDUSTRY NATURAL GAS DELIVERY FORECASTS MADE DURING THE 1970's



SOURCE: CALIFORNIA GAS REPORT 1970, 1974, and 1977 Editions

Figure E1.2

different times during the 1970s (California Gas Report, 1970, 1974, and 1977 editions). The 1970 forecast contained a prediction for steady growth in natural gas deliveries, reaching a level of greater than 1.6 trillion cubic feet per year in 1979. Instead, actual gas deliveries began an almost immediate decline. The 1974 forecast tended to show a short-term decline followed by a subsequent recovery of gas supply to 1974 levels. By 1977, however, the forecast for a quick recovery was abandoned in favor of continued decline in gas deliveries until at least 1980. From 1980 forward, two forecasts diverge. The "new supply" case which anticipates completion of several international supply projects shows recovery to 1974 levels by 1985, while the "no new supply" case projects a continued decline into the future. About the only trend common to more than one of these forecasts is that a lower bound to gas supply is provided by the extension of the 1970 through 1976 actual delivery line through to the 1977 "no new supply" case. A crosssection taken through all forecasts at the year 1979 indicates a divergence between forecasts made at seven-year intervals which is larger than the amount of gas now expected actually to be delivered in 1979.[3] The inference must be that any seven-year forecast prepared in this manner should be treated as a possibility

[3] That is, a 1970 forecast of greater than 1.6 trillion cubic feet delivered in 1979, a 1974 forecast for about 1.0 trillion cubic feet in 1979, and a 1977 forecast for less than 0.7 trillion cubic feet in 1979.

to be encouraged or discouraged as one sees fit, but should not be relied upon as a given. On the other hand, the utility forecaster's track record over a two-to-three year time period following the date of a particular forecast is not too bad.

With the above discussion in mind, natural gas supply conditions in Southern California during the early 1980s will be represented not by a forecast that one expects will actually happen but rather by a case which falls within the range of the forecasts shown in Figure E1.2, and which has public policy implications so important that that case should be examined closely. The level of gas service chosen for study corresponds to a gas delivery rate of 0.655 Tcf per year to Southern California. At that level of service in 1980, all high priority gas customers with no capability to use alternate fuels (California Public Utilities Commission priority groups 1 and 2A, plus underground injection) would receive service equal to 100% of their natural gas requirements. All other industries and electric utilities with alternate fuel capability would have their service almost completely curtailed (1977 California Gas Report, Table 1b-sc).

That level of natural gas service is chosen as the base case for our study for several important reasons. First, it corresponds to utility estimates for natural gas supply in the early 1980s at a time when the "new supply" and "no new supply" cases are nearly identical. Secondly, it represents an approximate average between the "new supply" and "no new supply" forecasts during the remainder of the first half of the 1980s. Most importantly, it represents the maximum amount of natural gas curtailment possible before small customers and thus the local economy would become seriously damaged financially. As such, it represents the point at which the California Public Utilities Commission would probably intervene to protect small customers by transferring gas from Northern to Southern California. In that case, the supply forecast is reinforced on its lower bound.

An air pollution control strategy predicated on this low level of natural gas supply in the early 1980s need not be inconsistent with actions that would be taken if the more optimistic "new supply" forecast in Figure E1.2 were to come to pass. Instead, the opportunity for new gas supplies should be viewed as a control strategy alternative. Determination of the air quality consequences in the absence of new gas supplies may well improve the chances that new supply projects will be completed.

E1.4 Stationary Source Fuel Combustion Estimates for Individual Sources Under Conditions of Low Natural Gas Supply

The source classes used to represent stationary source fuel combustion are:

- Electric Utility Steam Generators (residual oil fired)
- Electric Utility Combustion Turbines and Combined Cycle Generators (distillate oil fired)
- Petroleum Refineries
- Other Low Priority Natural Gas Customers (Priorities 2B, 3, and 4)
- High Priority Natural Gas Customers (Priorities 1 and 2A).

E1.4.1 Electric Utility Residual Fuel Oil Combustion

Eighteen separately inventoried electric generating stations within the South Coast Air Basin are listed in Table E1.1. Thirteen of these plant sites are located within the 50-by-50 mile square grid, while the remainder are off-grid sources whose emissions still will be entered into the air quality modeling calculations.

The Southern California Edison Company and the Los Angeles Department of Water and Power were contacted to determine the electrical generation load expected to be placed on South Coast Air Basin conventional steam plants in the year 1980. Utility personnel responded by furnishing expected capacity factors for each generating unit in the basin. Capacity factors represent the average percentage utilization of each generating unit's net electrical generation capability in a given year. In Tables E1.2 and E1.3, capacity factor forecasts are presented, and expected electrical generation at each location is computed from a knowledge of the size of each generating unit.

Information on the thermal efficiency of a given generating unit is stated in terms of its "heat rate." A plant's heat rate averaged over a year could be computed from the total number of BTU's of fuel consumed divided by net kwh of electricity produced. Table E1.4 provides heat rate data for South Coast Air Basin generating stations based upon 1976 actual performance. In general, the newest and largest generating stations show the lowest heat rates and thus the highest thermal efficiency.

TABLE E1.1

South Coast Air Basin Electric Generating Stations

Grid Square Location East/West I	Grid Square Location North/South J	Identification		County
ON-GRID		.13 Electric Generating Stations within the 50 by 50 mile grid		
7	12	SCE[b]	El Segundo Power Plant	Los Angeles
8	10	SCE	Redondo Power Plant	Los Angeles
12	7	SCE	Long Beach Power Plant	Los Angeles
16	7	SCE	Alamitos Power Plant	Los Angeles
19	3	SCE	Huntington Beach Power Plant	Orange
7	13	LADWP[c]	Scattergood Power Plant, El Segundo	Los Angeles
8	24	LADWP	Valley Power Plant, Sun Valley	Los Angeles
11	7	LADWP	Harbor Power Plant, Wilmington	Los Angeles
16	7	LADWP	Haynes Power Plant, Los Alamitos	Los Angeles
10	22	City of Burbank Power Plants		Los Angeles
11	21	City of Glendale Power Plant		Los Angeles
15	20	City of Pasadena - Glenarm		Los Angeles
15	20	City of Pasadena - Broadway		Los Angeles
OFF GRID		5 Electric Generating Stations located beyond the 50 by 50 mile grid		
-15	20	SCE	Ormond Beach	Ventura
-17	23	SCE	Mandalay	Ventura
32	19	SCE	Etiwanda	San Bernardino
38	16	SCE	Highgrove	San Bernardino
41	18	SCE	San Bernardino	San Bernardino

TABLE E1.2

. Mid-1977 Projection of 1980 Electrical Generation by Southern California Edison Company Conventional Oil-Fired Steam Plants in the South Costa Air Basin

Plant	Unit	Capacity (Megawatts) (a)	Capacity Factor (b)	Estimated Electrical Production (10^6 kwh/365 day year)
Alamitos	1	175	24.3	372.75
	2	175	24.3	372.75
	3	320	64.3	1,807.40
	4	320	64.3	1,807.40
	5	480	71.6	3,018.89
	6	480	71.6	3,018.89
El Segundo	1	175	24.3	372.75
	2	175	24.3	372.75
	3	335	64.3	1,892.12
	4	335	64.3	1,892.12
Etiwanda	1	132	8.5	98.56
	2	132	8.5	98.56
	3	320	64.3	1,807.40
	4	320	64.3	1,807.40
Highgrove	1	32.5	8.5	24.27
	2	32.5	8.5	24.27
	3	44.5	8.5	33.23
	4	44.5	8.5	33.23
Huntington Beach	1	215	58.6	1,106.70
	2	215	58.6	1,106.70
	3	215	58.6	1,106.70
	4	225	58.6	1,158.17
Long Beach	(a)	100	8.5	74.5
Mandalay	1	215	58.6	1,106.70
	2	215	58.6	1,106.70
Ormond Beach	1	750	69.2	4,558.90
	2	750	69.2	4,558.90
Redondo Beach	1	74	8.5	55.25
	2	74	8.5	55.25
	3	70	8.5	55.25
	4	74	8.5	55.25
	5	175	24.3	372.75
	6	175	24.3	372.75
	7	480	71.6	3,018.89
	8	480	71.6	3,018.89
San Bernardino	1	63	8.5	47.04
	2	63	8.5	47.04

Notes:

(a) Cluster of old units
(b) Reference: Southern California Edison Company (1976)
(c) Reference: Southern California Edison Company (1977)

TABLE E1.3

Mid-1977 Projection of 1980-81 Electrical Generation by Los Angeles Department of Water and Power Conventional Steam Plants in the South Coast Air Basin

Plant	Unit	Capacity (Megawatts)	Capacity Factor	Estimated Electricity Production (10^6 kwh/365 day year)
Haynes	1	222	50.22	977.6
	2	232	67.37	1,370.3
	3	220	66.41	1,279.8
	4	227	70.43	1,398.5
	5	344	69.91	2,109.6
	6	344	77.90	2,350.5
Scattergood	1	179	31.01	485.9
	2	179	33.70	528.0
	3	309	76.14	2,060.3
Harbor	1	78.5	0	0
	2	78.5	0	0
	3	92	0.92	7.4
	4	92	2.14	17.3
	5	94	1.61	13.3
Valley	1	101	4.73	41.9
	2	101	3.27	28.9
	3	171	9.41	141.0
	4	160	29.43	412.5
Total		3,224	46.84	13,222.7

Reference: Los Angeles Department of Water and Power (1977).

TABLE E1.4

1976 Average Heat Rates for Southern California Edison and Los Angeles Department of Water and Power Conventional Steam Generating Stations in the South Coast Air Basin

	1976 Actual Heat Rate[a] (BTU/kwh)	1976 Oil Burned (10^6 BTU/Yr)	1976 Natural Gas (10^6 BTU/Yr)	Heat Rate Adjusted to All Oil Operation[b] (BTU/kwh)
Southern California Edison				
Alamitos	9,868	68,197,613	8,850,727	9,830
El Segundo	10,022	30,204,169	10,354,953	9,936
Ediwanda	10,101	30,862,690	9,529,807	10,020
Highgrove	13,997	383,999	287,543	13,794
Huntington Beach	9,974	21,832,079	10,374,217	9,865
Mandalay	9,815	13,351,131	4,322,416	9,734
Ormond Beach	9,754	56,764,209	1,245,721	9,747
Redondo Beach	10,235	48,373,537	9,681,465	10,177
San Bernardino	10,268	3,419,742	4,373,825	10,073
Los Angeles Dept. of Water & Power				
Haynes	9,564	62,211,510	4,900,723	9,540
Scattergood	10,129	6,632,475	10,204,564	9,919
Harbor	12,801	393,242	922,494	12,668
Valley	11,299	3,800,348	4,271,610	11,116

Notes: (a) Heat rate: $\frac{\text{total BTU's of fuel heating value consumed}}{\text{net kwh of electricity produced}}$

(b) Electrical generation using oil is estimated to be 3.5% more thermally efficient than using natural gas.

References: Southern California Edison (1976)
Los Angeles Department of Water and Power (1976).

Our chosen level of natural gas supply anticipates the case in which electric utilities receive negligible amounts of natural gas for boiler fuel. Therefore, the electrical generation forecasts of Tables E1.2 and E1.3 were converted into equivalent barrels of fuel oil burned annually using the heat rate data for all oil operation from Table E1.4, plus a knowledge of the energy content of utility fuel oil.

The results of these fuel oil combustion calculations are shown in Tables E1.5 and E1.6. Residual fuel oil consumption expected by the smaller municipal utilities of the Cities of Glendale, Burbank, and Pasadena are given in Table E1.7. A total of nearly 92 million barrels of residual fuel oil combustion is expected annually under these conditions. That figure compares closely with the South Coast Air Quality Management District's 1980 forecast of 93.6 million barrels of residual oil to be burned by electric utilities in Los Angeles, San Bernardino, Orange, and Ventura Counties (South Coast Air Quality Management District, 1978a).

Annual fuel burning estimates at each utility plant site were converted to average daily fuel use for each month of a three-year test period based upon the seasonal variation in total power plant fuel use observed during each of the years 1972 through 1974. That seasonal variation was computed from data given in Table A2.3 of Appendix A2 to the study by Cass (1978).

During the year 1973, utility residual fuel oil sulfur content was limited to 0.5% sulfur by weight, and utilities were observed to consume fuel oil with an average sulfur content of 0.44% sulfur by weight.

TABLE E1.5

Early 1980's Projected Residual Fuel Oil Use by Southern California Edison Conventional Steam Generating Stations in the South Coast Air Basin

Plant	Unit	Residual Fuel Oil Consumption (Barrels/Year)[b]
Alamitos	1	598,608
	2	598,608
	3	2,902,550
	4	2,902,550
	5	4,848,114
	6	4,848,114
El Segundo	1	605,064
	2	605,064
	3	3,071,371
	4	3,071,371
Etiwanda	1	161,605
	2	161,605
	3	2,963,521
	4	2,963,521
Highgrove	1	54,693
	2	54,693
	3	74,885
	4	74,885
Huntington Beach	1	1,783,606
	2	1,783,606
	3	1,783,606
	4	1,866,557
Long Beach		154,183[a]
Mandalay	1	1,759,921
	2	1,759,921
Ormond Beach	1	7,259,437
	2	7,259,437
Redondo Beach	1	91,859
	2	91,859
	3	91,859
	4	91,859
	5	619,740
	6	619,740
	7	5,019,252
	8	5,019,252
San Bernardino	1	77,410
	2	77,410
Total		67,771,336

Notes: (a) Heat rate for the older Long Beach conventional generating units assumed to be 12,668 BTU/kwh based upon data from small, old units at the LADWP Harbor Plant.

(b) SCE residual fuel oil energy content given as 6,121,080 BTU/bbl.

TABLE E1.6

Early 1980's Projected Residual Fuel Oil Use
by Los Angeles Department of Water and Power Conventional
Steam Generating Stations in the South Coast Air Basin

Plant	Unit	Residual Oil Consumption (Barrels/year)
Haynes	1	1,524,192
	2	2,136,458
	3	1,995,358
	4	2,180,425
	5	3,289,113
	6	3,664,548
Scattergood	1	787,671
	2	855,918
	3	3,339,863
Harbor	1	0
	2	0
	3	15,320
	4	35,817
	5	27,535
Valley	1	76,119
	2	52,502
	3	256,152
	4	749,381
Total		20,986,372

Notes: (a) LADWP Residual Fuel Oil energy content given as 6,118,849 BTU/bbl

TABLE E1.7

Early 1980's Projected Residual Fuel Oil Use by Glendale, Burbank, and Pasadena Conventional Steam Generating Stations

Plant Site	Residual Fuel Oil Consumption (barrels/year)
Pasadena	1,327,870
Glendale	817,600
Burbank	1,009,225
Total	3,154,695

Reference: McCrackin (1976)

In late 1977, the South Coast Air Quality Management District adopted Rule 431.2 which reduced the allowable sulfur content of utility fuel to 0.25% sulfur by weight. In order to maintain a safe margin for compliance with that regulation, we expect that fuel oil actually burned in the early 1980's would average 0.22% sulfur by weight.

Sulfur oxides emissions were estimated on a spatially resolved basis using the plant-by-plant fuel burning estimates of Tables E1.5 through E1.7, plus the following fuel oil properties:

Residual fuel oil gravity ....24° API

Residual fuel oil sulfur content ....0.22% by weight

Emission factor (lbs SO_x/barrel) ....6.384 times % sulfur

Projected sulfur oxides emissions from residual fuel oil use by electric utilities located within the 50-by-50 mile square are shown in Figures E1.2 and E1.3 for a typical summer month and typical winter month.

E1.4.2 Electric Utility Distillate Fuel Oil Combustion

Light distillate fuel oils are used to power peaking turbines and combined cycle generators. Table E1.8 shows capacity utilization and electric generation forecasts for Southern California Edison Company (SCE) distillate-fired generating equipment. While SCE's peaking turbine capacity is nearly as large as its Long Beach combined cycle plant, utilization of the peaking turbines is so intermittent that they are minor emission sources compared to the combined cycle facilities.

UTILITY RESIDUAL OIL SOX EMISSIONS IN THE EARLY 1980'S: JAN OF TEST YEAR 2 , IN TONS/DAY AS SO2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	9.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	13.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	59.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.5	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

RESEDA, BURBANK, GLENDALE, PASADENA, AZUSA, GLENDORA, WEST COVINA, WEST LA, LOS ANGELES, SANTA MONICA, LENNOX, LYNWOOD, TORRANCE, LONG BEACH, ANAHEIM, GARDEN GROVE, SANTA ANA

SOX
TONS/DAY
126.095

Figure E1.2

UTILITY RESIDUAL OIL SOX EMISSIONS IN THE EARLY 1980'S: JULY OF TEST YEAR 2 , IN TONS/DAY AS SO2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	10.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	15.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	68.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.7	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

RESEDA · BURBANK · GLENDALE · PASADENA · AZUSA · GLENDORA · WEST COVINA · WEST LA · LOS ANGELES · SANTA MONICA · LENNOX · LYNWOOD · TORRANCE · LONG BEACH · ANAHEIM · GARDEN GROVE · SANTA ANA

SOX
TONS/DAY
145.771

Figure E1.3

TABLE E1.8

Mid-1977 Projection of 1980 Electrical Generation by Southern California Edison Company Combined Cycle and Peaking Turbine Generators in the South Coast Air Basin

Plant and Type	Capacity (Megawatts)	Capacity Factor	Electricity Production (10^6 kwh/365 day year)
Combined Cycle			
Long Beach	581	54.12	2,754.5
Combustion Turbine			
Alamitos	121	1.11	11.77
Etiwanda	121	1.11	11.77
Huntington Beach	121	1.11	11.77
Mandalay	121	1.11	11.77

Notes: (a) Fuel use at Ellwood neglected

(b) Fuel use at Garden State included with industrial fuel inventory.

Reference: Capacity Factors from Southern California Edison (1977).

The electricity generation forecasts of Table E1.8 were converted into annual fuel burning estimates using heat rate data for those plants provided by the South Coast Air Quality Management District (Zwiacher, 1978). Estimated distillate fuel oil use by Edison Company facilities is given in Table E1.9.

Distillate fuel oil consumption estimates for the municipal utilities of the Cities of Glendale, Burbank, and Pasadena are difficult to confirm. The fuel use projections for these utilities given in Table E1.9 are based upon data furnished to the South Coast Air Quality Management District in 1976 (McCrackin, 1976) and may well be obsolete by now. However, fuel use at the Long Beach Combined Cycle Plant is seen to account for 82% of the estimated combustion of distillate oil by utilities. While fuel use estimates for the municipal utilities of Glendale, Burbank, and Pasadena are uncertain, the overall air quality impact of uncertainties in those emissions estimates is minor.

During 1977, the sulfur content of utility distillate fuel oil was subject to a legal limit of 0.5% sulfur by weight. However, most distillate turbine fuels have properties similar to kerosene-type jet fuel which has traditionally shown a sulfur content closer to 0.05% sulfur by weight (see Table A3.10 of Cass, 1978). Since the Long Beach Combined Cycle Plant clearly dominates utility distillate oil use, characterization of utility distillate fuel oils will be based in large part on observed behavior at the Long Beach generating station. According to Southern California Edison Company personnel (Bagwell, 1978), fuel oil specifications at the Long Beach Combined Cycle Plant call for

TABLE E1.9

Early 1980's Projected Distillate Fuel Oil Use by South Coast Air Basin Combined Cycle and Peaking Turbine Generators

Plant and Type	Electricity Production (10^6 kwh/yr) (d)	Heat Rate (BTU/kwh) (e)	Distillate Fuel Oil Consumption (bbl/yr)
Southern California Edison			
Combined Cycle			
Long Beach	2,754.5	9,144	4,442,178 (a)
Combustion Turbine			
Alamitos	11.7	14,100	29,269 (a)
Etiwanda	11.7	14,100	29,269 (a)
Huntington Beach	11.7	14,100	29,269 (a)
Mandalay	11.7	14,100	29,269 (a)
Glendale			817,600 (b)
Burbank			4,380 (b)
Pasadena			47,815 (b)
Total			5,429,049

Notes: (a) Computed from generating load forecast assuming that distillate oil used is similar to kerosine-type jet fuel, at 5,670 x 10^3 BTU/bbl.

(b) From McCrackin (1976).

(c) Data on LADWP distillate oil use unavailable

(d) From Table E1.8

(e) From Zwiacher (1978).

TABLE E1.10

Sulfur Content of Fuel Oil at the
Long Beach Combined Cycle Plant

Month	Sulfur Content (weight percent)	
	1977	1978
January	---	0.04
February	0.06	0.04
March	0.06	0.04
April	0.06	0.04
May	0.06	0.04
June	0.06	0.04
July	0.04	
August	0.03	
September	0.03	
October	0.03	
November	0.04	
December	0.04	

Reference: Bagwell (1978)

a maximum limit of 0.08% sulfur in distillate fuel oil. That low level of fuel sulfur is needed to assure compliance with the particulate emissions limitation placed on that facility. Actual fuel sulfur content never reaches that limit as shown by the time series data of Table E1.10. The average sulfur content of distillate fuel at Long Beach during 1977 was 0.046 percent, while fuel sulfur content during 1977 was 0.046 percent, while fuel sulfur content during the first half of 1978 averaged 0.04% sulfur. Peaking turbines at other locations in early 1977 burned distillate fuels approximating 0.13% sulfur by weight (Bagwell, 1978), while data for those facilities during 1973 averaged about 0.05% sulfur by weight.

Based upon the history of jet turbine fuel sulfur content of Table A3.10 of Cass (1978), plus recently observed fuel properties at the Long Beach Generating Station, a weighted average of utility distillate fuel oil sulfur contents is expected to fall at about 0.05% sulfur by weight. It is understood, however, that the actual sulfur content of fuel burned at any site in a particular month could deviate from that expected value by several fold without encountering a legally binding limit on fuel sulfur content.

Sulfur oxides emissions from utility distillate fuel oil combustion were estimated on a spatially resolved basis using the plant-specific fuel burning estimates of Table E1.9, plus the following fuel oil properties:

Distillate turbine fuel sulfur content 0.05%

Distillate turbine fuel gravity .... 41.5° API

Emission factor (lbs SO_x/barrel) .... 5.737 times % sulfur

Projected sulfur oxides emissions from utility distillate fuel oil combustion are shown on a spatially resolved basis in Figure E1.4.

Sulfur oxides emissions projections for residual, plus distillate oil combustion at on-grid power plants are compared to total emissions forecast within the 50-by-50 mile square grid in Figure E1.5. Projected utility emissions average 131.42 tons per day during the early 1980's within the 50-by-50 mile square. Off-grid emissions from electric utilities are projected to average 47.54 tons per day under our stated assumptions about fuel quality.

E1.4.3 Refinery Fuel Burning

South Coast Air Basin refinery capacity in the year 1977 is shown in Table E1.11. By comparison with data from 1973 given in Table A2.4 of the study by Cass (1978) it is seen that refinery capacity has grown by 31% from 1,006,200 barrels per stream day in 1973 to 1,320,148 barrels per stream day in 1977.

Refinery fuel use during the 1970's is summarized in Table E1.12. In spite of substantial refinery capacity expansion over that period of time, total refinery fuel use has been held nearly constant. In effect, refiners have increased the thermal efficiency of their facilities about one third on a per-barrel-of-capacity basis since the Arab oil embargo. A second trend which is apparent is a general

UTILITY DISTILLATE SOX EMISSIONS IN THE EARLY 1980'S: TEST YEAR 2 , IN TONS/DAY AS SO2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	C.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0
21	0.0	0.C	0.0	C.C	0.C	0.0	0.0	0.0	0.0	0.0	0.32	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	C.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	C.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	C.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	C.0	0.0	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	C.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0
12	C.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	C.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.75	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	C.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	C.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

SOX
TONS/DAY
2.110

Figure E1.4

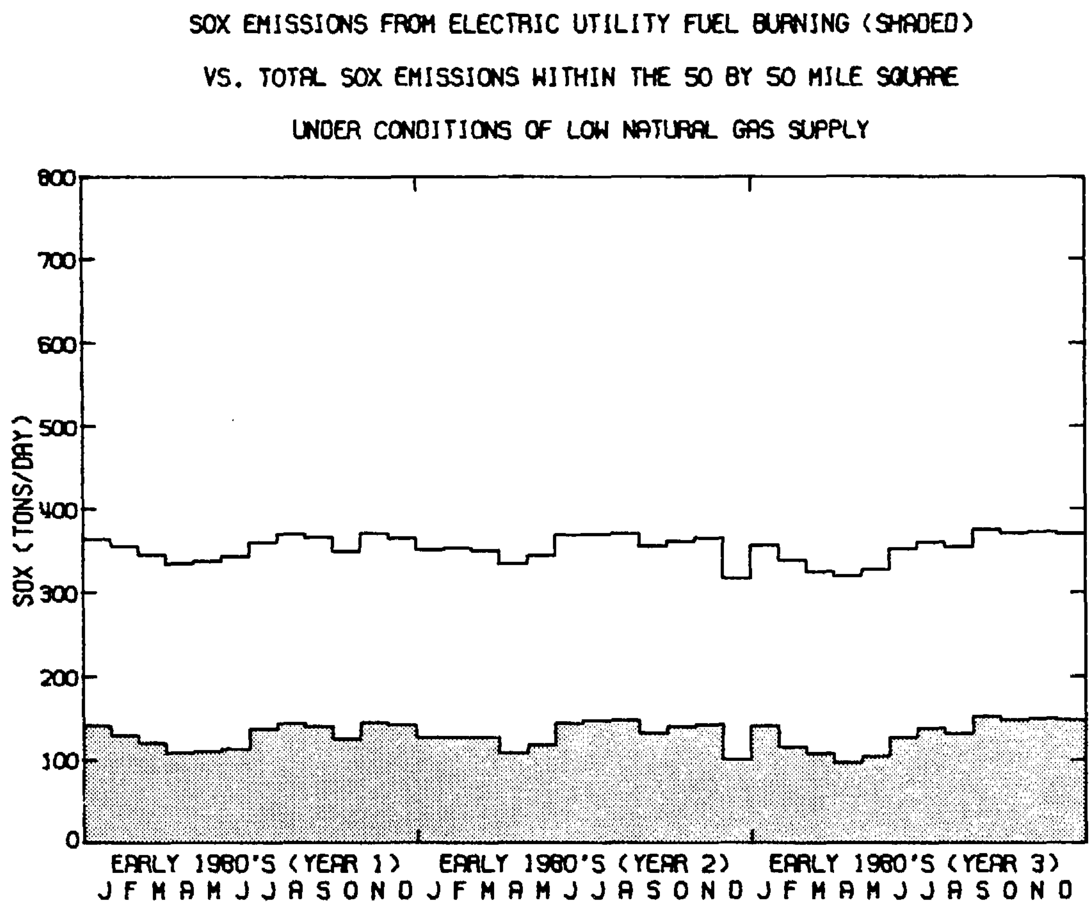

SOX EMISSIONS FROM ELECTRIC UTILITY FUEL BURNING (SHADED)
VS. TOTAL SOX EMISSIONS WITHIN THE 50 BY 50 MILE SQUARE
UNDER CONDITIONS OF LOW NATURAL GAS SUPPLY
SOX (TONS/DAY)
0
100
200
300
400
500
600
700
800
EARLY 1980'S (YEAR 1)
EARLY 1980'S (YEAR 2)
EARLY 1980'S (YEAR 3)
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D

Figure E1.5

TABLE E1.11

1977 Refinery Capacity in the South Coast Air Basin

Idenfication	Location	1977 Crude Oil Capacity (bbl/stream day)	1977 Crude Oil Capacity (bbl/calendar day)
Chevron U.S.A.	El Segundo	426,316	405,000
Atlantic Richfield	Carson	186,000	175,000
Mobil Oil	Torrance	131,100	123,500
Union Oil	Wilmington	111,000	108,000
Shell Oil	Wilmington	93,000	90,000
Texaco	Wilmington	78,947	75,000
Gulf Oil	Santa Fe Springs	53,800	51,500
Douglas Oil	Paramount	48,000	46,500
Powerine Oil	Santa Fe Springs	46,000	44,120
Champlin Petroleum	Wilmington	31,500	30,600
Edgington Oil	Long Beach	31,053	29,500
Fletcher Oil & Refining	Carson	20,000	19,200
USA Petrochem Corp.	Ventura	16,000	15,000
Golden Eagle Refining	Carson	13,000	12,350
Macmillan Ring-Free Oil	Signal Hill	12,200	11,590
Newhall Refining	Newhall	11,500	10,925
Lunday-Thagard Oil	South Gate	8,100	8,500
Oxnard Refinery	Oxnard	2,632	2,500
		1,320,148	1,258,785

Reference: Cantrell (1977)

TABLE E1.12

Refinery Fuel Use in Los Angeles County
(1970 through 1977)

Year	Fuel Oil (millions of barrels/year)	Natural Gas (10^6 equivalent barrels/year)	Refinery Gas (10^6 equivalent barrels/year)	Total (10^6 equivalent barrels/year)
1970	0.65	12.07	18.10	30.82
1971	0.94	11.56	17.91	30.41
1972	1.27	8.31	19.83	29.41
1973	1.75	7.36	22.76	31.87
1974	2.29	6.92	20.45	29.66
1975	2.60	5.08	21.25	28.93
1976	1.91	5.39	22.94	30.24
1977	0.85	6.39	23.69	30.93

Sources: (a) Years 1970 through 1975 from Southern California Air Pollution Control District (1976).

(b) Years 1976 and 1977 from South Coast Air Quality Management District (1978b).

increase in the level of refinery gas combustion, at a rate approximately èqual to the rate of refinery expansion. The decline in natural gas availability during the 1970's has been offset by this increased refinery gas use, combined with a strong energy conservation effort which limited the growth in total energy demand.

Total refinery fuel use in the early 1980's will be assumed to remain at the 1977 level of 30.93 million fuel oil equivalent barrels annually (an apparent dynamic balance between refinery expansion and energy conservation). From discussions with oil company personnel (O'Hare, 1978), it is thought that large increases in refinery gas production are unlikely to occur in the near future. Therefore, early 1980's refinery gas availability will be held constant at a 1977 level of 23.69 million fuel oil equivalent barrels per year. Subtracting refinery gas consumption from total energy demand yields a potential demand for auxilliary fuel (fuel oil plus natural gas) of 7.24 million equivalent barrels annually.

Under our assumed conditions of low natural gas supply, the auxillary fuel needs of all refinery equipment having an alternate fuel capability (falling into California Public Utilities Commission priority groups 2B, 3 and 4) would be met by burning fuel oil. Small equipment items with no alternate fuel capability (in PUC priority block 1) would continue to receive a steady natural gas supply. Refinery auxillary fuel demand classification into natural gas priority blocks can be estimated (roughly) using the exchange gas "requirements" of the Pacific Lighting Service Company, plus the assumption that most exchange gas is destined for petroleum industry use. From Table 1-b PLS of the 1977 California Gas Report, it is found that only 2.4% of those exchange gas "requirements" in 1978 were expected to fall into the essentially uninterruptible Priority 1 category. While this provides only an indirect estimate for local refiners, indications are that under conditions of low natural gas supply or a natural gas price exceeding the price of a "legal" grade of low sulfur fuel oil, virtually all refinery auxillary fuel needs could be met by burning oil. Our emissions projection will attempt to examine the case in which such a switch to fuel oil occurs.

Baseline fuel combustion data for each refinery within the 50-by-50 mile grid were acquired for the year 1977 from the South Coast Air Quality Management District (1978b), as summarized in Table E1.13. Sulfur oxides emissions for each plant site were also obtained for each type of fuel used in that year. Then the average sulfur content of each refinery's fuel oil and refinery gas supplies used in that year were calculated by relating the stated emissions to the quantities of fuel burned, assuming:

Residual Fuel Oil Emission Factor (lbs. SO_x/bbl.) = 6.59 times % sulfur

Refinery Gas Energy Content = 1,300 BTU/scf.

Fuel Oil Energy Content = 6.3×10^6 BTU/bbl.

The resulting sulfur content estimates for refinery gas and fuel oil also are given in Table E1.13.

TABLE E1.13

1977 Fuel Use at 15 Refineries Within the 50 by 50 Mile Square

Refinery Location Within the Grid System		Fuel Consumption (Equivalent Barrels/Year)				Sulfur Oxides Emissions (Tons/Years as SO_2)				Fuel Sulfur Content	
East/West I	North/South J	Fuel Oil	Refinery Gas	Natural Gas	All Fuels	SO_x Oil	SO_x Refinery Gas	SO_x Natural Gas	Total SO_x	Fuel Oil (wt. % S)	Refinery Gas (Grains/100cf)
29.00	24.00	281376.00	5431978.00	1176030.00	6889384.00	312.08	37.88	2.94	352.90	0.34	2.02
34.00	20.00	60011.00	2872519.00	528964.00	3461494.00	62.52	46.67	1.32	110.51	0.32	4.70
37.00	15.00	59001.00	2643464.00	1383981.00	4086446.00	58.38	96.70	3.46	158.54	0.30	10.59
37.00	17.00	51.00	365248.00	7806.00	373105.00	0.07	46.83	0.02	46.92	0.42	37.12
37.00	19.00	374.00	61244.00	78686.00	140304.00	0.29	*	0.20	0.49	0.24	**
39.00	19.00	16252.00	947578.00	309800.00	1273630.00	21.99	51.74	0.77	74.50	0.41	15.81
40.00	19.00	1025.00	1395224.00	421191.00	1817440.00	1.52	39.14	1.05	41.71	0.45	8.12
40.00	15.00	0.00	517371.00	2596.00	519967.00	0.0	31.02	0.01	31.03	0.40	17.36
40.00	16.00	53470.00	2652460.00	411380.00	3117310.00	46.73	212.89	1.03	260.65	0.27	23.24
40.00	17.00	257590.00	4369205.00	1269648.00	5896443.00	386.02	407.83	3.18	797.03	0.45	27.02
43.00	16.00	0.00	*	92753.00	92753.00	0.0	*	0.23	0.83	0.40	**
44.00	22.00	21528.00	0.00	296070.00	317598.00	25.52	0.0	0.74	26.26	0.36	**
45.00	23.00	20412.00	778245.00	218375.00	1017032.00	25.83	43.48	0.55	69.86	0.38	16.17
49.00	26.00	52336.00	773843.00	294048.00	1120227.00	83.29	3.65	0.73	87.67	0.48	1.37
51.00	24.00	18951.00	584128.00	191936.00	795015.00	13.82	26.99	0.48	41.29	0.22	13.38
Total		842377.00	23392496.00	6683264.00	30918144.00	1038.06	1045.42	16.71	2100.19	0.37	12.94
Average											

*Very small

**Not Applicable

An energy use and emissions projection for the early 1980's under conditions of 1977 emissions control regulations, plus low natural gas supply was constructed for each plant site by:

- Holding total energy use constant at the level observed in 1977.
- Holding refinery gas quantity and sulfur content constant at 1977 levels at each refinery.
- Reducing natural gas use at each refinery to 2.4% of 1977 levels while increasing fuel oil consumption by an energy equivalent amount.
- Re-estimating the fuel oil combustion SO_x emissions at that increased level of oil use while holding the sulfur content of oil burned at the 1977 level observed at each plant. At those facilities where no fuel oil was burned in 1977, a fuel oil sulfur content of 0.40 percent by weight was assumed to reflect behavior under emission control regulations prevailing in 1977.

Energy use, fuel quality, and SO_x emissions constructed for each refinery under these conditions are summarized in Table E1.14. A total of 27 tons of SO_x per average day would be emitted to the atmosphere at locations as shown in Figure E1.6. The seasonal variation in total refinery fuel use is slight, as can be seen from monthly data for 1973 and 1974 presented in Table A2.5 of Appendix A2 to the study by Cass (1978). Under conditions of low natural gas supply and negligible seasonal switching from natural gas to oil, daily refinery fuel burning SO_x emissions should be reasonably approximated by the annual average daily behavior shown in Figure E1.6.

REFINERY FUEL SOX EMISSIONS IN THE EARLY 1980'S: TEST YEAR 2 , IN TONS/DAY AS SO2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	4.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	0.0	0.2	3.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	7.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.1	1.8	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

SOX
TONS/DAY
27.003

Figure E1.6

TABLE E1.14

1980 Fuel Use Projection for 15 Refineries Within the 50 by 50 Mile Square

Refinery Location Within the Grid System		Fuel Consumption (Equivalent Barrels/Year)				Sulfur Oxides Emissions (Tons/Years as SO_2)				Fuel Sulfur Content	
East/West I	North/South J	Fuel Oil	Refinery Gas	Natural Gas	All Fuels	SO_x Oil	SO_x Refinery Gas	SO_x Natural Gas	Total SO_x	Fuel Oil (wt. % S)	Refinery Gas (Grains/100cf)
29.00	24.00	1429180.00	5431978.00	28224.69	6889382.00	1585.13	37.88	0.07	1623.08	0.34	2.02
34.00	20.00	576279.63	2872519.00	12695.12	3461493.00	600.37	46.67	0.03	647.07	0.32	4.70
37.00	15.00	1409765.00	2643464.00	33215.51	4086444.00	1394.92	96.70	0.08	1491.71	0.30	10.59
37.00	17.00	7669.00	365248.00	187.34	373104.00	10.53	46.83	0.00	57.36	0.42	37.12
37.00	19.00	77171.50	61244.00	1888.46	140303.94	59.84	*	0.00	59.84	0.24	**
39.00	19.00	318616.63	947578.00	7435.19	1273629.00	431.11	51.74	0.02	482.87	0.41	15.81
40.00	19.00	412107.19	1395224.00	10108.57	1817439.00	611.12	39.14	0.03	650.29	0.45	8.12
40.00	15.00	2533.70	517371.00	62.30	519966.94	3.34	31.02	0.00	34.36	0.40	17.36
40.00	16.00	454976.69	2652460.00	9873.11	3117309.00	397.63	212.89	0.02	610.54	0.27	23.24
40.00	17.00	1496765.00	4369205.00	30471.52	5896441.00	2243.02	407.83	0.08	2650.93	0.45	27.02
43.00	16.00	90526.88	*	2226.07	92752.94	119.31	*	0.01	119.92	0.40	**
44.00	22.00	310492.19	0.00	7105.67	317597.81	368.07	0.0	0.02	368.08	0.36	**
45.00	23.00	233545.88	778245.00	5240.99	1017031.81	295.54	43.48	0.01	339.03	0.38	16.17
49.00	26.00	339326.69	773843.00	7057.14	1120226.00	540.02	3.65	0.02	543.69	0.48	1.37
51.00	24.00	206280.44	584128.00	4606.46	795014.88	150.43	26.99	0.01	177.43	0.22	13.38
Total		7365237.00	23392496.00	160398.13	30918128.00	8810.38	1045.42	0.40	9856.20	0.36	12.94
Average											

*Very small

**Not Applicable

E1.4.4 Other Low Priority Natural Gas Customers

In Section A2.2.3 of Appendix A2 to the study by Cass (1978), a mathematical model was developed and validated which is capable of simulating the SO_x emissions impact of natural gas curtailment on the basis of an industrial customer's known priority for obtaining natural gas. That model will be used to project the SO_x emissions impact of non-refinery industrial fuel burning activities under conditions of low natural gas supply.

An estimate of total low priority industrial demand for fossil fuel in the early 1980's first will be made. That information is needed in order to scale energy use at each source from the 1974 levels used to calibrate the fuel switching model forward to levels expected to prevail in future years.

Natural gas historically has been priced below fuel oil or LPG. Thus total potential natural gas demand is nearly equal to total demand for fossil fuel. Natural gas "requirements" forecast for the early 1980's in the 1977 California Gas Report provide an indication of total low priority industrial demand for natural gas in the absence of any curtailment of gas deliveries. A comparison of forecast gas requirements to historical natural gas requirements given for 1974 in that report will serve as a basis for assessing the growth in demand for industrial fossil fuel.

Comparison of historical gas demand to future projections is complicated by the fact that the California Public Utilities

Commission and the State's gas utilities have changed their data reporting format and gas curtailment procedures in recent years. Details of the two accounting systems used are indicated in Table E1.15. Historical data on gas demand for 1974 are given in terms of the firm, interruptible and exchange gas categories in the left-hand column of that table. Forecasts of potential gas demand in the early 1980's are classified into priority groups 1, 2A, 2B, 3, 4, and 5. While our interest is in identifying the rate of growth of nonrefinery fuel use in priority groups 2B, 3, and 4, there is clearly no way to isolate just those data in comparable fashion from 1974 and 1980 in the California Gas Report. Instead, a higher level of aggregation must be used.

The closest match that can be made is to compare the 1974 gas demands of "industrial interruptible", plus "oil company exchange and payback" customers to 1980 forecasts of gas demand by priority groups 2A, 2B, 3, and 4. That comparison, shown in Table E1.16, indicates that total industrial interruptible-type demand for natural gas in the early 1980's is expected to be equal to that in 1974 to within our ability to reconcile the two accounting systems being used. Therefore, natural gas curtailment calculations for each month of three test years in the early 1980's will be assembled under the assumption that the quantity of fossil fuel energy consumed at each source during the years 1972 through 1974 remains a good representation of the level of heat input at each source during the same season of future test years. The combination of fuels used to meet that energy

TABLE E1.15

Description of the Natural Gas Customer Classification Scheme Used Prior to 1976 to the End Use Priority System Used at Present

Historical System--Prior to 1976

- FIRM - Service not normally subject to curtailment
    - RETAIL SALES - Includes firm sales to Domestic, Commercial, Firm Industrial and Gas Engine categories.
    - SPECIAL PRODUCER EXCHANGE - Requirement for exchange delivery to California producers under special contracts. (An exchange delivery is defined as delivery of gas by one party to another and the delivery of an equivalent quantity by the second party to the first. Such transactions usually involve different points of delivery and may or may not be concurrent.)
    - EXCHANGE WITH OTHER UTILITIES (see definition of exchange above)
    - WHOLESALE - Firm sales to customers having their own gas distribution system.
    - SYSTEM USES AND LOSSES
      (a) UNACCOUNTED FOR AND NET INVENTORY CHANGE - Includes line losses and measurement differences which result in a difference between the volume of gas taken by respondent and the volume delivered to loads and net changes in line pack and holder inventories.
      (b) COMPANY INCIDENTAL AND COMPRESSOR FUEL - Such uses as gas for Company building heat, meter testing and compressor fuel.
    - STORAGE AND INJECTION - Net volume of natural gas injected into underground storage facilities and volume of natural gas liquefied and stored. Does not include gas into buried high pressure pipe storage.

- INTERRUPTIBLE - Service subject to interruption or curtailment.
    - INDUSTRIAL - commercial and industrial interruptible loads supplied. This group is further subdivided by size into curtailment blocks A, B, C, D, and E. Block A customers are the largest and would be interrupted first.
    - OIL COMPANY EXCHANGE - Fuel requirement of California producers to be supplied by exchange.
    - STEAM ELECTRIC PLANTS - Interruptible sales to electric generating stations
    - WHOLESALE - Interruptible sales to customers having their own gas distribution system.

End Use Priority System--1976 and Following Years

PRIORITY	DESCRIPTION
1	All residential use regardless of size All other use with peak-day demands of 100 Mcf/d or less
2-A	All service where primary use is as a feedstock with no alternative All former firm non-residential use with peak-day demands greater than 100 Mcf/d. If conversion to alternate fuel is feasible, this use will be transferred to a lower priority by December 1977. Electric utilities start-up and igniter fuel.
2-B	All customers with LPG or other gaseous fuel standby facilities and peak day demands greater than 100 Mcf/d where conversion to alternate fuel is not feasible. Other customers with California Public Utilities Commission approved deviation from requirements for standby facilities.
3	All use not included in another priority.
4	Boiler fuel use with peak-day demand greater than 750 Mcf/d. All use in cement plant kilns.
5	All utility steam-electric generation plants and utility gas turbines, excluding start-up and igniter fuel.

TABLE E1.16

Comparison of 1974 Historical Natural Gas Consumption to that Forecast for 1980
(in mmcf/yr)

	Total So. California Natural Gas Requirements	Non-Pacific Lighting Co. Components of that Demand for Natural Gas: San Diego G&E	Non-Pacific Lighting Co. Components of that Demand for Natural Gas: Long Beach	Uses and Losses	Approximate Pacific Lighting Company Requirements Other Than Wholesale and System Use and Injection	Approximate South Coast Air Basin Requirements Other Than Wholesale and System Use and Injection	Total SCAB Low Priority Refinery Industrial And Feedstock Demand Comparison
1980 Forecast							
Priority 1	503,785	51,674	12,370	23,542	416,199	386,949	
Priority 2A	55,399	982	1,131		53,286	49,088	
Priority 2B	22,200	598	210		21,392	17,323	223,355 (Priorities 2A–4)
Priority 3	129,434	3,411	3,439		122,584	101,506	
Priority 4	71,205	2,296	1,555		67,354	55,438	
Priority 5	672,150	95,910	14,640		561,600	527,063	
Storage and Injection	89,123	715	0				
TOTAL	1,543,296	155,586	33,345		1,330,823	1,137,367	
1974 Historical							
Firm	473,999	41,952	11,821		420,226	391,296	
Retail Sales	1,712				1,712		
Special Producer Exchange	5,029						
Wholesale	0						
System Uses & Losses	33,609	1,899	353	31,357			
Storage and Injection	78,844	639					
Interruptible							
Industrial	237,276	7,262	5,729		224,285	185,157	216,161 (Industrial and Oil Co. Exchange)
Oil Co. Exchange	39,755	0			38,755	31,004	
Steam Electric Plants	476,429	74,572	3,052		398,805	387,105	
Wholesale	5	5					
TOTAL	1,346,658	126,329	20,955		1,083,783	994,562	

Source: 1977 California Gas Report

demand in the future, however, may differ significantly from the natural gas-dominated mix observed during 1972, 1973, and 1974.

Having set the level of energy use at each industrial facility, the fuel switching simulation model can be used to project SO_x emissions under low natural gas supply conditions, provided that detailed correspondence between the old and new curtailment procedures can be established. The situation of interest to us involves complete curtailment of natural gas priority groups 2B, 3, and 4. From Table E1.15 we note that these priority classes include virtually all of the former "industrial interruptible" sources with the exception of feedstock users. Since our simulation model included nonrefinery industrial interruptible combustion sources only, it would appear that complete curtailment of nonrefinery customers in priority groups 2B, 3, and 4 can be simulated by substituting the appropriate alternate fuels for natural gas at all class A, B, C, D, E, and exchange customers included within the fuel switching simulation model's data bank. This was accomplished by first calculating total energy consumption at each source in each month of interest. Then the type of standby fuel maintained by each source in the comparable month of the years 1972 through 1974 was sensed. The appropriate combination of LPG or fuel oil with a sulfur content equal to that historically consumed by each source was then substituted for the lost natural gas on a BTU-equivalent basis. Sulfur oxides emissions were then calculated from the fuel used as described in Appendix A2 of the study by Cass (1978).

Calculations for facilities located within the 50-by-50 mile square are summarized in Table E1.17. Total industrial heat input inferred from the 1977 California Gas Report and the fuel switching models of the present study is compared in Table E1.18. Agreement is quite close.

Total non-refinery fuel burning SO_x emissions under conditions of low natural gas supply are given on a spatially resolved basis for a typical summer month and a typical winter month in Figures E1.7 and E1.8. In the absence of natural gas, fuel burning SO_x emissions from these sources within our grid system would total approximately 44 tons per day, up from only about 2.3 tons per day in 1973. The greatest increase in emissions would be concentrated in an industrial section just south of downtown Los Angeles (squares I 12-13 by J 14-16), and to a lesser extent in the Long Beach Harbor area.

E1.4.5 High Priority Natural Gas Customers

High priority gas customers residing in priority groups 1 and 2A are not expected to burn any fuel oil under our assumed natural gas supply conditions. Much of the natural gas demand by priority 2A sources is for feedstock use. Thus growth in gas combustion between 1974 and 1980 may be assessed (roughly) by comparing expected 1980 sales to Priority 1 customers to 1974 historical data on "firm" retail gas sales. From Table E1.16, we note that growth in high priority gas demand has been small. Since sulfur oxides emissions from natural gas combustion are negligible, it will suffice to use the 1972 through 1974 firm customer natural gas emissions inventory of Section A2.24 of Appendix A2 to the study by Cass (1978) to represent emissions by high priority gas customers in each month of our three test years in the early 1980's.

TABLE E1.17

Fuel Burning Simulation Results for Low-Priority Natural Gas Customers
Within the 50-by-50 Mile Grid -- Early 1980's Under Low Natural Gas Supply Conditions
Heat Input by Fuel Type (in 10^9 BTU's for each month)

YEAR	MONTH	NATURAL GAS	FUEL OILS	LIQUIFIED PETROLEUM GAS	HEAT INPUT	TONS	TONS/DAY
Test Year 1	JAN	0.0	9908.01	1447.33	11355.34	1531.81	49.41
	FEB	0.0	9491.27	1413.12	10904.39	1458.00	50.28
	MAR	0.0	9832.12	1271.23	11103.35	1511.40	48.75
	APR	0.0	9780.88	1329.03	11109.91	1499.32	49.98
	MAY	0.0	9709.23	1246.08	10955.30	1484.64	47.89
	JUN	0.0	9494.36	1194.81	10689.18	1453.24	48.44
	JUL	0.0	9108.05	827.94	9935.99	1383.97	44.64
	AUG	0.0	9176.28	911.86	10088.14	1415.88	45.67
	SEP	0.0	9370.73	1117.11	10487.85	1439.57	47.99
	OCT	0.0	9444.50	1291.38	10735.88	1449.41	46.76
	NOV	0.0	9520.39	1542.41	11062.80	1448.68	48.29
	DEC	0.0	9389.54	1436.94	10826.48	1407.09	45.39
	TOTAL	0.0	114,225.31	15,029.26	129,254.63	17,483.00	47.77
Test Year 2	JAN	0.0	10435.27	1585.55	12020.82	1540.27	49.69
	FEB	0.0	9477.63	1331.28	10808.90	1406.46	50.23
	MAR	0.0	9458.01	1488.12	10946.13	1399.82	45.16
	APR	0.0	9766.48	1298.58	11065.06	1444.95	48.16
	MAY	0.0	9624.25	1322.44	10946.69	1421.42	45.85
	JUN	0.0	9084.02	1193.04	10277.06	1343.10	44.77
	JUL	0.0	9050.56	979.34	10029.89	1345.78	43.41
	AUG	0.0	8891.82	846.64	9738.45	1329.23	42.88
	SEP	0.0	9121.16	1088.13	10209.29	1354.99	45.17
	OCT	0.0	9161.16	1207.87	10369.03	1375.90	44.38
	NOV	0.0	9095.42	1239.32	10334.73	1355.81	45.19
	DEC	0.0	8879.00	948.24	9827.24	1324.66	42.73
	TOTAL	0.0	112,044.75	14,528.55	126,573.25	16,642.39	45.60
Test Year 3	JAN	0.0	8794.02	1108.81	9902.83	1343.66	43.34
	FEB	0.0	8952.13	971.84	9923.97	1361.83	48.64
	MAR	0.0	8932.60	997.53	9930.13	1365.75	44.06
	APR	0.0	8813.48	868.19	9681.67	1348.30	44.94
	MAY	0.0	8750.52	825.79	9576.30	1336.89	43.13
	JUN	0.0	8646.16	790.15	9436.31	1326.65	44.22
	JUL	0.0	8507.88	745.14	9253.02	1284.65	41.44
	AUG	0.0	8533.55	900.25	9433.80	1301.28	41.98
	SEP	0.0	8871.71	1053.80	9925.51	1345.50	44.85
	OCT	0.0	8881.53	1172.64	10054.17	1349.29	43.53
	NOV	0.0	9114.30	1128.06	10242.36	1384.88	46.16
	DEC	0.0	8859.24	917.60	9776.84	1314.07	42.39
	TOTAL	0.0	105,657.06	11,479.80	117,136.88	16,062.74	44.01

TABLE E1.18

Comparison of 1980 South Coast Air Basin Industrial Fuel Requirements Inferred from the 1977 California Gas Report vs the Results of the Fuel Switching Models Used in the Present Study

<u>1977 California Gas Report</u>

Industrial "Requirements" Inferred in Categories P4, P3, and P2B (as derived in Table E1.1)

	Natural Gas "Requirement" (mmcf/yr)	Energy Equivalent (10^9 BTU/yr)
P4	55,438	58,764
P3	101,506	107,596
P2B	17,323	18,362
		184,722

<u>Fuel Switching Projection (Present Study)</u>

On Grid	Energy Use (10^9 BTU/yr)
Refinery Auxillary Fuel	46,305[1]
Non-Refinery Low Priority Industrial Fuel (Test Year 1)	129,255[2]
Off Grid	
Kaiser Steel Auxillary Fuel	6,514[1]
	182,074

Notes: (1) Includes fuel oil plus natural gas only; excludes refinery gas, coke oven gas, process gas and other fuel sources which do not represent a "requirement" for natural gas supply planning purposes.

(2) From Table E1.17.

OTHER LOW PRIORITY GAS CUSTOMER SOX EMISSIONS IN THE EARLY 1980'S: JAN OF TEST YEAR 2 , IN TONS/DAY AS SO2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	0.0	0.0	0.0	0.0	0.0	0.05	0.03	0.01	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.01	0.04	0.19	0.00	0.0	0.0	0.04	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.07	0.0	0.0	0.01	0.37	0.02	0.03	0.06	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.06	0.0	0.0	0.0	0.10	0.01	0.07	0.17	0.22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.01	0.0	0.01	0.06	0.09	0.07	0.02	0.0	0.0	0.01	0.0	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.07	0.0	0.23	0.04	0.06	0.10	0.34	0.0	0.0	0.0	0.01	0.0	0.25	0.0	0.01	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.20	0.25	0.07	0.13	0.01	0.0	0.03	0.11	0.0	0.0	0.04	0.09	0.01	0.00	0.0	0.0	0.01
18	0.0	0.0	0.0	0.0	0.0	1.39	0.05	0.11	0.14	0.14	0.16	0.28	0.80	0.12	0.04	0.0	0.06	0.24	0.01	0.0	0.0	0.00	0.0	0.0	1.88
17	0.0	0.0	0.0	0.0	0.03	0.33	0.48	0.02	0.0	0.14	0.49	1.87	0.11	0.04	0.01	0.0	0.01	0.0	0.28	0.0	0.0	0.0	0.0	0.22	0.03
16	0.0	0.0	0.0	0.01	0.03	0.06	0.01	0.05	0.05	0.01	0.34	1.11	1.75	0.48	0.26	0.03	0.05	0.01	0.19	0.01	0.01	0.20	0.14	0.0	0.0
15	0.0	0.0	0.0	0.0	0.01	0.02	0.08	0.01	0.01	0.11	0.49	4.49	2.20	1.06	1.21	0.03	0.02	0.01	0.0	0.0	0.11	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.04	0.02	0.06	0.0	0.01	1.35	0.90	0.57	0.01	0.0	0.68	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.13	0.26	0.0	0.01	0.41	0.11	0.17	0.13	0.03	0.31	0.01	0.0	0.0	0.08	0.05	0.02	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.14	0.05	0.0	0.10	0.08	0.27	0.25	0.0	0.01	0.17	0.24	0.0	0.0	0.06	0.0	1.50	1.46	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.04	0.0	0.0	0.29	0.10	0.03	0.05	0.22	0.02	0.0	0.01	0.11	0.07	0.50	0.10	0.45	0.12	0.02	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.12	1.63	0.06	0.58	0.14	0.01	0.01	0.0	0.0	0.0	0.03	0.01	0.18	0.05	0.03	0.01	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.22	0.01	1.29	0.0	0.02	0.04	0.0	0.10	0.0	0.01	0.0	0.14	0.15	0.09	0.0	0.04
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.56	0.61	0.07	0.0	0.05	0.01	0.0	0.0	0.03	0.0	0.05	0.04	0.02	0.00
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.40	0.50	0.11	0.0	0.0	0.0	0.0	0.23	0.13	0.01	0.01	0.02	0.21	0.05	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.56	0.01	0.0	0.0	0.0	0.02	0.0	0.0	0.0	0.00	0.0	0.0	0.24	0.02	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.0	0.08	0.0	0.40	0.02	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.0	0.16	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.20	0.00	0.0	0.0	0.00	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

SOX
TONS/DAY
49.686

Figure E1.7

OTHER LOW PRIORITY GAS CUSTOMER SOX EMISSIONS IN THE EARLY 1980'S: JULY OF TEST YEAR 2 , IN TONS/DAY AS SO2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	0.0	0.0	0.0	0.0	0.0	0.04	0.03	0.01	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.01	0.03	0.16	0.00	0.0	0.0	0.04	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.03	0.0	0.0	0.01	0.33	0.02	0.02	0.07	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.05	0.0	0.0	0.0	0.09	0.01	0.06	C.14	0.19	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.01	0.0	0.01	0.05	0.07	0.06	0.02	0.0	0.0	0.01	0.0	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.06	0.0	0.20	0.03	0.05	0.09	0.28	0.0	0.0	0.0	0.01	0.0	0.31	0.0	0.01	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.17	0.21	0.06	0.11	0.01	0.0	0.02	0.09	0.0	0.0	0.03	0.07	0.01	0.00	0.0	0.C	0.01
18	0.0	0.0	0.0	0.0	0.0	1.29	0.05	0.09	0.12	0.11	0.13	0.24	0.50	0.10	0.04	0.0	0.05	0.21	0.01	0.0	0.0	0.00	0.0	0.0	1.73
17	0.0	0.0	0.0	0.0	0.03	0.22	0.42	0.02	0.0	0.12	0.42	1.65	0.10	0.03	0.01	0.0	0.01	0.0	0.28	0.0	0.0	0.0	0.0	0.18	0.03
16	0.0	0.0	0.0	0.01	0.03	0.11	0.01	0.05	0.04	0.01	0.24	0.99	1.42	0.47	0.22	0.03	0.04	0.01	0.16	0.01	0.01	0.17	0.13	0.0	0.0
15	0.0	0.0	0.0	0.0	0.01	0.02	0.09	0.01	0.00	0.02	0.41	2.45	2.43	0.89	1.06	0.02	0.02	0.01	0.0	0.0	0.10	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.03	0.01	0.05	0.0	C.01	1.02	0.68	0.51	0.01	0.0	0.59	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	C.0	C.0	0.0	0.0	0.C	0.0	0.01	0.11	0.22	0.0	0.01	0.34	0.11	0.14	0.11	0.03	0.29	0.01	0.0	0.0	0.06	0.04	0.01	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.12	0.04	0.0	0.09	0.07	0.21	0.25	0.0	0.01	0.14	C.20	0.0	0.0	0.05	0.0	1.50	1.46	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.19	0.08	0.03	0.04	0.19	0.02	0.0	0.01	0.09	0.06	0.44	0.08	0.38	0.10	0.02	0.0
10	C.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.09	2.10	0.06	0.60	0.12	0.01	0.01	0.0	0.0	0.0	0.02	0.01	0.15	0.0	0.03	0.01	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.24	0.01	1.16	0.0	0.02	0.01	0.0	0.08	0.0	0.01	0.0	0.11	0.13	0.08	0.0	0.03
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.01	0.64	0.63	0.06	0.0	0.03	0.01	0.0	0.0	0.02	0.0	0.04	0.04	0.02	C.00
7	C.0	C.0	0.0	C.0	0.0	0.0	0.0	0.0	0.0	0.01	0.36	0.32	0.11	0.0	0.0	0.0	0.0	0.19	0.11	0.01	0.01	0.02	0.18	0.04	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.90	0.01	0.0	0.0	0.0	0.01	0.0	0.0	0.0	0.00	0.0	0.0	0.20	0.01	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.01	0.0	0.07	0.0	0.36	0.02	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.02	0.0	0.14	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.17	0.00	0.0	0.0	0.00	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.00	0.0	0.C	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

SOX
TONS/CAY
43.412

Figure E1.8

E1.4.6 Total Non-Utility Fuel Combustion Emissions

Sulfur oxides emissions estimates from fuel burning at refineries, industrial, plus commercial and residential sources are combined and compared to total SO_x emissions within the 50-by-50 mile grid in Figure E1.9. Under conditions of low natural gas supply, those sources would emit about 73 tons of SO_x per average day at locations shown in Figure E1.10. That would represent an emission increase from these sources of more than sixty tons per average day above levels prevailing in 1973.[4]

E1.5 Chemical Plant Emissions

Emissions estimates for the early 1980's were made for two major chemical plant categories:

- Sulfur Recovery Plants
- Sulfuric Acid Plants

Emissions from these sources are compared to total SO_x emissions within the 50-by-50 mile square in Figure E1.11. Other smaller fugitive chemical plant emissions sources will be included within the miscellaneous stationary source category to be defined later.

E1.5.1 Sulfur Recovery Plants

With one exception, sulfur recovery plant emissions projected for the early 1980's were based upon the South Coast Air Quality

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[4] See Table A2.15a and Figure A2.12 of the study by Cass (1978).

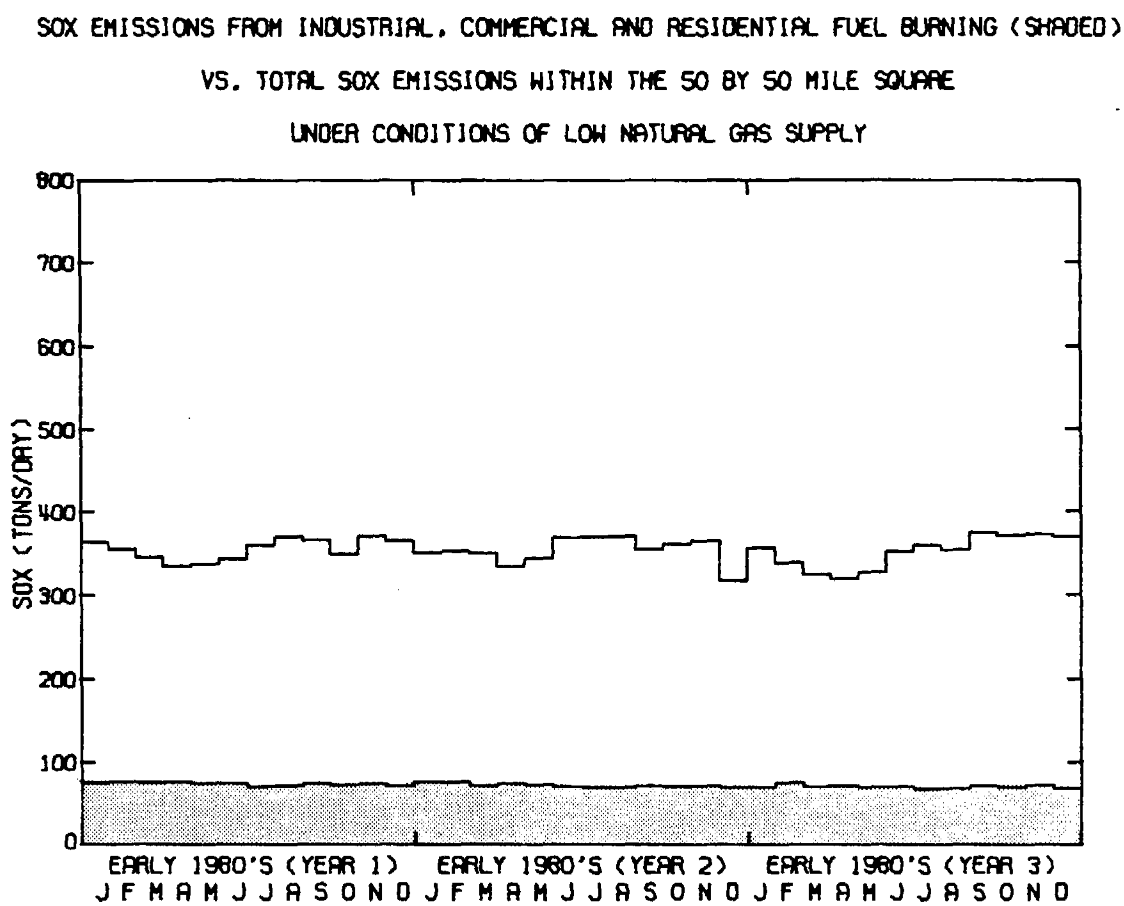

SOX EMISSIONS FROM INDUSTRIAL, COMMERCIAL AND RESIDENTIAL FUEL BURNING (SHADED)
VS. TOTAL SOX EMISSIONS WITHIN THE 50 BY 50 MILE SQUARE
UNDER CONDITIONS OF LOW NATURAL GAS SUPPLY
SOX (TONS/DAY)
800
700
600
500
400
300
200
100
0
EARLY 1980'S (YEAR 1)
EARLY 1980'S (YEAR 2)
EARLY 1980'S (YEAR 3)
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D

Figure E1.9

EARLY 1980'S INDUSTRIAL, RESIDENTIAL & COMMERCIAL FUEL SOX EMISSIONS: YEAR 2 IN CASE OF LOW NATURAL GAS SUPPLY, TONS/DAY

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	0.00	0.00	0.00	0.00	0.00	0.05	0.03	0.01	0.01	0.00	0.00	0.00	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.01	0.04	0.18	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.04	0.00	0.00	0.01	0.34	0.02	0.04	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.0C	0.0	0.C1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0C	0.05	0.00	0.00	0.00	C.C9	0.01	0.C6	0.15	0.21	C.0C	0.00	0.00	0.00	0.00	0.00	0.CC	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0C	0.00	0.00	C.C0	0.00	0.01	0.00	0.01	0.06	0.08	0.06	0.02	0.00	0.00	0.01	0.00	0.C1	C.00	0.00	0.00	0.00	0.0	0.00	0.00	0.0
20	0.00	0.00	0.00	0.00	0.00	0.0C	0.00	0.C1	0.06	0.00	0.21	0.04	0.05	0.10	0.31	0.00	0.0C	0.00	0.01	0.00	0.26	0.00	0.01	0.C0	0.00
19	0.0C	0.00	0.0	0.C	0.C0	0.0C	0.00	0.C1	C.18	0.22	0.06	0.12	0.01	0.00	0.03	0.10	0.0C	0.00	0.04	0.08	0.02	0.00	0.00	0.C0	0.01
18	0.0C	0.00	0.00	0.00	0.00	1.29	0.05	0.10	0.12	0.12	0.14	0.25	0.64	0.11	0.04	0.00	0.C6	C.23	0.01	0.00	0.00	0.00	0.00	0.00	1.70
17	0.00	0.00	0.00	0.00	0.03	0.27	0.43	0.02	0.00	0.13	0.44	1.71	0.10	0.04	0.01	0.00	0.C1	0.00	0.28	0.00	0.00	0.00	0.00	0.20	0.03
16	0.0	0.0	0.0	C.01	0.03	C.15	0.01	0.05	0.05	0.01	0.28	1.03	1.48	0.45	0.23	0.03	0.C5	0.01	0.18	0.01	0.01	0.20	0.13	0.00	0.0
15	0.0	0.0	0.0	0.0	0.01	0.02	0.09	0.01	C.01	0.03	0.45	2.70	2.40	0.97	1.12	0.02	0.C2	0.01	0.00	0.00	0.10	0.00	0.00	0.00	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0C	0.03	0.C1	C.05	0.00	0.01	1.17	0.74	0.54	0.01	0.00	0.62	0.01	0.00	0.00	0.00	0.0	0.00	0.0C	0.0
13	C.0	C.0	0.0	0.C	0.0	0.30	0.01	0.12	0.24	0.00	0.01	0.38	0.12	0.15	0.11	0.03	1.78	0.01	0.00	0.00	0.07	0.04	0.01	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	4.45	0.16	0.04	0.00	0.05	0.07	0.24	0.27	0.93	0.01	0.16	0.70	0.00	0.00	0.06	0.00	1.50	1.46	0.00
11	0.0	0.0	0.0	0.0	0.0	0.0	0.04	0.00	0.00	0.25	0.08	0.03	0.05	1.21	0.02	0.00	0.C1	0.10	0.06	0.45	0.09	0.41	0.11	0.C2	0.00
10	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	1.87	2.07	0.22	3.69	0.12	0.01	0.01	0.00	0.CC	0.C0	0.02	0.01	0.16	0.04	0.03	0.01	0.00
9	0.0	0.0	0.0	0.0	0.0	C.0	0.00	0.C0	C.01	0.24	C.17	8.53	0.00	0.02	0.04	0.00	0.C5	0.00	0.01	0.00	0.12	0.14	0.08	0.00	0.04
8	0.0	0.0	0.0	0.0	0.0	C.0	0.00	0.00	0.00	0.00	4.09	2.41	0.59	0.40	0.00	0.05	0.C1	0.00	0.00	0.03	0.00	0.04	0.04	C.02	0.00
7	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.01	0.38	0.38	0.11	0.00	0.00	0.00	0.CC	0.21	0.12	0.01	0.01	0.02	0.19	0.04	0.00
6	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00	C.92	0.01	0.00	0.0	0.0	0.02	0.0C	0.00	0.00	0.00	0.00	0.00	0.22	0.02	0.00
5	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.CC	C.00	0.02	0.00	0.08	0.00	0.37	0.02	0.00
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.02	0.00	0.15	0.00	0.00	0.00	0.00
3	0.0	0.0	0.0	C.0	0.0	0.0	0.0	0.C	C.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.00	0.19	0.00	0.00	0.00	0.00	0.0
2	C.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.00	0.00	0.00	0.00	0.0	0.0
1	0.0	0.0	0.0	C.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.00	0.00	0.C	0.0

SOX
TONS/DAY
72.8E4

Figure E1.10

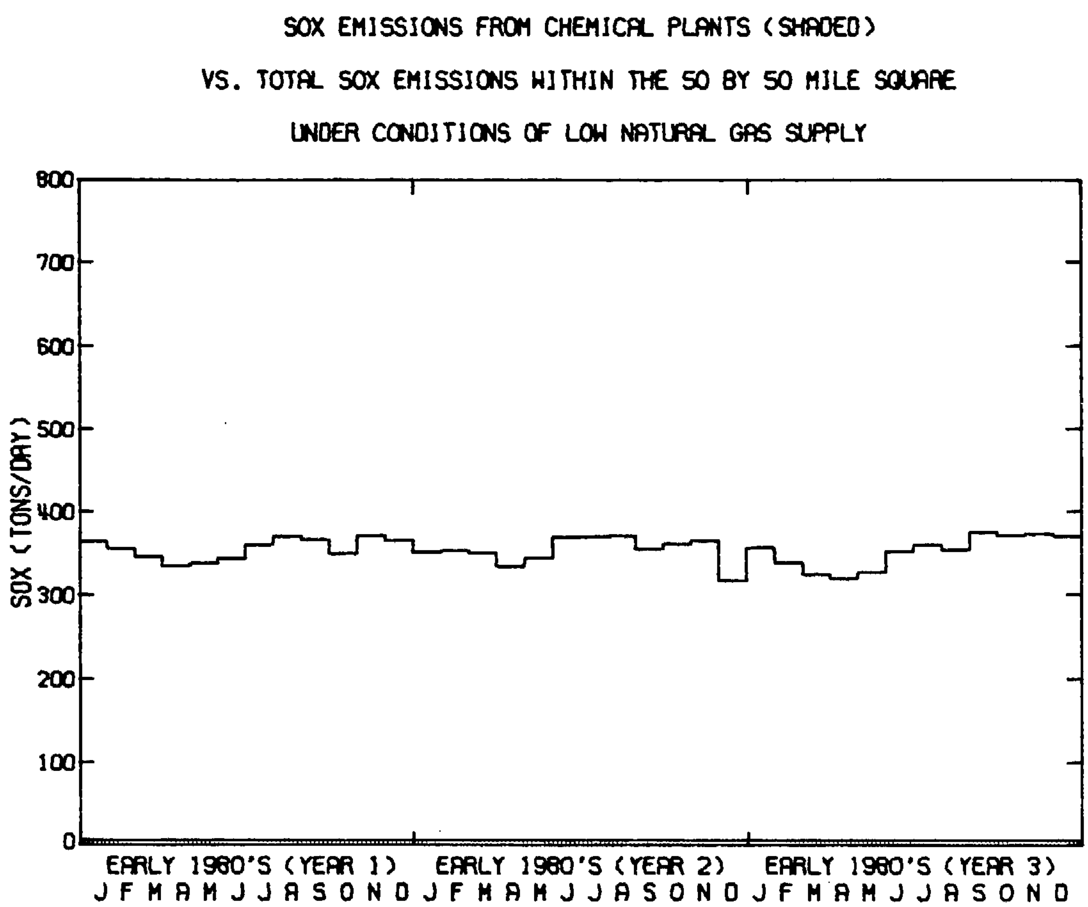

SOX EMISSIONS FROM CHEMICAL PLANTS (SHADED)
VS. TOTAL SOX EMISSIONS WITHIN THE 50 BY 50 MILE SQUARE
UNDER CONDITIONS OF LOW NATURAL GAS SUPPLY
SOX (TONS/DAY)
800
700
600
500
400
300
200
100
0
EARLY 1980'S (YEAR 1)
EARLY 1980'S (YEAR 2)
EARLY 1980'S (YEAR 3)
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D

Figure E1.11

Management District's 1976 sulfur balance on these facilities (South Coast Air Quality Management District, 1977a). One refinery whose tail gas unit was out of order in 1976 will be assumed to have been returned to complaince by the target date for our forecast. Projected sulfur recovery plant SO_x emissions for the early 1980's total 3.51 tons per day as shown in Figure E1.12, down from 93.53 tons per day in 1972. This emissions reduction is due to enforcement of the Los Angeles APCD's Rule 53.2 (now South Coast Air Quality Management District Rule 468).

E1.5.2 Sulfuric Acid Plants

Projected sulfuric acid plant SO_x emissions in the early 1980's are detailed in Figure E1.13. These emissions estimates were based upon the South Coast Air Quality Management District's 1976 sulfur balance on these facilities (South Coast Air Quality Management District, 1977a). Emissions from sulfuric acid plants in the early 1980's are expected to total about 3.08 tons per day, down from 25 tons per day in 1972. This emissions reduction was achieved by adding demisters and process modifications in accordance with Los Angeles APCD Rule 53.3.

E1.6 Emissions from Petroleum Refining and Production

Projected SO_x emissions from petroleum refining and production are compared to total SO_x emissions within the 50-by-50 mile square in Figure E1.14. The geographic distribution of emissions for a

SULFUR RECOVERY SOX EMISSIONS IN THE EARLY 1980'S: TEST YEAR 2 , IN TONS/DAY AS SO2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.34	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.04	0.0	0.0	0.04	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.06	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.66	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.07	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

SOX
TONS/DAY
3.512

Figure E1.12

SULFURIC ACID PLANT SOX EMISSIONS IN THE EARLY 1980'S: TEST YEAR 2 , IN TONS/DAY AS SO2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	C.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	C.0	0.0	0.0	C.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	C.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	C.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	C.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0
12	0.0	0.0	0.0	0.0	0.0	C.0	0.22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.06	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.80	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0
4	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	C.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	C.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

SOX
TONS/DAY
3.080

Figure E1.13

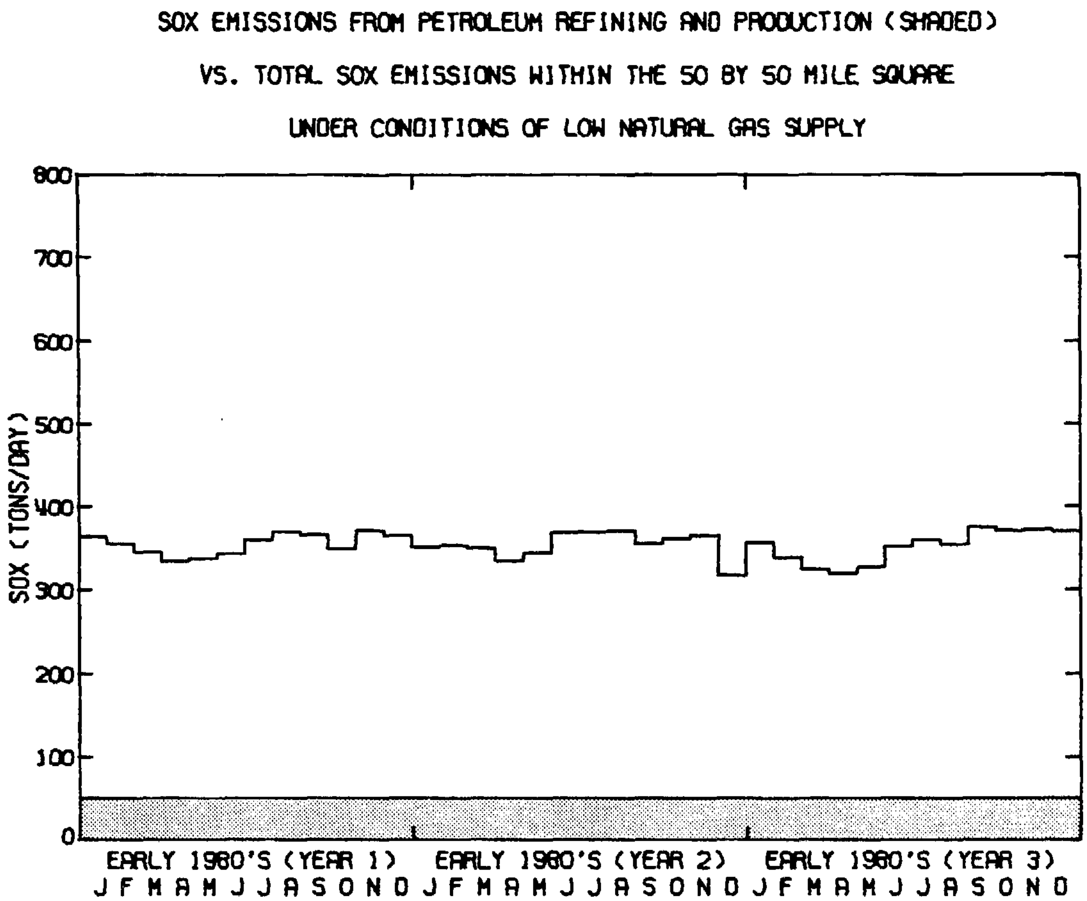

SOX EMISSIONS FROM PETROLEUM REFINING AND PRODUCTION (SHADED)
VS. TOTAL SOX EMISSIONS WITHIN THE 50 BY 50 MILE SQUARE
UNDER CONDITIONS OF LOW NATURAL GAS SUPPLY
SOX (TONS/DAY)
800
700
600
500
400
300
200
100
0
EARLY 1980'S (YEAR 1)
EARLY 1980'S (YEAR 2)
EARLY 1980'S (YEAR 3)
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D

Figure E1.14

day in the early 1980's is shown in Figure E1.15. For the purposes of this discussion, the source classes used to represent SO_x emissions from petroleum refining and production are:

- Fluid Catalytic Crackers
- Other Refinery Process Equipment
- Oil Field Production Operations

E1.6.1 Fluid Catalytic Crackers

Fluid Catalytic Cracker emissions anticipated in the early 1980's were based upon the South Coast Air Quality Management District's 1976 sulfur balance on local refineries (South Coast Air Quality Management District, 1977b). A total of 44.95 tons per day of SO_x were released from cracking operations in that year at locations as shown in Figure E1.16.

E1.6.2 Other Refinery Process Equipment

Other refinery process equipment SO_x emissions are modest by comparison to emissions from fluid catalytic cracking and sulfur recovery operations. The South Coast Air Quality Management District's 1976 sulfur balance on local refineries indicates SO_x emissions from other process units of 1.79 tons per day. Slightly over 1 ton per day of SO_x emissions is due to water treatment facilities, as shown in Figure E1.17. The remaining miscellaneous process unit emissions are from caustic regeneration and SO_2 treating, at locations as shown in Figure E1.18. All delayed cokers are now said to be connected to sulfur recovery plants during all phases of the coking cycle

PETRCLEUM PROCESSING SOX EMISSICNS IN THE EARLY 1980'S: TEST YEAR 2 , IN TONS/CAY AS SO2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.06	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	4.38	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.91	0.0	0.0	6.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	7.50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.20	3.10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.30	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

SOX
TONS/DAY
51.040

Figure E1.15

REFINERY CAT CRACKER SOX EMISSIONS IN THE EARLY 1980'S: TEST YEAR 2 , IN TONS/DAY AS SO2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	4.30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.90	0.0	0.0	6.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.20	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

SOX
TONS/DAY
44.950

Figure E1.16

SOUR WATER STRIPPER SOX EMISSIONS IN THE EARLY 1980'S: TEST YEAR 2, IN TONS/DAY AS SO2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.90	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

SOX
TONS/DAY
1.033

Figure E1.17

MISC. REFINERY UNIT SOX EMISSIONS IN THE EARLY 1980'S: TEST YEAR 2 , IN TONS/DAY AS SO2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.06	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.06	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.36	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.0	0.0	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

SOX
TONS/DAY
0.757

Figure E1.18

(Chatfield, 1978). Delayed coker blow-down unit emissions listed in the 1972 through 1974 historical emissions inventory of Appendix A2 of the study by Cass (1978) are now assumed to be fully controlled.

E1.6.3 Oil Field Production Operations

Under current regulations, sulfur oxides emissions from oil field fire flooding operations in Southern Orange County are expected to continue into the foreseeable future. 1977 source tests on these facilities indicate an emissions rate of 4.33 tons per day (Kaye, 1978), as shown in Figure E1.19. That emissions rate was assumed to represent conditions likely to prevail in the early 1980's.

E1.7 Miscellaneous Stationary Sources

The miscellaneous stationary source category includes SO_x emissions from:

- Petroleum Coke Calcining Kilns
- Glass Furnaces
- Ferrous Metals Industries
- Non-Ferrous Metals
- Miscellaneous Chemical Plants
- Mineral Processing Plants
- Sewage Treatment Plants
- Other Industrial Processes
- Industrial/Commercial/Institutional Incinerators

SO_x emissions from miscellaneous stationary sources are compared to total emissions within the 50-by-50 mile square in Figure E1.20.

OIL FIELD OPERATION SOX EMISSIONS IN THE EARLY 1980'S: TEST YEAR 2 , IN TONS/DAY AS SO2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.30	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

RESEDA, BURBANK, GLENDALE, PASADENA, AZUSA, GLENDORA, WEST COVINA, WEST LA, LOS ANGELES, SANTA MONICA, LENNOX, LYNWOOD, TORRANCE, LONG BEACH, ANAHEIM, GARDEN GROVE, SANTA ANA

SOX
TONS/DAY
4.300

Figure E1.19

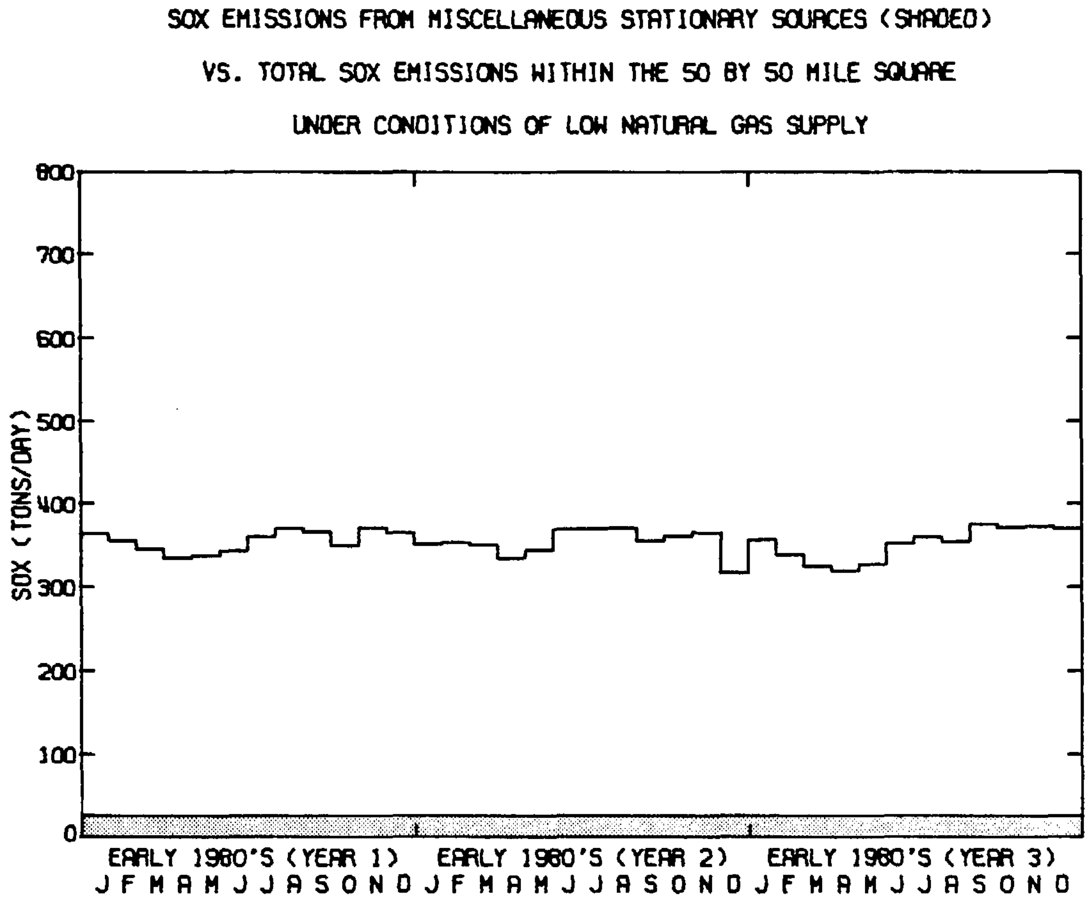

SOX EMISSIONS FROM MISCELLANEOUS STATIONARY SOURCES (SHADED)
VS. TOTAL SOX EMISSIONS WITHIN THE 50 BY 50 MILE SQUARE
UNDER CONDITIONS OF LOW NATURAL GAS SUPPLY
SOX (TONS/DAY)
800
700
600
500
400
300
200
100
0
EARLY 1980'S (YEAR 1)
EARLY 1980'S (YEAR 2)
EARLY 1980'S (YEAR 3)
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D

Figure E1.20

The spatial distribution of emissions from these sources is given in Figure E1.21.

E1.7.1 Petroleum Coke Calcining Kilns

At the time of our resurvey of emissions sources, only four of the five petroleum coke calcining kilns in the basin were in operation. Sulfur oxides emissions totalling 22.82 tons per day at locations shown in Figure E1.22 were calculated for these sources based upon recent South Coast Air Quality Management District source tests. That recent emissions behavior was assumed to represent the early 1980's if 1977 emission control regulations were to be continued.

E.1.7.2 Glass Furnaces

Sulfur oxides emissions from glass furnaces were discussed in Section A2.5.2 of Appendix A2 of the study by Cass (1978). Those estimates represented only emissions from loss of sulfur contained in raw materials charged to the furnaces; emissions from fuel oil combustion, if any, are included in our industrial fuel burning estimates. Discussions with South Coast Air Quality Management District personnel revealed no expected major changes in glass furnace operations other than increases in oil combustion which would already have been accounted for in our fuel burning survey. Therefore, late 1974 emissions from glass furnaces as given in Section A2.5.2 of Cass (1978) were used to represent SO_x emissions from glass furnace raw materials in the early 1980's. Approximately two tons per day of SO_x emissions are expected from 22 glass furnaces at 13 locations within the

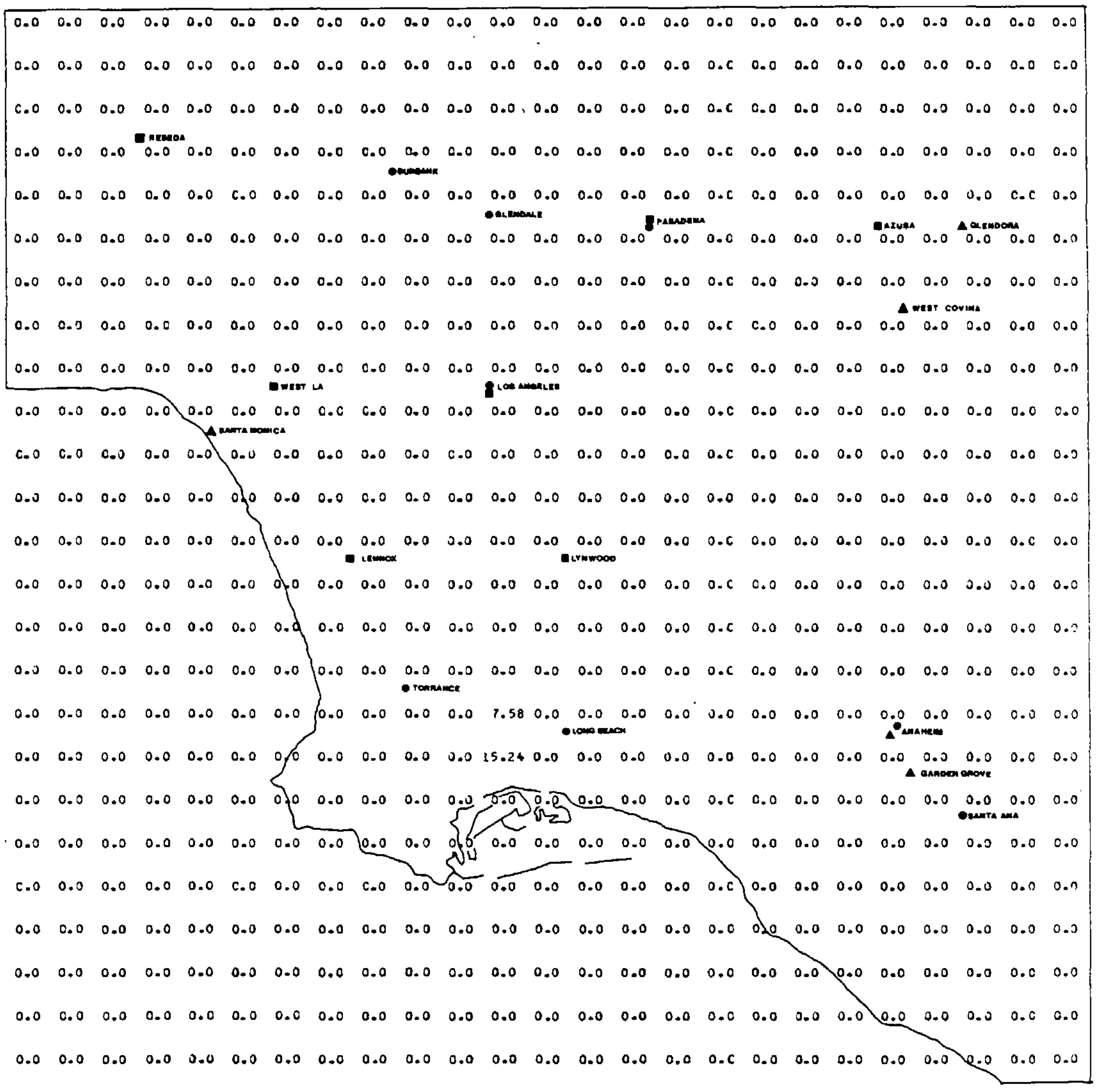
MISC. INDUSTRIAL PROCESS SOX EMISSIONS IN THE EARLY 1980'S: TEST YEAR 2 . IN TCNS/DAY AS SO2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	C.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0
21	0.0	0.0	0.0	0.C0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.02	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.02	0.0	0.0	0.0	0.0C	0.0	0.C	0.0	0.0	0.0	0.0	0.00	0.0	0.C	0.0
18	C.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.06	0.00	0.0	0.0	0.0	0.C	0.19	0.0	0.00	0.0	0.0	0.0	0.0	0.00
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0C	0.0C	0.0	0.0	0.0	0.0	0.0	0.CC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.09	0.36	0.0	0.0	0.00	0.C	0.0	0.43	0.0	0.0	0.0	0.02	0.C	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.51	0.39	0.0	0.00	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0C	0.0	0.00	0.02	0.0	C.0	0.22	0.00	0.00	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.10	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.02	0.0	0.CC	0.00	0.02	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.01	0.00	0.0	0.00	0.00	0.0	0.0	0.CC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	C.0	0.0	C.08	0.0	0.00	0.00	0.0	0.0	0.CC	0.0	0.0	0.13	0.0	0.0	0.0	0.0	0.0
10	C.0	0.0	0.0	C.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.CC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	7.58	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	C.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	15.24	0.00	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0C	0.00	0.0	0.00	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.42	0.0	0.0
5	C.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.18	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.35	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	C.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

SOX
TONS/DAY
26.5C2

Figure E1.21

PETROLEUM COKE KILN SOX EMISSIONS IN THE EARLY 1980'S: TEST YEAR 2 , IN TONS/DAY AS SO2



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	C.0
23	C.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	C.0	0.0	C.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	C.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	C.C	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	C.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	C.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	C.0	C.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	C.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.58	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	C.0	0.0	0.0	0.0	0.0	C.0	0.0	0.0	C.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

SOX
TONS/DAY
22.820

Figure E1.22

GLASS FURNACE SOX EMISSICNS IN THE EARLY 1980'S: TEST YEAR 2 , IN TONS/DAY AS SO2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.17	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.09	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.51	0.39	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.13	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.42	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

SOX
TONS/DAY
2.000

Figure E1.23

50-by-50 mile grid, as shown in Figure E1.23. An additional 0.23 tons per day of SO_x emissions are attributed to four off-grid furnaces which are included within the air quality modeling emission inventory.

E1.7.3 Ferrous Metals

Iron and steel industry emissions are dominated by Kaiser Steel located at Fontana, California, to the east of our grid system. Sulfur oxides emissions from that source in 1974 totalled 38.02 tons per day at a time when mill utilization stood at 91% of full capacity (see Table A2.10 of Appendix A2 of Cass (1978). In 1976, emissions from this source were reported as 34.09 tons per day (South Coast Air Quality Management District, 1978c).

From data given by Hunter and Helgeson (1976) it is estimated that coke oven gas accounted for about 23.05 tons/day or 61% of Kaiser's 1974 emissions total. Since that time Kaiser has entered into a consent agreement to desulfurize its coke oven gas. South Coast Air Quality Management District personnel estimate that 95% of the sulfur previously present in coke oven gas will be removed. 1980's emissions for Kaiser steel thus were estimated as follows: Kaiser's 1976 sulfur oxides emissions total was subdivided into 20.67 tons per day from coke oven gas and 13.42 tons per day from other sources, in the same relative proportions as observed in 1974. Then coke oven gas was desulfurized by 95% and the resulting new level of coke oven gas emissions were recombined with the remaining non-coke oven gas subtotal. Total Kaiser facility emissions of 14.45 tons per day are estimated for the early 1980's. One additional off-grid steel processing facility contributes about 0.1 ton per day of SO_x emissions, bringing total emissions from this source class to 14.55 tons per day at locations itemized in Table E1.19.

E1.7.4 Nonferrous Metals Industries

The principal source of sulfur oxides emissions from nonferrous metals industries arises from secondary lead smelters which recover lead from scrap automobile batteries. In 1974, SO_x emissions from five secondary lead smelters at two locations within the 50-by-50 mile grid totalled 8.67 tons per day.

In December 1977, the South Coast Air Quality Management District adopted Rule 1101 which required an approximately 90% reduction in SO_x emissions from those sources not already having appropriate emissions control equipment. Review of the proceedings of that regulatory discussion (South Coast Air Quality Management District, 1977c) permitted us to identify two additional small secondary lead smelters which had been excluded from the 1972 through 1974 emissions inventory. Combining those sources into our inventory, and assuming that the emissions reductions required under Rule 1101 are implemented on schedule, yields an emissions estimate for these sources of 0.89 tons per day of SO_x in the early 1980's.

When combined with three other miscellaneous metallurgical process sources, total emissions from this source class rise to 0.985 tons per day. The spatial distribution of emissions from on-grid nonferrous metals processing plants is given in Figure E1.24. Off-grid sources are itemized in Table E1.19.

NON-FERROUS METALS SOX EMISSIONS IN THE EARLY 1980'S: TEST YEAR 2 , IN TONS/DAY AS SO2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	C.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0
2C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.06	0.0	0.0	0.0	0.0	0.C	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.35	0.0	0.0	0.0	0.C	0.0	0.43	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.07	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	C.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

SOX
TONS/DAY
0.944

Figure E1.24

TABLE E1.19

Itemization of Non-Utility Off-Grid Sources Included Within the Air Quality Modeling Emissions Projection for the Early 1980's

Stationary Source Type	Grid Square Location East/West I	Grid Square Location North/South J	Emission Rate (tons/day SO_x)
Glass Furnaces			
Thatcher Glass	04	30	0.124[a]
Brockway Glass	26	17	0.103[a]
Steel Industries			
Kaiser Steel	33	18	14.45[b]
Ameron Steel	32	19	0.10[a]
Nonferrous Metals			
San Bernardino Metals	39	19	0.041[c]
Mineral Products			
Crestlite	29	-3	1.00[a]
Rockwool	33	18	0.90[a]

References: (a) See 1974 data in Table A2.11 of Cass (1978)
(b) See Text, Section E1.7.3
(c) South Coast Air Quality Management District (1977c)

E1.7.5 Miscellaneous Chemical Plants

Two small chemical process operations within the 50-by-50 mile grid are included within this source class. One process involves detergent manufacturing, while the other involves SO_2 treating of bottles destined for medical use. Sulfur oxides emissions from these sources are estimated at 0.038 tons per day at locations shown in Figure E1.25.

E1.7.6 Mineral Processing Plants

Mineral processing plant emissions in the early 1970's were described in Section A2.5.4 of Cass (1978). Under current regulations, emissions from these sources are expected to remain unchanged into the early 1980's. Both mineral processing plants of interest are located beyond our 50-by-50 mile grid. Their emissions totalling 1.90 tons per day of SO_x are itemized in Table E1.19.

E1.7.7 Sewage Treatment Plants

Sewage treatment plant digester gas is used for powering treatment plant equipment. On some occasions, excess gas is flared. Hydrogen sulfide contained in that digester gas is converted to sulfur oxides air pollutant emissions upon combustion in either case.

Los Angeles area sewage works are currently in the process of upgrading all treatment plants to full secondary treatment standards. When that occurs, a far greater amount of sewage sludge will be processed at these plants than was the case in the past. If that slude is digested before disposal, then digester gas emissions may increase. But until a final processing scheme has been adopted, it is impossible for us to estimate future

MISC. CHEMICAL PLANT SOX EMISSIONS IN THE EARLY 1980'S: TEST YEAR 2 , IN TONS/DAY AS SO2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

SOX
TONS/DAY
0.038

Figure E1.25

emissions levels accurately. Therefore, it will be assumed that new source review rules will limit the potential SO_x emissions increase to a very small quantity.

An inventory of digester gas SO_x emissions in the early 1970's was presented in Section A2.5.6 of the study by Cass (1978). That inventory will be assumed to represent the early 1980's. Emissions of 0.64 tons per day of SO_x would then be indicated at locations as shown in Figure E1.26.

E1.7.8 Other Industrial Processes

In Section A2.5.5 of Cass (1978), a survey was performed which identified 42 items of industrial equipment with emissions too small to warrant a discussion of their mode of operation. Those sources are assumed to continue operation into the early 1980's, with emissions totalling 0.023 tons per day. All sources in this group have SO_x emissions less than 0.005 tons per day, and thus would not show on a gridded emissions summary given in tons per day to two decimal places.

E1.7.9 Permitted Incinerators

Historical emissions from incinerators under permit in the early 1970's were discussed in Section A2.5.7 of Cass (1978). That survey will be assumed to represent emissions from these sources in the early 1980's. A total of 0.074 tons per day of sulfur oxides are emitted from 49 incinerators, most of which are too small to show on one of our emissions maps.

SEWAGE TREATMENT SOX EMISSIONS IN THE EARLY 1980'S: TEST YEAR 2 , IN TONS/DAY AS SO2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.18	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.35	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

SOX
TONS/DAY
0.641

Figure E1.26

E1.8 Mobile Sources

The mobile source emissions projection includes contributions from a variety of gasoline and diesel highway vehicles, plus ships, railroads, and aircraft. The categories used to represent mobile source emissions are:

- Catalyst-equipped automobiles and light trucks on surface streets
- Catalyst-equipped automobiles and light trucks on freeways
- Noncatalyst gasoline-fueled vehicles
- Diesel trucks and buses
- Airport operations
- Shipping operations
- Railroad operations

As mentioned previously, the principal reason for subdividing automotive and truck traffic into the four categories shown is to permit an analysis of the future sulfate air quality impact of oxidation catalyst-equipped vehicles. Catalytic converters were introduced to the vehicle fleet at the start of the 1975 model year in an effort to reduce automotive hydrocarbons and CO emissions. These oxidizing catalysts also are capable of oxidizing a portion of the sulfur originally contained in gasoline to form sulfuric acid mist at the car's tail pipe. A change in the relative proportion of SO_2 and H_2SO_4 in vehicle exhaust in future years can be modeled conveniently if the catalyst-equipped vehicle SO_x emissions are separable from noncatalyst vehicles in the inventory. Only autos and light trucks are currently being equipped with oxidation catalysts. Freeway and surface street driving are separated since driving cycle influences catalyst-equipped vehicle sulfuric acid mist emission rates.

Sulfuric acid mist emission rates from post-1975 automobiles and light trucks are a strong function of emission control system design. Choices available to manufacturers over the next few years include oxidation catalysts alone or with air injection, three-way catalysts alone or with air injection and a clean-up oxidation catalyst, and lean burning or stratified charge engines. Each of these vehicle types have different characteristic ratios of sulfates to total sulfur in their exhaust (Sommers et al., 1977). From conversations with California Air Resources Board personnel (Rubenstein, 1978), it would appear that manufacturer's plans through the 1980 model year are essentially fixed at present. Thus the sales-weighted fraction of the vehicle population expected to use each particular emissions control system can be estimated yearly from 1975 through 1980. Beyond 1980 or 1981, the choice of future emissions control equipment and the degree of deterioration of emissions control hardware already on the road becomes so uncertain that detailed analysis of the level contemplated here must await further data. For that reason, the sulfur oxides emissions from mobile sources in the early 1980's will be calculated for conditions expected in the year 1980.

E1.8.1 Traffic Volume Projections to the Year 1980

In Section A2.6.1 of the study by Cass (1978), baseline surface street traffic volumes within the 50-by-50 mile square were calculated for the year 1974. Those 1974 traffic volume estimates are shown in

Figure E1.27. As part of that survey, the annual compound rate of growth in surface street traffic volume between 1969 and 1974 was computed within "neighborhoods" defined by sectioning the 50-by-50 mile study area into ten-mile-by-ten-mile subdivisions. Those neighborhood-averaged growth rates are reproduced in Figure E1.28.

Growth rates averaged over each neighborhood were assigned to each individual 2-mile-by-2-mile square in that neighborhood. The resulting matrix was then used to scale the 1974 surface street traffic counts of Figure E1.27 to the year 1980 as shown in Figure E1.29. Total surface street traffic in 1974 is estimated to average 79,376,000 vehicle miles traveled per day within the 50-by-50 mile study area. By 1980, surface street traffic volume is expected to increase to 87,395,000 vehicle miles traveled per day.

Freeway traffic growth between 1969 and 1974 was next examined by the neighborhood scale factor method previously described for surface streets. Freeway traffic counts in those years derived in Appendix A2 of Cass (1978) are reproduced in Figures E1.30 and E1.31. The 1969 traffic volumes were subtracted from 1974 traffic on a grid-square-by-grid-square basis. Then the annual rate of growth of freeway traffic in each square was determined. Much of the growth in freeway traffic over the 1969 to 1974 period was due to new freeway construction. Between 1975 and 1980 new freeway projects are expected to be minimal. Therefore, an attempt was made to calculate future growth in freeway traffic on the basis of only that part of the historic freeway traffic growth rate which was due to expanded use of existing roadways. Calculated growth rates of greater

SURFACE STREET TRAFFIC COUNTS FOR 1974 IN THOUSANDS OF VMT PER DAY

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	37	12	36	160	157	202	158	50	32	20	1	0	0	4	2	0	1	1	0	0	0	0	2	0	0
24	64	166	217	240	271	260	178	100	77	98	79	7	2	0	0	1	0	0	0	0	0	0	2	0	0
23	147	274	256	256	286	347	295	274	63	23	29	171	54	4	0	0	0	0	0	0	0	0	2	0	0
22	257	269	268	269	284	487	386	324	249	253	4	143	63	99	123	17	0	1	0	0	0	1	2	0	0
21	149	127	115	208	196	412	315	329	290	211	223	223	22	189	263	175	129	75	47	0	6	6	2	0	0
20	29	35	20	14	70	75	145	186	139	30	258	255	201	171	335	307	240	217	182	76	114	135	137	69	29
19	10	29	0	2	35	84	38	313	576	452	273	173	122	200	249	226	235	184	159	129	140	210	129	59	69
18	0	21	0	8	117	341	485	661	617	689	499	238	229	241	300	242	249	241	113	189	254	221	64	9	89
17	56	76	118	140	277	617	417	553	576	564	677	611	306	210	196	74	107	172	130	179	129	16	43	45	66
16	0	0	0	149	570	306	407	314	496	497	540	346	342	309	278	194	126	42	38	226	109	40	48	24	4
15	0	0	0	0	0	339	283	283	345	531	484	369	296	277	303	243	227	84	25	100	48	104	38	13	0
14	0	0	0	0	0	117	295	459	435	368	399	277	327	309	269	310	233	362	146	51	25	1	43	1	5
13	0	0	0	0	0	24	290	329	441	316	319	258	296	259	392	322	281	287	222	294	181	119	24	10	8
12	0	0	0	0	0	0	210	283	364	398	178	269	297	261	302	295	282	165	139	76	150	132	110	66	4
11	0	0	0	0	0	0	137	239	458	358	213	122	274	317	305	114	117	127	331	219	337	229	95	55	34
10	0	0	0	0	0	0	9	383	345	246	116	74	191	270	403	241	163	220	361	287	350	261	122	33	6
9	0	0	0	0	0	0	1	254	324	265	164	88	265	180	264	195	183	205	307	270	329	183	133	118	11
8	0	0	0	0	0	0	49	129	200	283	238	147	387	362	297	192	88	137	247	260	276	161	182	176	30
7	0	0	0	0	0	0	81	52	29	151	136	70	147	118	143	207	71	148	251	237	237	270	288	197	34
6	0	0	0	0	0	0	4	5	26	187	82	0	0	0	0	37	56	135	231	137	180	220	206	106	20
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	47	31	175	177	158	101	109	15	35
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	47	165	140	338	293	136	39	20
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	44	136	378	128	155	13	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	297	267	70	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	162	24	0

TOTAL SURFACE STREET TRAFFIC FOR 1974 = 79375.8 IN THOUSANDS OF VMT PER DAY

Figure E1.27

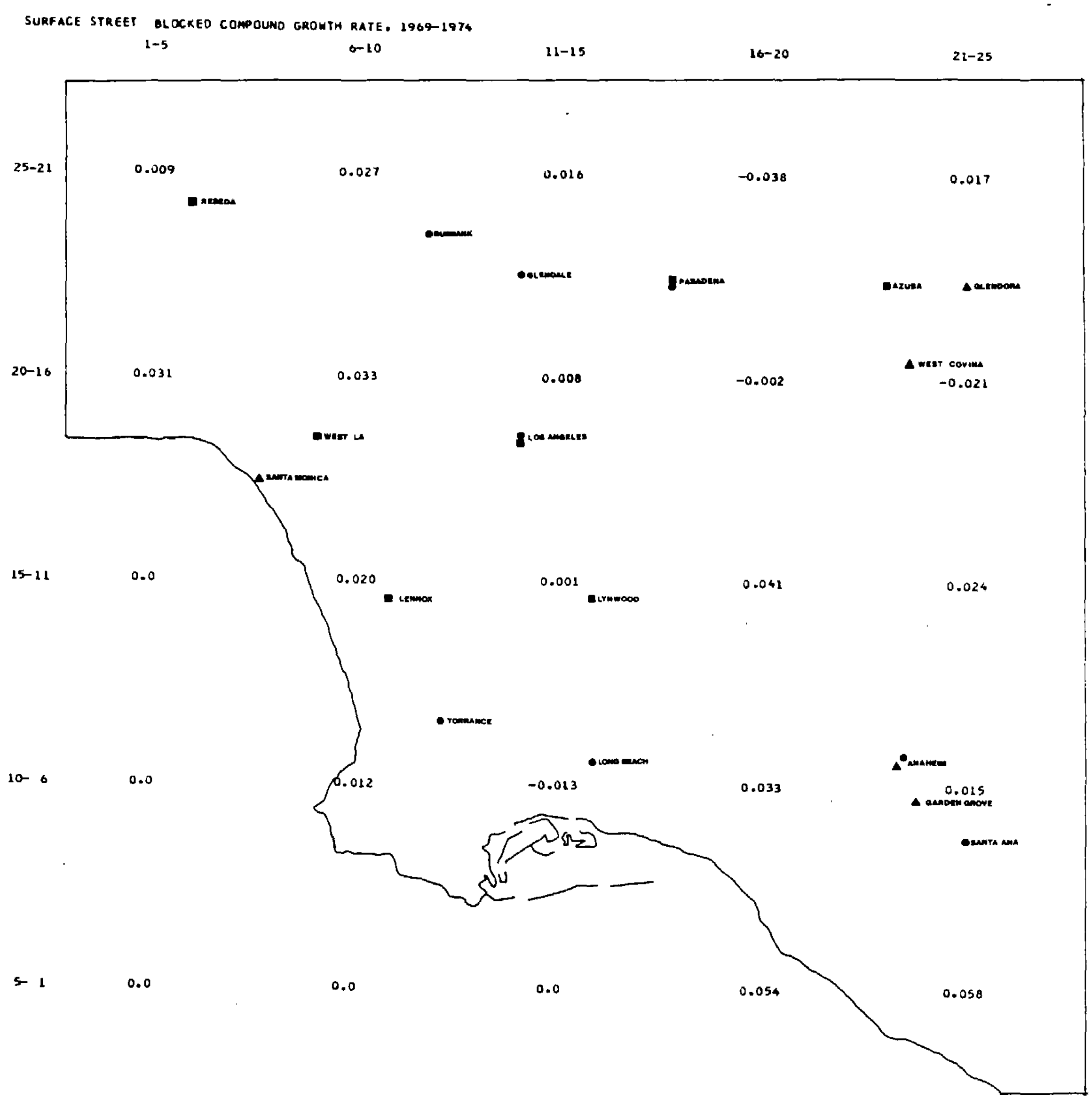

SURFACE STREET BLOCKED COMPOUND GROWTH RATE, 1969-1974
1-5
6-10
11-15
16-20
21-25
25-21
0.009
0.027
0.016
-0.038
0.017
GLENDALE
PASADENA
AZUSA
GLENDORA
20-16
0.031
0.033
0.008
-0.002
WEST COVINA
-0.021
WEST LA
LOS ANGELES
SANTA MONICA
15-11
0.0
0.020
LENNOX
0.001
LYNWOOD
0.041
0.024
TORRANCE
LONG BEACH
ANAHEIM
10- 6
0.0
0.012
-0.013
0.033
0.015
GARDEN GROVE
SANTA ANA
5- 1
0.0
0.0
0.0
0.054
0.058

Figure E1.28

SURFACE STREET TRAFFIC COUNTS FOR 1980 IN THOUSANDS OF VMT PER DAY

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	38	13	37	164	161	231	181	57	37	22	1	0	0	4	2	0	1	1	0	0	0	0	2	0	0
24	66	171	223	246	278	297	204	114	88	113	86	8	2	0	0	1	0	0	0	0	0	0	2	0	0
23	151	281	262	262	293	397	338	313	72	26	31	186	59	4	0	0	0	0	0	0	0	0	2	0	0
22	264	276	275	276	291	557	441	371	285	289	4	155	68	107	133	13	0	1	0	0	0	1	2	0	0
21	153	130	118	214	201	471	360	377	332	242	241	241	24	205	285	139	102	59	37	0	7	7	2	0	0
20	34	41	23	16	82	90	173	222	166	35	267	264	208	176	347	301	235	213	179	75	99	118	119	60	25
19	12	34	0	2	41	100	45	372	685	537	282	179	126	207	257	222	231	181	156	127	122	183	113	52	61
18	0	25	0	9	136	405	577	786	733	819	516	246	236	250	311	237	244	236	111	186	221	193	56	7	78
17	65	89	138	163	322	733	495	657	685	670	701	632	316	217	203	73	105	169	128	176	112	14	38	39	57
16	0	0	0	174	664	364	484	374	590	591	559	358	353	319	288	190	124	42	38	222	95	35	41	21	3
15	0	0	0	0	88	380	317	317	387	595	483	365	296	276	303	306	286	106	32	126	54	117	42	15	0
14	0	0	0	0	0	132	331	514	488	412	398	276	326	309	268	391	294	456	184	65	28	1	48	1	6
13	0	0	0	0	0	27	325	368	494	355	318	257	296	258	391	407	354	362	280	371	203	134	27	11	9
12	0	0	0	0	0	0	295	317	408	446	178	268	297	260	302	373	356	209	176	96	168	148	123	74	5
11	0	0	0	0	0	0	154	268	513	401	212	122	273	316	305	144	148	161	418	277	377	256	106	62	39
10	0	0	0	0	0	0	10	411	370	263	106	68	175	248	370	292	197	266	437	346	378	282	132	36	7
9	0	0	0	0	0	0	1	273	347	284	150	80	243	165	242	236	222	247	371	326	356	198	144	127	12
8	0	0	0	0	0	0	52	138	214	303	218	135	355	332	273	232	107	166	299	315	298	174	196	191	32
7	0	0	0	0	0	0	34	55	31	162	124	64	135	108	131	250	85	179	303	286	256	291	311	213	37
6	0	0	0	0	0	0	4	5	28	201	15	0	0	0	0	45	68	163	279	166	194	238	222	114	22
5	0	0	0	0	0	0	0	0	0	5	5	0	0	0	0	0	64	42	237	241	215	137	148	20	48
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	64	225	191	461	399	186	53	27
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	60	185	515	174	212	18	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	405	364	96	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	221	33	0

RESEDA
BURBANK
GLENDALE
PASADENA
AZUSA
GLENDORA
WEST COVINA
WEST LA
LOS ANGELES
SANTA MONICA
LENNOX
LYNWOOD
TORRANCE
LONG BEACH
ANAHEIM
GARDEN GROVE
SANTA ANA

TOTAL SURFACE STREET TRAFFIC FOR 1980 = 87394.6 IN THOUSANDS OF VMT PER DAY

Figure E1.29

FREEWAY TRAFFIC COUNTS FOR 1969 IN THOUSANDS OF VMT PER DAY (PRESENT STUDY)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	68	9	0	0	102	136	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	164	53	179	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	232	0	160	145	164	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	292	0	102	41	103	150	0	0	0	37	0	0	0	0	0	0	0	0	0	0	0
21	159	248	304	352	759	414	407	494	179	322	301	49	0	4	0	0	0	12	0	0	0	0	0	0	0
20	0	0	0	0	325	0	0	96	296	0	330	13	14	124	24	0	0	29	79	65	40	0	0	0	0
19	0	0	0	0	348	0	0	0	116	299	165	380	206	61	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	141	209	0	0	0	115	428	635	212	274	314	324	316	281	379	246	258	196	181	179	171
17	0	0	0	0	0	416	170	289	403	474	832	546	503	451	224	228	197	332	47	0	0	0	0	0	0
16	0	0	0	0	91	235	541	87	0	0	478	393	575	543	0	0	273	124	142	67	0	0	0	0	0
15	0	0	0	0	0	0	256	168	0	0	360	0	0	239	313	0	234	0	0	2	47	0	0	0	0
14	0	0	0	0	0	0	0	382	0	0	323	0	0	215	144	386	12	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	345	0	0	286	0	0	220	0	520	21	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	323	41	0	249	0	80	116	0	295	302	96	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	377	340	222	0	223	0	54	314	91	239	282	0	0	13	0	0	0
10	0	0	0	0	0	0	0	0	0	0	584	40	213	0	0	213	0	33	77	345	216	123	98	138	0
9	0	0	0	0	0	0	0	0	0	0	122	341	519	370	345	201	0	0	0	0	176	78	0	135	0
8	0	0	0	0	0	0	0	0	0	0	101	45	60	0	0	578	348	241	163	0	33	412	153	169	0
7	0	0	0	0	0	0	0	0	0	0	78	22	0	0	0	0	0	180	112	171	145	0	248	135	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	163	70	0	0	56	265	94
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	135	165	137	212	0	96
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	53	76	64
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

RESEDA
BURBANK
GLENDALE
PASADENA
AZUSA
GLENDORA
WEST COVINA
WEST LA
LOS ANGELES
SANTA MONICA
LENNOX
LYNWOOD
TORRANCE
LONG BEACH
ANAHEIM
GARDEN GROVE
SANTA ANA

TOTAL VMT/DAY IN 1969 = 40155. IN THOUSANDS OF VMT PER DAY

Figure E1.30

FREEWAY TRAFFIC COUNTS FOR 1974 IN THOUSANDS OF VMT PER DAY (PRESENT STUDY)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	93	34	0	0	112	161	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	174	59	208	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	241	0	186	150	176	0	6	38	21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	302	0	130	51	111	161	0	0	15	56	0	0	0	0	0	0	0	0	0	0	0
21	172	257	316	376	795	413	389	532	217	386	383	134	49	58	0	0	72	44	0	0	0	0	0	0	0
20	0	0	0	0	343	0	0	106	348	0	331	13	55	140	22	0	0	56	173	163	126	54	42	59	4
19	0	0	0	0	362	0	0	0	133	315	163	381	192	66	0	0	0	0	167	0	0	57	59	71	0
18	0	0	0	0	144	216	0	0	0	116	425	636	208	275	301	308	286	252	448	203	211	161	144	250	197
17	0	0	0	0	0	443	183	313	431	495	880	550	522	504	274	267	240	388	51	0	0	0	0	98	4
16	0	0	0	0	104	270	582	95	0	0	490	432	614	571	0	0	312	181	261	156	0	0	60	253	78
15	0	0	0	0	0	0	342	184	0	0	386	0	0	236	340	0	253	0	0	6	149	135	169	0	0
14	0	0	0	0	0	0	0	393	0	0	352	0	0	214	163	429	12	0	0	0	0	0	120	0	0
13	0	0	0	0	0	0	0	358	0	0	329	0	0	221	0	608	22	0	0	0	0	95	0	0	0
12	0	0	0	0	0	0	0	340	41	0	291	0	78	116	0	412	317	91	0	0	0	128	0	0	0
11	0	0	0	0	0	0	0	0	401	368	258	0	305	331	316	584	259	272	258	0	0	157	0	0	76
10	0	0	0	0	0	0	0	0	0	0	650	40	264	0	0	297	0	122	244	542	331	267	202	348	69
9	0	0	0	0	0	0	0	0	0	0	191	340	529	372	361	293	0	0	0	0	233	100	0	217	0
8	0	0	0	0	0	0	0	0	0	0	144	45	67	0	0	673	404	251	159	0	37	510	193	273	0
7	0	0	0	0	0	0	0	0	0	0	135	23	0	0	0	0	0	243	145	179	160	0	302	235	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	244	103	0	0	89	368	114
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	197	239	207	349	0	116
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	80	93	145	131
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

RESEDA, BURBANK, GLENDALE, PASADENA, AZUSA, GLENDORA, WEST COVINA, WEST LA, LOS ANGELES, SANTA MONICA, LENNOX, LYNWOOD, TORRANCE, LONG BEACH, ANAHEIM, GARDEN GROVE, SANTA ANA

TOTAL VMT/DAY IN 1974 = 49523. IN THOUSANDS OF VMT PER DAY

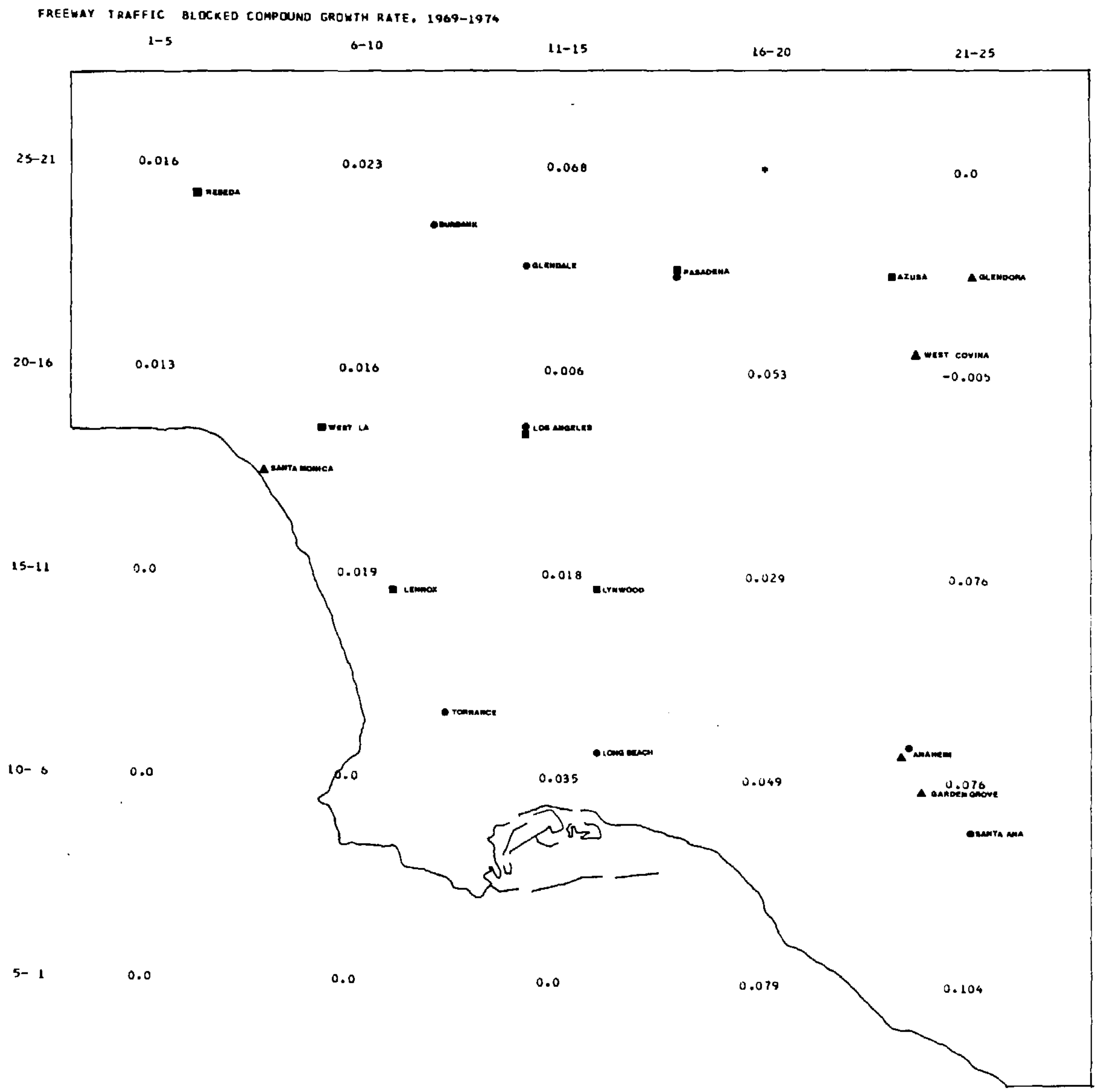
Figure E1.31

than 20% per year in individual grid squares were almost always due to construction of a new freeway segment between 1969 and 1974. Therefore, growth rate data from such squares were disregarded. Freeway traffic growth rates from the remaining squares within each ten-mile-by-ten mile "neighborhood" next were averaged. Then 1974 freeway traffic volumes were projected to 1980 using the compound freeway traffic growth rates calculated for each neighborhood.

In two neighborhoods, freeway traffic was almost completely dominated by new freeways constructed since 1969. Alternative projection methods had to be engaged in those cases. In the Diamond Bar area (neighborhood I 21-25 by J 15-11) the new freeways were opened prior to 1974, and 1980 volumes could be projected from 1974 data using the growth rate calculated for the next neighborhood to the south. In the Pasadena area (neighborhood I 16-20 by J 25-21) the new freeway of interest was opened after 1974 and baseline traffic counts were not available. 1980 traffic on that newly opened stretch of Interstate 210 was estimated manually by looking at projected 1980 traffic flows on similarly sized sections of other freeways. Neighborhood-averaged freeway traffic growth rates are given in Figure E1.32. The resulting 1980 freeway traffic projections are shown in Figure E1.33.

E1.8.2 Sulfur Oxides Emissions from Highway Vehicles

The annual average daily traffic densities given in Figures E1.29 and E1.33 were then used to compute highway vehicle SO_x emissions on a spatially-resolved basis. Total surface street and freeway traffic densities were uniformly apportioned to vehicle miles traveled daily by



* FREEWAY TRAFFIC GROWTH IN THIS REGION IS LARGELY DUE TO NEW FREEWAY CONSTRUCTION IN THE POST-1974 PERIOD. FUTURE TRAFFIC VOLUME WILL BE ESTIMATED MANUALLY.

Figure E1.32

FREEWAY TRAFFIC COUNTS FOR 1980 IN THOUSANDS OF VMT PER DAY

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	102	37	0	0	123	184	0	0	0	C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	191	67	238	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0 ■ RESEDA	265	0	213	171	201	0	8	56	31	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	332	0	148	58	127	184 ● BURBANK	0	0	22	83	0	0	0	0	0	0	0	0	0	0	0
21	189	283	348	414	876	473	445	609	248	442	568	198 ● GLENDALE	72	86	(200) ■ PASADENA	(200)	(200)	(88)	0	0	0	0	0	0	0
20	0	0	0	0	369	0	0	116	383	0	343	13	57	145	22	0	0	(112)	235	222	■ AZUSA 122	52	▲ GLENDORA 40	57	3
19	0	0	0	0	390	0	0	0	146	346	168	394	199	68	0	0	0	0	227	0	0 ▲ WEST COVINA	55	57	68	0
18	0	0	0	0	155	237	0	0	0	127	440	659	215	285	312	419	389	343	610	276	204	156	139	242	191
17	0	0	0	0	0	487	201 ■ WEST LA	344	474	544	912	570 ■ LOS ANGELES	541	522	284	363	327	528	69	0	0	0	0	95	3
16	0	0	0	0	112	297 ▲ SANTA MONICA	640	104	0	0	507	447	636	591	0	0	425	246	355	212	0	0	58	245	75
15	0	0	0	0	0	0	381	205	0	0	430	0	0	263	379	0	299	0	0	7	231	209	262	0	0
14	0	0	0	0	0	C	0	438	0	0	392	0	0	238	181	508	14	0	0	0	0	0	186	0	0
13	0	0	0	0	0	0	0	399	0 ■ LENNOX	0	367	0	0	246 ■ LYNWOOD	0	720	26	0	0	0	0	147	0	0	0
12	0	0	0	0	0	0	0	379	45	0	324	0	87	129	0	488	375	107	0	0	0	198	0	0	0
11	0	0	0	0	0	0	0	0	447	410	287	0	340	369	352	692	306	322	305	0	0	243	0	0	117
10	0	0	0	0	0	0	0	0	0	0 ● TORRANCE	797	49	323	0	0	382	0	162	324	721	513	414	313	539	105
9	0	0	0	0	0	0	0	0	0	0	222	417	649	456 ● LONG BEACH	442	390	0	0	0	0	361 ▲● ANAHEIM	155	0	336	0
8	0	0	0	0	0	0	0	0	0	0	176	55	82	0	0	896	538	334	211	0	57	790 ▲ GARDEN GROVE	294	423	0
7	0	0	0	0	0	0	0	0	0	0	165	28	0	0	0	0	0	323	193	238	248	0	468 ● SANTA ANA	364	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	324	137	0	0	138	570	176
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	310	433	375	632	0	210
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	144	177	262	237
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TOTAL FREEWAY TRAFFIC FOR 1980 = 60220.3 IN THOUSANDS OF VMT PER CAY

NOTE: ( ) INDICATES ROUGH ESTIMATE OF FUTURE TRAFFIC VOLUME ON A STRETCH OF FREEWAY COMPLETED AFTER 1974.

Figure E1.33

automobiles and light trucks, heavy duty gasoline trucks and buses, and diesel trucks and buses according to the fraction of total VMT driven by each vehicle type as given in Table E1.20. Automotive and light truck traffic in 1980 was subdivided into the fraction traveled by 1975 and later model year vehicles ("catalyst-equipped" cars and trucks) and older cars ("noncatalyst-equipped" cars and trucks) on the basis of mileage accumulation estimates given for each model year in Table E1.21.

Average vehicle miles traveled daily by each vehicle type were converted to annual average fuel quantities consumed in each grid cell daily using the fuel economy data given in Table E1.20. In the case of 1975 and later model year cars and light trucks, that fuel consumption figure was calculated in Table E1.21 as a weighted average over several model years with progressively improving fuel economy, as expected from manufacturers response to the 1975 Energy Policy and Conservation Act (see Marks, 1977).

Sulfur oxides emissions for each vehicle type were then calculated from the sulfur content of the fuel used. Diesel fuel was taken as 0.23 percent sulfur by weight based on historical data for the year 1973 as given previously in Table A2.13 of Cass (1978). The sulfur content of the entire gasoline pool was also held at a level based on historical experience, subject to the sulfur content of unleaded gasoline in 1980 not exceeding present California regulatory limits:

$$f_u \cdot s_u + f_l \, s_l = s_{t_o} \qquad \text{(E1.1)}$$

$$\text{subject to} \quad s_u < 0.04 \qquad \text{(E1.2)}$$

TABLE E1.20

Percentage of Vehicle Miles Traveled and Fuel Economy for each Vehicle Type in 1980

Vehicle Type	Fraction of Daily Total Vehicle Miles Traveled (a)(b)	Weighted Average Fuel Economy (miles/gallon)
Automobiles		
Catalyst-Equipped	53.0%	17.8[c]
Non-Catalyst Type	23.8%	13.6[d]
Light Trucks		
Catalyst-Equipped	9.2%	13.1[e]
Non-Catalyst Type	4.1%	10.0[d]
Medium and Heavy Duty Gasoline Trucks and Buses	6.5%	6.83[f]
Diesel Trucks and Buses	3.5%	4.6[d]

Notes:

(a) Fraction of vehicle miles traveled by automobiles, light trucks, medium and heavy gasoline trucks and buses and diesel trucks and buses computed from 1975 data reported for the South Coast Air Basin by TRW (Goodman et al. 1977; Arledge and Tan, 1977).

(b) Light duty vehicle miles traveled are divided into 69% by catalyst equipped vehicles and 31% by non-catalyst vehicles, as computed from Table E1.21.

(c) Computed in Table E1.21.

(d) See Environmental Protection Agency (1975).

(e) Assuming improvement is newer light track fuel economy proportional to that observed for newer automobiles.

(f) Heavy trucks computed at 6 mpg (Environmental Protection Agency, 1975); medium trucks evaluated at 8 mpg.

TABLE E1.21

Gasoline Use Calculation for 1980 Auto Fleet Light Duty Vehicle Use

Age (years)	Model Year	Fraction of Total Vehicles In Use (c)	Annual Avg Mileage Driven (c)	Fraction of Annual Travel	Fuel Economy (mpg)	Weighted Average Fuel Economy (mpg)
1	1980	0.083	15,900	0.116	20.0[a]	
2	1979	0.103	15,000	0.135	19.0[a]	
3	1978	0.102	14,000	0.125	18.0[a]	wt. avg.
4	1977	0.106	13,100	0.122	17.5[b]	17.8
5	1976	0.099	12,200	0.106	16.5[b]	
6	1975	0.087	11,300	0.086	14.7[b]	
7	1974	0.092	10,300	0.083		
8	1973	0.088	9,400	0.072		
9	1972	0.068	8,500	0.051		
10	1971	0.055	7,600	0.037		13.6[c][d]
11	1970	0.039	6,700	0.023		
12	1969	0.021	6,700	0.012		
≥13	1968(-)	0.057	6,700	0.033		

Notes: (a) Energy Policy and Conservation Act Goals (see Marks, 1977).

(b) U.S. Environmental Protection Agency, Fleet Average Fuel Economy Data, reduced to 94% of measured value (see Bureau of National Affairs, 1977a,b and 1978).

(c) Environmental Protection Agency (1975).

(d) Pre-catalyst auto fleet average fuel economy.

where

- f_u is the market share held by unleaded fuel in 1980, in %/100.
- f_l is the market share held by leaded fuel in 1980, in %/100.
- S_u is the sulfur content of unleaded gasoline in 1980, in weight percent.
- S_l is the sulfur content of leaded gasoline in 1980, in weight percent.
- S_{t_o} is the sulfur content of the entire gasoline pool during a base time period prior to large scale use of unleaded fuel, in weight percent.

From Table E1.22, we note that unleaded gasoline sulfur content historically has been lower than that of the leaded gasoline pool as a whole. Therefore, in the absence of deliberate desulfurization of gasoline, higher sulfur blending stocks formerly sold as leaded gasoline will have to be mixed into the unleaded pool as cars requiring unleaded fuel increasingly come to dominate the vehicle population. Refiners are assumed to blend their gasoline stocks such that the relative quality of the leaded and unleaded fuels is not permitted to depart greatly from historical norms. That behavior will be represented by holding the ratio, r, of leaded to unleaded fuel sulfur content at historic levels while unleaded fuel production climbs through the early 1980's.

$$\frac{S_l}{S_u} = r \qquad \text{(E1.3)}$$

In 1973, prior to the introduction of catalyst-equipped cars, 50% of the gasoline sales in California were of leaded premium grades (Ethyl

TABLE E1.22

Sulfur Content of Southern California Gasolines
(% sulfur by weight)

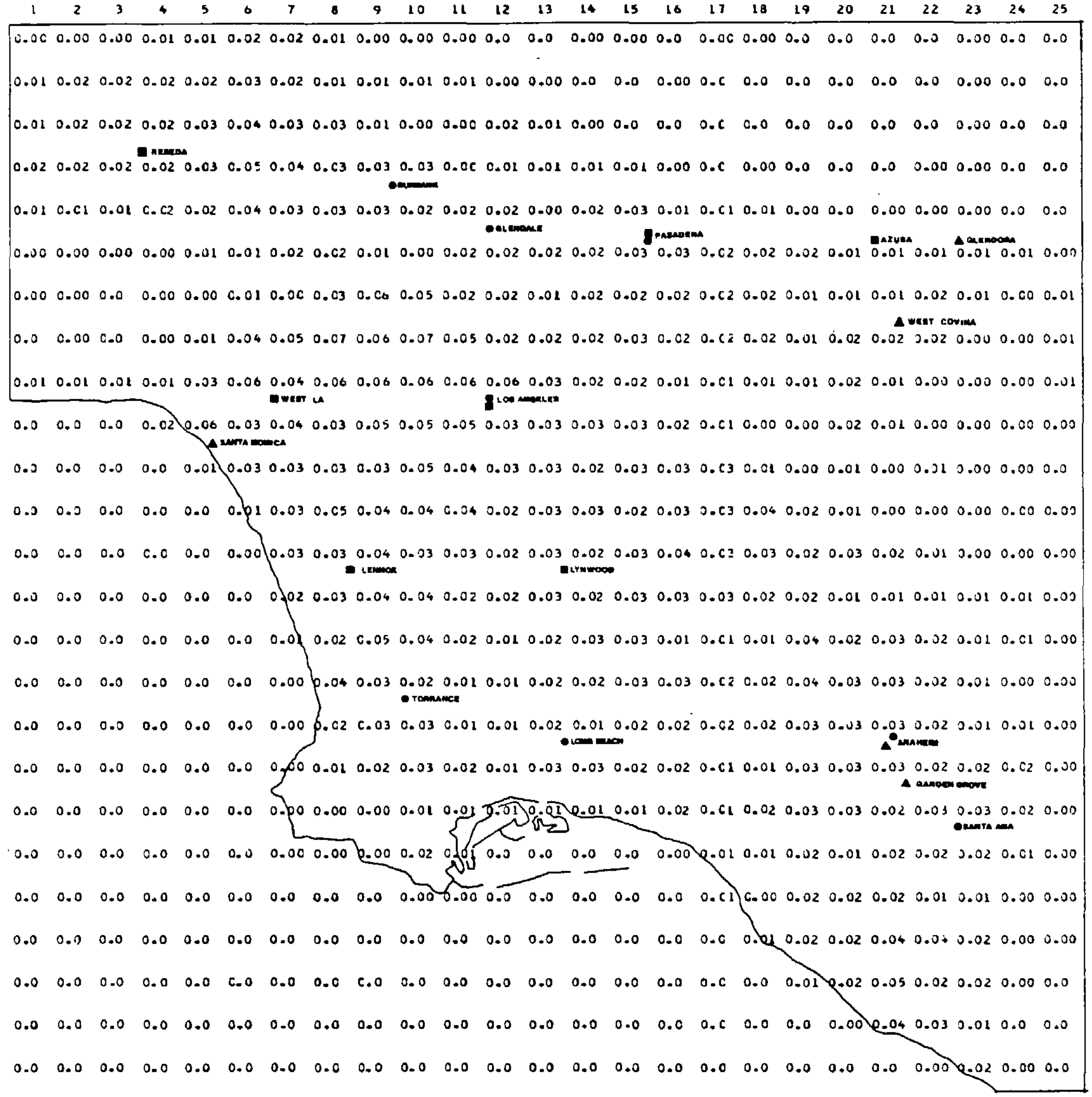
	Leaded Regular	Leaded Premium	Average of Leaded Grades	Unleaded Grade	Ratio Leaded to Unleaded
Summer 1974	0.057	0.033	0.045	0.026	1.73
Winter 1974-75	0.067	0.045	0.056	0.044	1.27
Summer 1975	0.057	0.034	0.045	0.041	1.10
Winter 1975-76	0.061	0.033	0.047	0.038	1.22
Summer 1976	0.062	0.034	0.048	0.029	1.66
Average					1.4

Reference: Shelton (1974)

Corporation, 1974), while virtually all of the remainder consisted of leaded regular. The average sulfur content of the southern California gasoline pool in that year was computed in Section A3.8.2.1 and Table A3.10 of Cass (1978) as 0.047% by weight from a calendar-weighted average of U.S. Bureau of Mines data: 25% winter 1972-1973 samples; 50% summer 1973 samples; 25% winter 1973-1974 samples. That 0.047% sulfur content will be taken as our historical gasoline pool sulfur content, S_{t_o}. From Table E1.22, we note that the mean ratio of leaded to unleaded gasoline sulfur contents is $r \approx 1.4$. From the fuel economy data and relative vehicle use levels given in Table E1.20, it is estimated that gasoline demand in 1980 will be for 54% unleaded fuel and 46% leaded fuels. Setting the sulfur content of the gasoline pool at 1973 levels of 0.047%, with $f_u = 0.54$, $f_l = 0.46$, $r \approx 1.4$, we may solve equations E1.1 and E1.3 for the desired 1980 gasoline sulfur contents provided that unleaded fuel sulfur content satisfies inequality E1.2. An unleaded fuel sulfur content estimate for 1980 of 0.039% sulfur by weight is obtained, along with an estimate that the leaded gasoline pool would average 0.056% sulfur by weight. Both those figures are within the range of experience in recent years, as shown in Table E1.22.

Highway vehicle SO_x emissions projected for the early 1980's are summarized in Figures E1.34 through E1.37. While diesel trucks and buses account for only 3.5% of highway miles traveled, they still account for a large fraction of highway traffic SO_x emissions because the sulfur content of diesel fuel is much higher than that of gasoline. In a similar fashion, even though catalyst-equipped cars and trucks will account for

CATALYST-EQUIPPED VEHICLE SURFACE STREET SOX EMISSIONS IN THE EARLY 1980'S: TEST YEAR 2 , IN TONS/DAY AS SO2



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	0.00	0.00	0.00	0.01	0.01	0.02	0.02	0.01	0.00	0.00	0.00	0.0	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.0	0.0	0.0	0.00	0.0	0.0
24	0.01	0.02	0.02	0.02	0.02	0.03	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0
23	0.01	0.02	0.02	0.02	0.03	0.04	0.03	0.03	0.01	0.00	0.00	0.02	0.01	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0
22	0.02	0.02	0.02	0.02	0.03	0.05	0.04	0.03	0.03	0.03	0.00	0.01	0.01	0.01	0.01	0.00	0.0	0.00	0.0	0.0	0.0	0.00	0.00	0.0	0.0
21	0.01	0.01	0.01	0.02	0.02	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.00	0.02	0.03	0.01	0.01	0.01	0.00	0.0	0.00	0.00	0.00	0.0	0.0
20	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.02	0.01	0.00	0.02	0.02	0.02	0.02	0.03	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.00
19	0.00	0.00	0.0	0.00	0.00	0.01	0.00	0.03	0.06	0.05	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.02	0.01	0.00	0.01
18	0.0	0.00	0.0	0.00	0.01	0.04	0.05	0.07	0.06	0.07	0.05	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.00	0.00	0.01
17	0.01	0.01	0.01	0.01	0.03	0.06	0.04	0.06	0.06	0.06	0.06	0.06	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.01	0.00	0.00	0.00	0.01
16	0.0	0.0	0.0	0.02	0.06	0.03	0.04	0.03	0.05	0.05	0.05	0.03	0.03	0.03	0.03	0.02	0.01	0.00	0.00	0.02	0.01	0.00	0.00	0.00	0.00
15	0.0	0.0	0.0	0.0	0.01	0.03	0.03	0.03	0.03	0.05	0.04	0.03	0.03	0.02	0.03	0.03	0.03	0.01	0.00	0.01	0.00	0.01	0.00	0.00	0.0
14	0.0	0.0	0.0	0.0	0.0	0.01	0.03	0.05	0.04	0.04	0.04	0.02	0.03	0.03	0.02	0.03	0.03	0.04	0.02	0.01	0.00	0.00	0.00	0.00	0.00
13	0.0	0.0	0.0	0.0	0.0	0.00	0.03	0.03	0.04	0.03	0.03	0.02	0.03	0.02	0.03	0.04	0.03	0.03	0.02	0.03	0.02	0.01	0.00	0.00	0.00
12	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.03	0.04	0.04	0.02	0.02	0.03	0.02	0.03	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.00
11	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.02	0.05	0.04	0.02	0.01	0.02	0.03	0.03	0.01	0.01	0.01	0.04	0.02	0.03	0.02	0.01	0.01	0.00
10	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.04	0.03	0.02	0.01	0.01	0.02	0.02	0.03	0.03	0.02	0.02	0.04	0.03	0.03	0.02	0.01	0.00	0.00
9	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.02	0.03	0.03	0.01	0.01	0.02	0.01	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.02	0.01	0.01	0.00
8	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.01	0.02	0.03	0.02	0.01	0.03	0.03	0.02	0.02	0.01	0.01	0.03	0.03	0.03	0.02	0.02	0.02	0.00
7	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.03	0.03	0.02	0.03	0.03	0.02	0.00
6	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.02	0.01	0.0	0.0	0.0	0.0	0.00	0.01	0.01	0.02	0.01	0.02	0.02	0.02	0.01	0.00
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.01	0.00	0.02	0.02	0.02	0.01	0.01	0.00	0.00
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.02	0.02	0.04	0.04	0.02	0.00	0.00
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.02	0.05	0.02	0.02	0.00	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.04	0.03	0.01	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.02	0.00	0.0

SOX
TONS/DAY
7.721

FIGURE E1.34

CATALYST-EQUIPPED VEHICLE FREEWAY SOX EMISSIONS IN THE EARLY 1980'S: TEST YEAR 2 , IN TONS/DAY AS SO2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	0.01	0.00	0.0	0.0	0.01	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.02	0.01	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	C.0	0.0	0.0	0.0	0.02	0.0	0.02	0.02	0.02	0.0	0.00	0.00	0.00	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.03	0.0	0.01	0.01	0.01	0.02	0.0	0.0	0.00	0.01	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.02	0.03	0.03	0.04	0.08	C.04	0.04	0.05	0.02	0.04	0.05	0.02	0.01	0.01	0.02	0.02	0.C2	0.01	0.0	0.0	0.0	0.0	0.0	0.C	0.0
20	0.0	0.0	0.0	0.0	0.03	0.0	0.0	0.01	0.03	0.0	0.03	0.00	0.01	0.01	0.00	0.0	0.C	0.01	0.02	0.02	0.01	0.00	0.00	0.01	0.00
19	0.0	0.0	0.0	0.0	0.03	0.0	0.0	0.0	0.01	0.03	0.01	0.03	0.02	0.01	0.0	0.0	0.C	0.0	0.02	0.0	0.0	0.00	0.01	0.01	0.0
18	0.0	0.0	0.0	C.0	0.01	0.02	0.0	0.0	0.0	0.01	0.04	0.06	0.02	0.03	0.03	0.04	0.C3	0.C3	0.05	0.02	0.02	0.01	0.01	0.02	0.02
17	0.0	0.0	0.0	0.0	0.0	0.04	0.02	0.03	0.04	0.05	0.08	0.05	0.05	0.05	0.03	0.03	0.C3	0.05	0.01	0.0	0.0	0.0	0.0	0.01	0.00
16	0.0	0.0	0.0	0.C	0.01	0.03	0.06	0.C1	C.0	0.0	0.04	0.04	0.06	0.05	0.0	0.0	0.C4	0.02	0.03	0.02	0.0	0.0	0.01	0.02	0.01
15	0.0	0.0	0.0	0.0	0.0	0.0	0.03	0.02	0.0	0.0	C.04	0.0	0.0	0.02	0.03	0.0	0.C3	0.0	0.0	0.00	0.02	0.02	0.02	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.04	0.0	0.0	0.03	0.0	0.0	0.02	0.02	0.04	0.0C	0.0	0.0	0.0	0.0	0.0	0.02	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.04	0.0	0.0	0.03	0.0	0.0	0.02	0.0	0.06	0.0C	0.0	0.0	0.0	0.0	0.01	0.0	0.C	0.0
12	C.0	0.0	0.0	0.0	0.0	0.0	0.0	0.03	0.00	0.0	0.03	0.0	0.01	0.01	0.0	0.04	0.C3	0.01	0.0	0.0	0.0	0.02	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.04	0.04	0.03	0.0	0.03	0.03	0.03	0.06	0.C3	0.03	0.03	0.0	0.0	0.02	0.0	0.0	0.01
10	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.07	0.00	0.03	0.0	0.0	0.03	0.C	0.01	0.03	0.06	0.05	0.04	0.03	0.05	0.01
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	C.02	0.04	0.06	0.04	0.04	0.03	0.C	0.0	0.0	0.0	0.03	0.01	0.0	0.03	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.02	0.00	0.01	0.0	0.0	0.08	0.C5	0.03	0.02	0.0	0.01	0.07	0.03	0.04	0.0
7	0.0	0.0	0.0	C.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.00	0.0	0.0	0.0	0.0	0.C	0.03	0.02	0.02	0.02	0.0	0.04	0.03	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.03	0.01	0.0	0.0	0.01	0.05	0.02
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.03	0.04	0.03	0.06	0.C	0.02
4	C.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.01	0.02	0.02	0.02
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

SOX
TONS/CAY
5.379

Figure E1.35

NON-CATALYST GASOLINE VEHICLE SOX EMISSIONS IN THE EARLY 1980'S: TEST YEAR 2 , IN TONS/DAY AS SO2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	0.02	0.01	0.00	0.02	0.03	0.04	0.02	0.01	0.00	0.00	0.00	0.0	0.0	0.00	0.00	0.0	0.CC	0.00	0.0	0.0	0.0	0.0	0.00	0.0	0.0
24	0.01	0.02	0.02	0.03	0.05	0.04	0.05	0.01	0.01	0.01	0.01	0.00	0.00	0.0	0.0	0.00	0.C	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0
23	C.02	0.03	0.03	0.03	0.06	0.04	0.06	0.05	0.03	0.00	0.00	0.03	0.01	0.00	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0
22	0.03	0.03	0.03	0.03	0.C7	C.06	0.06	0.C5	C.04	0.05	C.0C	0.02	0.01	0.02	0.01	0.00	0.C	0.00	0.0	0.0	0.0	0.00	0.00	0.0	0.0
21	0.04	0.04	0.05	C.C7	0.12	0.10	0.09	0.11	0.06	0.07	0.05	0.05	0.01	0.03	0.05	0.04	0.C3	0.02	0.00	0.0	0.00	0.00	0.00	0.0	0.0
20	0.00	0.00	0.00	0.00	0.05	0.01	0.02	0.04	0.06	0.00	0.07	0.03	0.03	0.03	0.04	0.C3	0.03	0.03	0.04	0.03	0.02	0.02	0.02	0.01	0.00
19	0.0C	0.00	0.0	C.00	0.05	0.01	0.00	0.C4	0.09	0.09	0.05	0.06	0.03	0.03	0.03	0.02	0.C2	0.02	0.04	0.01	0.01	0.03	0.02	0.C1	0.01
18	0.0	0.00	0.0	0.00	0.03	0.07	0.06	0.08	0.08	0.10	0.10	0.10	0.05	0.06	0.07	0.C7	0.C7	0.06	0.08	0.05	0.05	0.04	0.02	0.03	0.03
17	0.01	0.01	0.01	0.02	0.03	0.13	0.07	0.11	0.12	0.13	0.17	0.13	0.09	0.08	0.05	0.05	0.05	0.07	0.02	0.02	0.01	0.00	0.00	0.01	0.01
16	0.0	0.0	0.0	0.02	0.C8	0.07	0.12	0.05	0.06	0.06	0.11	0.09	0.11	0.10	0.03	0.02	0.C6	0.03	0.04	0.05	0.01	0.00	0.01	0.03	0.01
15	0.0	0.0	0.0	0.0	0.01	0.04	0.08	0.C6	0.04	0.06	0.1C	0.04	0.03	0.06	0.07	0.C3	0.C6	0.01	0.00	0.01	0.03	0.04	0.03	0.00	0.0
14	0.0	0.0	0.0	0.0	0.0	0.01	0.04	0.10	0.05	0.04	0.08	0.03	0.04	0.06	0.05	0.10	0.C3	0.05	0.02	0.01	0.00	0.00	0.03	0.CC	0.00
13	0.0	C.0	C.0	C.C	0.0	0.00	0.03	0.08	0.05	0.04	0.07	0.03	0.03	0.05	0.04	0.12	0.C4	0.04	0.03	0.04	0.02	0.03	0.00	0.00	0.00
12	0.0	0.0	0.0	0.0	0.0	0.0	0.03	0.07	0.05	0.05	0.05	0.03	0.04	0.04	0.C3	0.09	0.08	0.03	0.02	0.01	0.02	0.04	0.01	0.01	0.00
11	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.03	0.10	0.09	0.05	0.01	0.07	0.07	0.07	0.09	0.C5	0.05	0.08	0.03	0.04	0.05	0.01	0.C1	0.02
1C	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.04	0.04	0.03	0.10	0.01	0.05	0.03	0.04	0.07	0.C2	0.05	0.08	0.11	0.10	0.07	0.05	0.06	0.01
9	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.03	0.04	0.03	0.04	0.05	0.10	0.07	0.07	0.07	0.C2	0.03	0.04	0.04	0.08	0.04	0.02	0.05	0.00
8	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.01	0.02	0.03	0.04	0.02	0.05	0.04	0.03	0.12	0.C7	0.05	0.05	0.03	0.04	0.10	0.05	0.C7	0.00
7	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.C1	0.00	0.02	0.03	0.01	0.01	0.01	0.01	0.03	0.C1	C.05	0.05	0.06	0.05	0.03	0.08	0.06	0.00
6	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.C0	0.00	0.02	0.01	0.0	0.0	0.0	0.0	0.00	0.01	0.02	0.06	0.03	0.02	0.03	0.04	0.07	0.02
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.C1	0.00	0.03	0.06	0.07	0.06	0.08	0.00	0.03
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.01	0.02	0.02	0.05	0.06	0.04	0.03	0.03
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	C.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.01	0.02	0.06	0.02	0.02	0.00	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.00	0.04	0.04	0.01	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	C.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.02	0.00	0.0

SOX
TONS/CAY
15.906

Figure E1.36

DIESEL TRUCK AND BUS SOX EMISSIONS IN THE EARLY 1980'S: TEST YEAR 2 , IN TONS/DAY AS SO2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	0.02	0.01	0.00	0.02	0.04	0.05	0.02	0.01	0.00	0.00	0.00	0.0	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.0	0.0	0.0	0.00	0.0	0.0
24	0.01	0.02	0.03	0.03	0.06	0.05	0.06	0.01	0.01	0.01	0.01	0.00	0.00	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0
23	0.02	0.04	0.03	0.03	0.07	0.05	0.07	0.06	0.03	0.00	0.00	0.03	0.01	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0
22	0.03	0.03	0.03	0.03	0.08	0.07	0.07	0.05	0.05	0.06	0.00	0.02	0.01	0.02	0.02	0.00	0.0	0.00	0.0	0.0	0.0	0.00	0.00	0.0	0.0
21	0.04	0.05	0.06	0.08	0.14	0.12	0.10	0.12	0.07	0.09	0.10	0.06	0.01	0.04	0.06	0.04	0.04	0.02	0.00	0.0	0.00	0.00	0.00	0.0	0.0
20	0.00	0.01	0.00	0.00	0.06	0.01	0.02	0.04	0.07	0.00	0.08	0.04	0.03	0.04	0.05	0.04	0.03	0.04	0.05	0.04	0.03	0.02	0.02	0.01	0.00
19	0.00	0.00	0.0	0.00	0.05	0.01	0.01	0.05	0.11	0.11	0.06	0.07	0.04	0.03	0.03	0.03	0.03	0.02	0.05	0.02	0.02	0.03	0.02	0.02	0.01
18	0.0	0.00	0.0	0.00	0.04	0.08	0.07	0.10	0.09	0.12	0.12	0.11	0.06	0.07	0.08	0.08	0.08	0.07	0.09	0.06	0.05	0.04	0.02	0.03	0.03
17	0.01	0.01	0.02	0.02	0.04	0.15	0.09	0.13	0.15	0.15	0.20	0.15	0.11	0.09	0.06	0.06	0.05	0.09	0.02	0.02	0.01	0.00	0.00	0.02	0.01
16	0.0	0.0	0.0	0.02	0.10	0.08	0.14	0.06	0.07	0.07	0.14	0.10	0.13	0.12	0.04	0.02	0.07	0.04	0.05	0.06	0.01	0.00	0.01	0.03	0.01
15	0.0	0.0	0.0	0.0	0.01	0.05	0.09	0.07	0.05	0.08	0.12	0.05	0.04	0.07	0.05	0.04	0.07	0.01	0.00	0.02	0.04	0.04	0.04	0.00	0.0
14	0.0	0.0	0.0	0.0	0.0	0.02	0.04	0.12	0.06	0.05	0.10	0.03	0.04	0.07	0.06	0.11	0.04	0.06	0.02	0.01	0.00	0.00	0.03	0.00	0.00
13	0.0	0.0	0.0	0.0	0.0	0.00	0.04	0.10	0.06	0.04	0.09	0.03	0.04	0.06	0.05	0.14	0.05	0.05	0.04	0.05	0.03	0.04	0.00	0.00	0.00
12	0.0	0.0	0.0	0.0	0.0	0.0	0.03	0.09	0.06	0.06	0.06	0.03	0.05	0.05	0.04	0.11	0.09	0.04	0.02	0.01	0.02	0.04	0.02	0.01	0.00
11	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.03	0.12	0.10	0.06	0.02	0.08	0.09	0.08	0.11	0.06	0.06	0.09	0.04	0.05	0.06	0.01	0.01	0.02
10	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.05	0.05	0.03	0.11	0.01	0.06	0.03	0.05	0.09	0.02	0.05	0.10	0.14	0.11	0.09	0.06	0.07	0.01
9	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.03	0.04	0.04	0.05	0.06	0.11	0.08	0.09	0.08	0.03	0.03	0.05	0.04	0.09	0.04	0.02	0.06	0.00
8	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.02	0.03	0.04	0.05	0.02	0.06	0.04	0.03	0.14	0.08	0.06	0.06	0.04	0.04	0.12	0.06	0.08	0.00
7	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.01	0.00	0.02	0.04	0.01	0.02	0.01	0.02	0.03	0.01	0.06	0.06	0.07	0.06	0.04	0.10	0.07	0.00
6	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.03	0.01	0.0	0.0	0.0	0.0	0.01	0.01	0.02	0.08	0.04	0.02	0.03	0.05	0.09	0.03
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.01	0.01	0.03	0.07	0.08	0.06	0.10	0.00	0.03
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.03	0.02	0.06	0.07	0.05	0.04	0.03
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.02	0.07	0.02	0.03	0.00	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.05	0.05	0.01	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.03	0.00	0.0

RESEDA, BURBANK, GLENDALE, PASADENA, AZUSA, GLENDORA, WEST COVINA, WEST LA, LOS ANGELES, SANTA MONICA, LENNOX, LYNWOOD, TORRANCE, LONG BEACH, ANAHEIM, GARDEN GROVE, SANTA ANA

SOX
TONS/DAY
18.746

Figure E1.37

the majority of light duty vehicle miles traveled in 1980, the SO_x emissions from older cars will be higher due to the expected higher sulfur content of leaded gasoline.

E1.8.3 SO_x Emissions from Airport, Shipping and Railroad Operations

The spatial distribution of SO_x emissions from airport, shipping and railroad operations was established for the year 1973 in Appendix A2 of Cass (1978). Those emissions were scaled forward to the year 1980 on the basis of anticipated changes in the level of use of each transportation mode.

Airport emissions within our grid system are dominated by activities at Los Angeles International Airport. A forecast of the level of air carrier operations at Los Angeles International Airport was thus used to estimate future emissions from aircraft landing and take-off. While passenger traffic has climbed sharply in recent years, much of that traffic increase has been reflected in higher passenger load factors per plane rather than in a great increase in the number of aircraft landings per se. As shown in Table E1.23, actual aircraft operations (landings plus take-offs) are expected to be about the same in 1980 as was observed during the early 1970's. SO_x emissions from airport operations were scaled to 1980 from 1973 data given in Figure A2.37 of Cass (1978) based on the ratio of 1980 to 1973 air carrier operations estimated from Table E1.23.

TABLE E1.23

Air Carrier Operations at Los Angeles International Airport

Year	Air Carrier Operations
1972	371,563
1973	377,466
1974	342,540
1975	340,090
1976	356,536
1977	360,516
1980 forecast	363,600

Source: Kaplan (1978).

1980 forecast is said to be from the September 1978 edition of the LAX draft Environmental Impact Report.

Total SO_x emissions from aircraft operations in 1980 are expected to average 1.02 tons per day within our 50-by-50 mile grid, as shown in Figure E1.38.

Historical data on merchant vessel arrivals at Los Angeles and Long Beach Harbors are given in Table E1.24 (Alber, 1978). A projection of vessel arrivals in 1980 was made based on a linear regression line drawn through the historical data in that table. Then sulfur oxides emissions from shipping operations within our grid system were scaled to 1980 from 1973 values given in Figure A2.38 of Cass (1978) based on the ratio of estimated 1980 to 1973 merchant vessel arrivals at Los Angeles plus Long Beach harbors. A 1980 total of 13.21 tons per day of SO_x emissions from shipping operations within our grid system are projected to occur at locations shown in Figure E1.39. The effect of emissions from ships in the shipping lanes beyond our grid system is assumed to have been included in our estimate of sulfate background air quality.

Sales of fuel oil to railroads in California during the years 1972 through 1976 are indicated in Table E1.25. Conversations with Union Pacific Railroad personnel (Cocking, 1978) indicate that the low levels of fuel use in 1975 and 1976 were due to slack economic conditions in those years. A sharp rebound in fuel consumption was reported by Union Pacific, with fuel use growing by about 20% per year during the period 1977-1978. From discussions with Amtrak personnel (Adams, 1978) it is felt that railroad fuel use will climb a total of another 30% from 1978 through 1980. A railroad fuel sales projection for 1980 thus was constructed by growing 1976 fuel sales to railroads by 20% per year during

TABLE E1.24

Merchant Vessel Arrivals
Los Angeles plus Long Beach Harbors

Year	Merchant Vessel Arrivals
1972	4718
1973	5019
1974	4839
1975	4804
1976	5071
1977	5546
1978	(6723)[1]

Source: Alber (1978).

Note: (1) Extrapolated to 12 months from the 4482 vessel arrivals which occurred through the end of August 1978.

TABLE E1.25

Sales of Fuel Oil to Railroads in California

Year	Thousands of Barrels of Distillate Oil
1970	10,081
1971	11,275
1972	8,806
1973	8,530
1974	8,406
1975	6,567
1976	5,839

Reference: Bureau of Mines (1971 through 1977).

AIRPORT OPERATION SOX EMISSIONS IN THE EARLY 1980'S: TEST YEAR 2 , IN TONS/DAY AS SO2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0
23	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.02	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0
2C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	C.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.00
18	0.0	0.0	C.0	C.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.85	0.C	0.0	0.0	C.0	0.0	0.0	0.0	0.C	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	C.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.C	C.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.01	0.01	0.0	0.C	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	C.0	0.0	0.0	0.0	0.0	0.0	0.0C	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.02	0.02	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	C.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	C.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

SOX
TONS/DAY
1.022

Figure E1.38

SHIPPING OPERATION SOX EMISSIONS IN THE EARLY 1980'S: TEST YEAR 2 , IN TONS/DAY AS SO2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	C.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	C.C	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	C.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	C.0	0.0	0.0	0.0	C.0	0.0	0.0	C.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	C.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	U.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	C.0	0.0	0.C	C.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	C.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	D.0	0.0	0.0	0.0	0.0	0.C	0.0
13	0.0	0.0	0.0	0.C	0.0	0.67	C.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.05	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.54	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0
7	0.05	0.13	0.03	C.0	0.0	0.0	0.0	0.0	0.0	0.0	2.44	2.23	1.62	0.02	0.01	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.03	0.01	0.11	0.12	0.02	0.0	0.0	0.0	0.0	0.0	2.44	0.02	0.02	0.02	0.C2	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.05	0.09	0.02	0.05	0.14	0.08	0.05	0.C5	0.05	0.05	0.02	0.02	0.02	0.02	0.02	0.02	0.C1	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0
4	0.0	0.01	0.07	0.09	0.01	0.05	0.08	0.08	0.08	0.08	0.02	0.02	0.02	0.02	0.02	0.02	0.C1	0.05	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.02	0.08	0.09	0.08	0.09	0.10	0.08	C.02	0.02	0.02	0.02	0.02	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.02	0.02	0.09	0.01	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0
1	C.0	C.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.06	0.08	0.07	0.0	0.0	C.0	0.0	0.0	0.0	0.0	0.0	0.0

SOX
TONS/DAY
13.212

Figure E1.39

1977 and 1978 and by 15% per year during 1979 and 1980. The ratio of projected 1980 to actual 1973 fuel sales to railroads in California was then used to scale the railroad operations SO_x emissions distribution of Figure A2.39 of Cass (1978) up to the 1980 forecast levels shown in Figure E1.40. Sulfur oxides emissions of 4.33 tons per average day are projected for the early 1980's within our 50-by-50 mile grid.

E1.8.4 Mobile Source Emissions in Time Series

In order to recover thirty-six consecutive monthly emissions estimates for our three-year test period in the 1980's, annual average emissions rates for highway vehicles were modulated by the seasonal variation in gasoline sales observed during each month of the years 1972 through 1974 as computed from Ethyl Corporation (1974) data. In spite of the inclusion of a seasonal variation in fuel sales to highway vehicles, monthly average mobile source SO_x emissions are nearly constant throughout the years of interest, as shown in Figures E1.41 and E1.42.

While automotive emissions seem nearly constant over time on a seasonal basis, there is still a strong diurnal variation in hourly traffic volumes. Diurnal variation estimates for automobiles and light trucks, diesel trucks, and aircraft are given in Table E1.26. The data for automobile travel on freeways and surface streets are from Nordsieck (1974) as presented previously in Figure 4.11 and Table 4.8 of Chapter 4 of Cass (1978). The time history of diesel traffic flow given in Table E1.26 was obtained by weighting the diurnal variation in total freeway travel given in the first column of that table by the fraction of freeway traffic due to heavy duty diesels at each hour (given by Arledge and Tan,

RAILROAD OPERATION SOX EMISSIONS IN THE EARLY 1980'S: JAN OF TEST YEAR 2 , IN TONS/DAY AS SO2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	0.00	0.00	0.0	0.0	0.0	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.01	0.01	0.0	0.0	0.0	0.0	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0
23	C.0	0.01	0.01	0.01	0.01	0.02	0.0	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.01	0.0	0.0	0.01	0.0C	0.02	0.C2	0.04	0.03	C.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.01	0.01	0.0	0.00	0.01	0.01	0.01	0.01	0.02	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.0	0.0	0.00	0.02	0.01	0.C1	0.01	0.01	0.01	0.02	0.01	0.01	0.00	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	C.0	C.0	0.0	0.14	0.01	0.00	0.0	0.01	0.C	0.0	0.0	0.00	0.01	0.0	0.00	0.01	0.08
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.19	0.01	0.0	0.03	0.00	0.C1	0.01	0.0	0.01	0.01	0.01	0.00	0.0	0.04
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.24	0.06	0.01	0.0	0.0	0.C	0.00	0.01	0.01	0.0	0.0	0.0	0.0	0.08
16	0.0	C.0	0.0	0.C	0.00	0.01	0.01	0.C1	0.01	0.01	0.01	0.19	0.15	0.08	0.02	0.01	0.C	0.01	0.01	0.03	0.02	0.00	0.01	0.02	0.0
15	0.0	0.0	0.0	0.0	0.00	0.01	0.02	0.01	0.01	0.01	0.01	0.11	0.07	0.07	0.03	0.02	0.C2	0.00	0.0	0.0	0.01	0.03	0.01	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.00	0.0	0.0	0.04	0.03	0.01	0.00	0.02	0.C4	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.C	0.0	0.0	0.00	0.01	0.01	0.01	0.01	0.02	0.03	0.03	0.01	0.01	0.C2	0.00	0.01	0.01	0.01	0.01	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.03	0.00	0.0	0.01	0.01	0.02	0.03	0.01	0.00	0.C1	0.03	0.00	0.0	0.01	0.0	0.01	0.01	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.C	0.01	0.0	0.01	0.01	0.04	0.01	0.00	0.01	0.CC	0.01	0.03	0.03	0.03	0.02	0.01	0.01	0.05
10	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.00	0.00	0.02	0.02	0.01	0.04	0.01	0.0	0.0	0.C1	0.00	0.00	0.01	0.0	0.02	0.0	0.01	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.01	0.04	0.03	0.0	0.0	0.0	0.0C	0.02	0.02	0.01	0.01	0.02	0.02	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.00	0.0	0.09	0.0	0.01	0.00	0.0	0.C	0.0	0.00	0.01	0.00	0.01	0.02	0.0	0.0
7	0.0	0.0	C.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.05	0.0	0.0	0.0	0.02	0.12	0.04	0.01	0.0	0.01	0.01	0.02	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.04	0.0	0.0	0.0	0.0	0.02	0.C4	0.02	0.01	0.0	0.0	0.0	0.01	0.01	0.0
5	0.0	0.0	0.0	0.0	0.0	C.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C1	0.00	0.01	0.0	0.01	0.01	0.01	0.CC	0.01
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.01	0.01	0.0	0.0	0.0	0.0	0.0	0.01
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.01	0.0	0.0	0.0	0.0	0.0	0.01
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01

RESEDA, BURBANK, GLENDALE, PASADENA, AZUSA, GLENDORA, WEST COVINA, WEST LA, LOS ANGELES, SANTA MONICA, LENNOX, LYNWOOD, TORRANCE, LONG BEACH, ANAHEIM, GARDEN GROVE, SANTA ANA

SOX
TONS/DAY
4.332

Figure E1.40

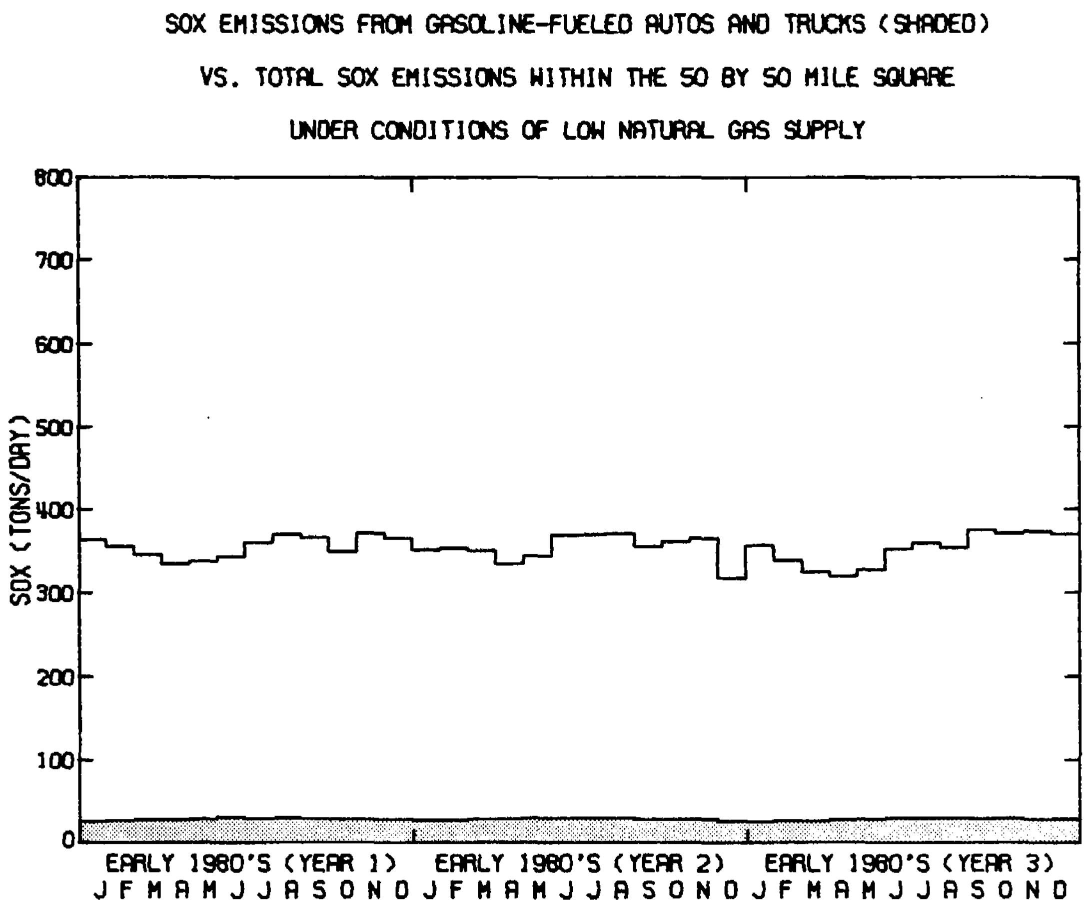

SOX EMISSIONS FROM GASOLINE-FUELED AUTOS AND TRUCKS (SHADED)
VS. TOTAL SOX EMISSIONS WITHIN THE 50 BY 50 MILE SQUARE
UNDER CONDITIONS OF LOW NATURAL GAS SUPPLY
SOX (TONS/DAY)
800
700
600
500
400
300
200
100
0
EARLY 1980'S (YEAR 1)
EARLY 1980'S (YEAR 2)
EARLY 1980'S (YEAR 3)
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D

Figure E1.41

SOX EMISSIONS FROM SHIPS, AIRCRAFT, RAILROADS AND DIESEL VEHICLES (SHADED)
VS. TOTAL SOX EMISSIONS WITHIN THE 50 BY 50 MILE SQUARE
UNDER CONDITIONS OF LOW NATURAL GAS SUPPLY

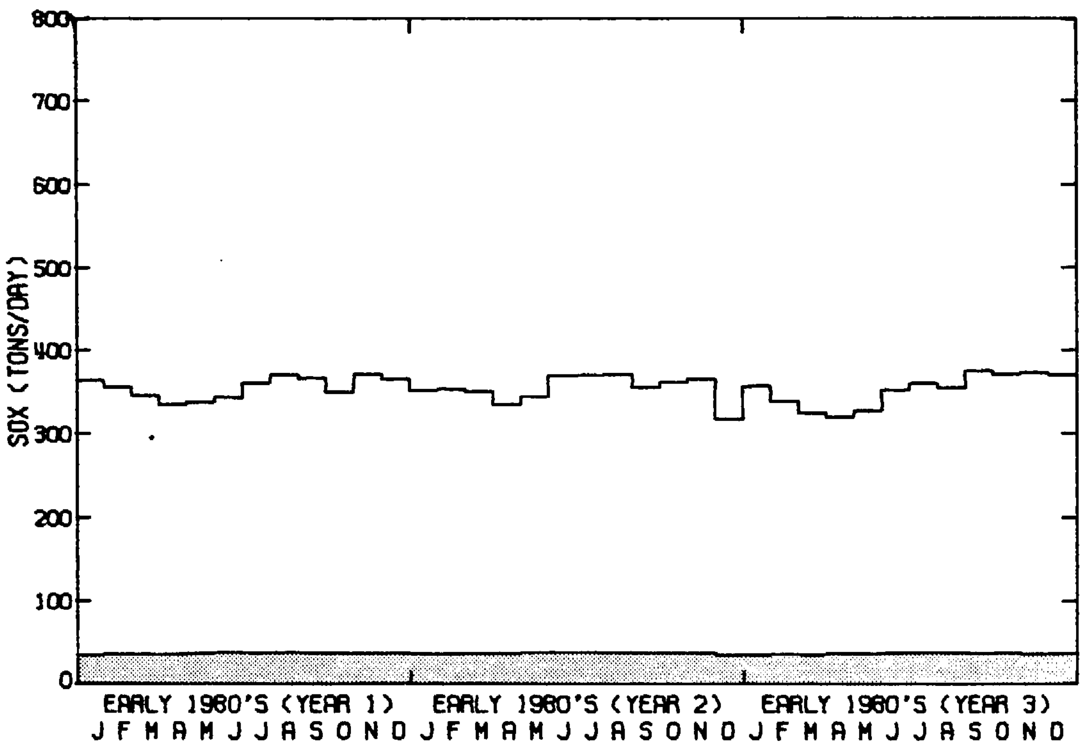


Figure E1.42

TABLE E1.26

Diurnal Variations of Source Activities (1974)
(Fraction of Daily Total Assignable to a 1 hour Period)

			Gasoline Fueled Highway Vehicles				
		Power Plants	Freeways (a)(b)	Surface Streets (a)(c)	Weighted Average (d) (0.39 Freeway + 0.61 Surface)	Diesel Highway Vehicles (e)	Los Angeles International Airport (f)
(Midnight)	2400-100	0.02756	0.00776	0.00677	0.00716	0.013	0.024
	100-200	0.01911	0.00776	0.00677	0.00716	0.015	0.009
	200-300	0.01695	0.00776	0.00677	0.00716	0.017	0.008
	300-400	0.01484	0.00776	0.00677	0.00716	0.019	0.008
	400-500	0.01381	0.00776	0.00677	0.00716	0.021	0.008
	500-600	0.01484	0.0178	0.00677	0.01107	0.053	0.009
A.M.	600-700	0.01695	0.0591	0.0293	0.0409	0.063	0.009
	700-800	0.02334	0.0768	0.0651	0.0697	0.082	0.043
	800-900	0.03709	0.0648	0.0651	0.0650	0.069	0.063
	900-1000	0.04451	0.0536	0.0502	0.0515	0.057	0.063
	1000-1100	0.05095	0.0494	0.0502	0.0499	0.052	0.063
	1100-1200	0.05404	0.0494	0.06088	0.0564	0.052	0.063
	1200-1300	0.05616	0.0494	0.06088	0.0564	0.052	0.063
	1300-1400	0.06043	0.0494	0.06088	0.0564	0.048	0.063
	1400-1500	0.06146	0.0569	0.06088	0.0593	0.052	0.063
	1500-1600	0.06387	0.0746	0.06088	0.0662	0.060	0.063
	1600-1700	0.06043	0.0746	0.0820	0.0791	0.057	0.063
	1700-1800	0.05940	0.0746	0.0820	0.0791	0.050	0.063
P.M.	1800-1900	0.05724	0.0598	0.0540	0.0563	0.037	0.055
	1900-2000	0.05306	0.0302	0.0540	0.0447	0.017	0.054
	2000-2100	0.05404	0.0302	0.03077	0.0306	0.016	0.048
	2100-2200	0.05616	0.0302	0.03077	0.0306	0.016	0.036
	2200-2300	0.04771	0.0302	0.03077	0.0306	0.039	0.036
(Midnight)	2300-2400	0.03606	0.0302	0.03077	0.0306	0.043	0.024

Notes: (a) From Nordsieck (1974)
(b) Used for catalyst equipped autos and light trucks - freeway.
(c) Used for catalyst equipped autos and light trucks - surface streets.
(d) Used for non-catalyst gasoline vehicles.
(e) Computed from freeway diesel use data given by Arledge and Jan (1977).
(f) From Roth et al. (1974).

1977). The result indicates, not supprisingly, that diesel traffic is relatively heavier at night than automobile traffic. The diurual variation in aircraft flights was adapted from data given for Los Angeles International Airport by Roth et al., (1974). Lacking any other data, the level of fuel use by railroads and ships was assumed to be constant throughout the day.

E1.9 Emissions Projection Summary and Discussion

Figure E1.43 summarizes the sulfur oxides emissions projection for the central portion of the South Coast Air Basin under conditions of low natural gas supply. In the event of the loss of the industrial natural gas supply, emissions within the 50-by-50 mile grid would total about 355 tons per average day. Major off-grid sources would amount to another 64.3 tons per day of SO_x emissions. Those figures correspond quite closely to the 343 tons per day on-grid, plus 91 tons per day off-grid during the year 1974. In spite of the introduction of several new emissions control regulations during the late 1970's future air quality might look much like past air quality if large amounts of fuel oil were burned by local industries.

Comparison of Figure E1.43 to Figure E1.44 shows that annual average data hide some remarkable changes which have occurred between 1974 and our forecast period. The strong seasonal variation in electric utility fuel SO_x emissions present in the early 1970's would be absent under conditions of low natural gas supply. The annual average value of those utility fuel SO_x emissions would remain about the same in spite of a great increase in oil combustion because the sulfur content of fuel

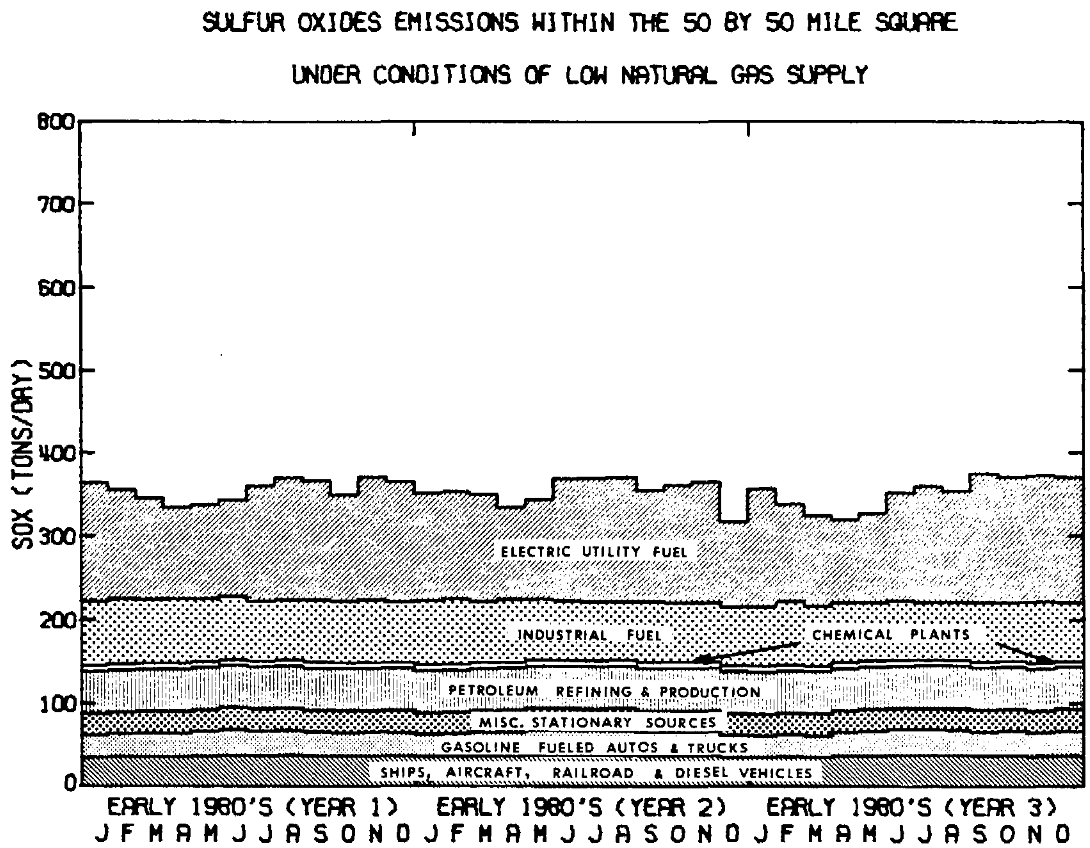

SULFUR OXIDES EMISSIONS WITHIN THE 50 BY 50 MILE SQUARE
UNDER CONDITIONS OF LOW NATURAL GAS SUPPLY
SOX (TONS/DAY)
800
700
600
500
400
300
200
100
0
ELECTRIC UTILITY FUEL
INDUSTRIAL FUEL
CHEMICAL PLANTS
PETROLEUM REFINING & PRODUCTION
MISC. STATIONARY SOURCES
GASOLINE FUELED AUTOS & TRUCKS
SHIPS, AIRCRAFT, RAILROAD & DIESEL VEHICLES
EARLY 1980'S (YEAR 1) EARLY 1980'S (YEAR 2) EARLY 1980'S (YEAR 3)
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D

Figure E1.43

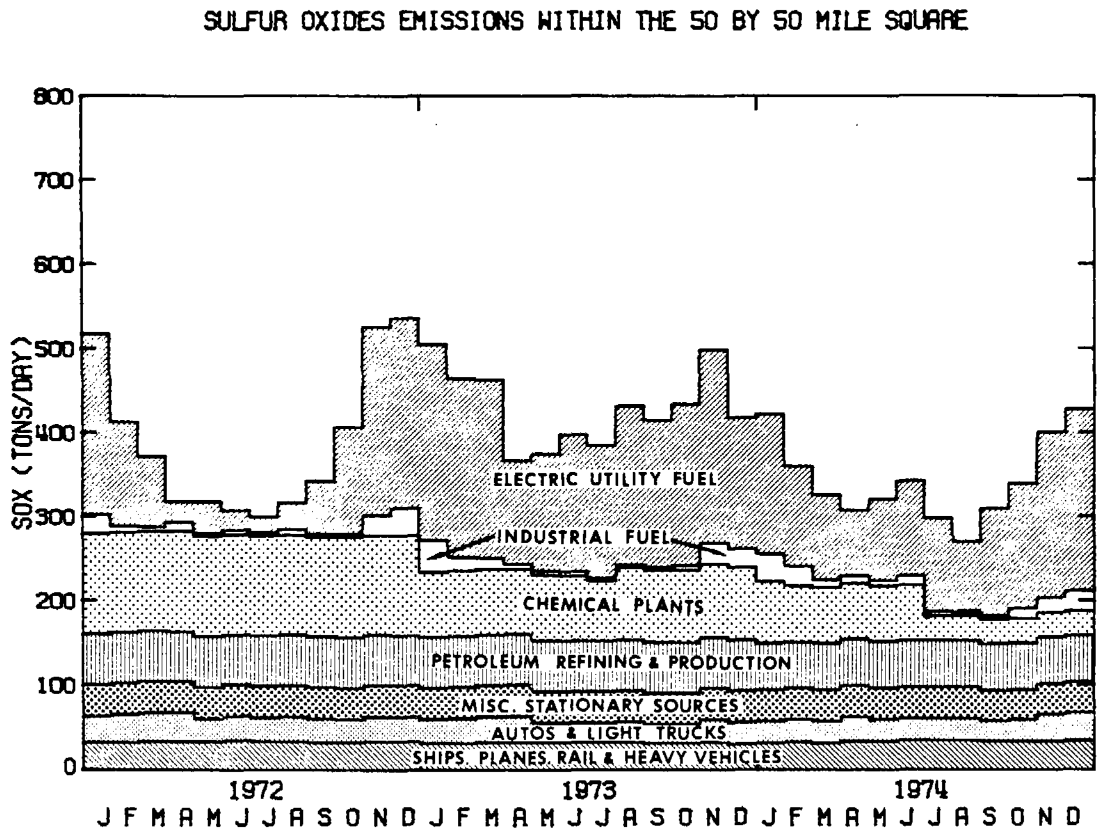

SULFUR OXIDES EMISSIONS WITHIN THE 50 BY 50 MILE SQUARE
SOX (TONS/DAY)
800
700
600
500
400
300
200
100
0
ELECTRIC UTILITY FUEL
INDUSTRIAL FUEL
CHEMICAL PLANTS
PETROLEUM REFINING & PRODUCTION
MISC. STATIONARY SOURCES
AUTOS & LIGHT TRUCKS
SHIPS, PLANES, RAIL & HEAVY VEHICLES
1972
1973
1974
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D

Figure E1.44

was cut from 0.44% by weight in 1974 down to 0.22% sulfur by weight at present.

A second major change in emissions between the early 1970's and the early 1980's involved the nearly complete elimination of SO_x emissions from chemical plants. However, in place of the chemical plant emissions, more than 70 tons per day of SO_x emissions would occur from industrial fuel burning under conditions of low natural gas supply. Bringing fuel burning emissions under control through restoration of the natural gas supply or installation of desulfurization or emissions control equipment thus is seen to be critical during the decade of the 1980's if sulfate air quality is to be improved beyond 1974 levels.

Tables E1.27 through E1.29 show the monthly emissions history for individual source and equipment types within the general source categories of Figure E1.43. The emissions inventory created for air quality model use contains spatially resolved source strength data defined on the 50-by-50 mile grid for each of the 26 source types shown in Table E1.27 through E1.29 for each month of three test years in the early 1980's. An itemization of large off-grid sources is also included.

One principal reason for compiling emissions on a source-by-source basis is to be able to display the spatial distribution of SO_x emission strength. Figures E1.45 through E1.47 summarize annual average SO_x emissions density for those test years. It is seen that the largest SO_x emission source densities are still located in a narrow strip along the coastline stretching from Los Angeles International Airport (near

TABLE E1.27a

Sulfur Oxides Emissions Within the 50 by 50 Mile Square Grid
Early 1980's Test Year 1
(in short tons per day as SO_2)

STATIONARY SOURCES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
FUEL COMBUSTION													
ELECTRIC UTILITIES													
RESIDUAL OIL	139.80	127.93	119.15	107.61	110.18	113.12	136.13	143.48	139.07	124.44	144.54	141.57	128.95
DISTILLATE OIL	2.28	2.09	1.94	1.76	1.80	1.85	2.22	2.34	2.27	2.03	2.36	2.31	2.10
REFINERY FUEL	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00
LOW PRIORITY NATURAL GAS CUSTOMERS	49.41	50.28	48.75	49.98	47.89	48.44	44.64	45.67	47.99	46.76	48.29	45.39	47.77
HIGH PRIORITY NATURAL GAS CUSTOMERS	0.46	0.43	0.29	0.27	0.24	0.20	0.17	0.15	0.16	0.18	0.30	0.40	0.27
CHEMICAL PLANTS													
SULFUR RECOVERY	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51
SULFURIC ACID	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08
OTHER CHEMICALS	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
PETROLEUM REFINING AND PRODUCTION													
FLUID CATALYTIC CRACKERS	44.95	44.95	44.95	44.95	44.95	44.95	44.95	44.95	44.95	44.95	44.95	44.95	44.95
SOUR WATER STRIPPERS	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03
DELAYED COKERS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MISC. REFINERY PROCESS	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76
OIL FIELD PRODUCTION	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30
MISC. STATIONARY SOURCES													
PETROLEUM COKE KILNS	22.82	22.82	22.82	22.82	22.82	22.82	22.82	22.82	22.82	22.82	22.82	22.82	22.82
GLASS FURNACES	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
NON-FERROUS METALS	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
FERROUS METALS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MINERAL PRODUCTS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SEWAGE TREATMENT DIGESTERS	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64
OTHER INDUSTRIAL PROCESSES	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
PERMITTED INCINERATORS	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
MOBILE SOURCES													
CATALYST-EQUIPPED LT. DUTY VEHICLES - SURFACE	7.06	7.38	7.57	7.50	7.84	8.26	7.92	8.13	7.74	7.61	7.71	7.67	7.70
CATALYST-EQUIPPED LT. DUTY VEHICLES - FREEWAY	4.92	5.14	5.27	5.23	5.46	5.76	5.52	5.66	5.39	5.30	5.37	5.34	5.36
NON-CATALYST LT. DUTY VEHICLES	14.55	15.20	15.59	15.45	16.16	17.02	16.32	16.75	15.95	15.67	15.88	15.80	15.86
HEAVY HIGHWAY DIESEL VEHICLES	17.15	17.91	18.38	18.21	19.04	20.06	19.23	19.74	18.80	18.47	18.71	18.62	18.69
AIRPORT OPERATIONS	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
SHIPPING OPERATIONS	13.21	13.21	13.21	13.21	13.21	13.21	13.21	13.21	13.21	13.21	13.21	13.21	13.21
RAILROAD OPERATIONS	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33
TOTAL	365.35	356.08	346.66	335.73	338.33	344.43	361.87	371.64	367.09	350.18	372.88	366.82	356.4

TABLE E1.27b

Major Off-Grid Emission Sources Included within the
South Coast Air Basin Sulfur Oxides Modeling Inventory
Early 1980's Test Year 1
(in short tons per day as SO_2)

STATIONARY SOURCES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
FUEL COMBUSTION													
ELECTRIC UTILITIES													
RESIDUAL OIL	51.38	47.02	43.79	39.55	40.50	41.58	50.03	52.74	51.11	45.74	53.13	52.03	47.40
DISTILLATE OIL	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.03	0.03	0.02
REFINERY FUEL	---	---	---	---	---	---	---	---	---	---	---	---	---
LOW PRIORITY NATURAL GAS CUSTOMERS	---	---	---	---	---	---	---	---	---	---	---	---	---
HIGH PRIORITY NATURAL GAS CUSTOMERS	---	---	---	---	---	---	---	---	---	---	---	---	---
CHEMICAL PLANTS													
SULFUR RECOVERY	---	---	---	---	---	---	---	---	---	---	---	---	---
SULFURIC ACID	---	---	---	---	---	---	---	---	---	---	---	---	---
OTHER CHEMICALS	---	---	---	---	---	---	---	---	---	---	---	---	---
PETROLEUM REFINING AND PRODUCTION													
FLUID CATALYTIC CRACKERS	---	---	---	---	---	---	---	---	---	---	---	---	---
SOUR WATER STRIPPERS	---	---	---	---	---	---	---	---	---	---	---	---	---
DELAYED COKERS	---	---	---	---	---	---	---	---	---	---	---	---	---
MISC. REFINERY UNITS	---	---	---	---	---	---	---	---	---	---	---	---	---
OIL FIELD PRODUCTION	---	---	---	---	---	---	---	---	---	---	---	---	---
MISC. STATIONARY SOURCES													
PETROLEUM COKE KILNS	---	---	---	---	---	---	---	---	---	---	---	---	---
GLASS FURNACES	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
NON-FERROUS METALS	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
FERROUS METALS	14.55	14.55	14.55	14.55	14.55	14.55	14.55	14.55	14.55	14.55	14.55	14.55	14.55
MINERAL PRODUCTS	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90
SEWAGE TREATMENT DIGESTERS	---	---	---	---	---	---	---	---	---	---	---	---	---
OTHER INDUSTRIAL PROCESSES	---	---	---	---	---	---	---	---	---	---	---	---	---
PERMITTED INCINERATORS	---	---	---	---	---	---	---	---	---	---	---	---	---
TOTAL OFF-GRID STATIONARY SOURCES	68.12	63.74	60.53	56.29	57.24	58.32	66.77	69.49	67.85	62.48	69.88	68.78	64.14

TABLE E1.28a

Sulfur Oxides Emissions Within the 50 by 50 Mile Square Grid
Early 1980's Test Year 2
(in short tons per day as SO_2)

STATIONARY SOURCES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
FUEL COMBUSTION													
ELECTRIC UTILITIES													
RESIDUAL OIL	126.10	126.41	126.70	107.76	117.74	143.06	145.77	146.63	131.75	138.79	141.45	99.46	129.31
DISTIALLATE OIL	2.06	2.06	2.07	1.76	1.92	2.33	2.38	2.39	2.15	2.26	2.31	1.62	2.11
REFINERY FUEL	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00
LOW PRIORITY NATURAL GAS CUSTOMERS	49.69	50.23	45.16	48.16	45.85	44.77	43.41	42.88	45.17	44.38	45.19	42.73	45.60
HIGH PRIORITY NATURAL GAS CUSTOMERS	0.46	0.46	0.37	0.33	0.26	0.21	0.17	0.16	0.19	0.20	0.26	0.36	0.28
CHEMICAL PLANTS													
SULFUR RECOVERY	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51
SULFURIC ACID	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08
OTHER CHEMICALS	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
PETROLEUM REFINING AND PRODUCTION													
FLUID CATALYTIC CRACKERS	44.95	44.95	44.95	44.95	44.95	44.95	44.95	44.95	44.95	44.95	44.95	44.95	44.95
SOUR WATER STRIPPERS	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03
DELAYED COKERS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MISC. REFINERY PROCESS	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76
OIL FIELD PRODUCTION	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30
MISC. STATIONARY SOURCES													
PETROLEUM COKE KILNS	22.82	22.82	22.82	22.82	22.82	22.82	22.82	22.82	22.82	22.82	22.82	22.82	22.82
GLASS FURNACES	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
NON-FERROUS METALS	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
FERROUS METALS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MINERAL PRODUCTS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SEWAGE TREATMENT DIGESTERS	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64
OTHER INDUSTRIAL PROCESSES	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
PERMITTED INCINERATORS	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
MOBILE SOURCES													
CATALYST-EQUIPPED LT. DUTY VEHICLES - SURFACE	7.19	7.41	7.72	7.79	8.16	8.08	8.02	8.15	7.68	7.67	7.67	7.09	7.72
CATALYST-EQUIPPED LT. DUTY VEHICLES - FREEWAY	5.01	5.16	5.38	5.43	5.68	5.63	5.58	5.68	5.35	5.34	5.34	4.94	5.38
NON-CATALYST LT. DUTY VEHICLES	14.82	15.27	15.90	16.06	16.81	16.65	16.52	16.80	15.82	15.80	15.80	14.60	15.91
HEAVY HIGHWAY DIESEL VEHICLES	17.46	17.99	18.74	18.92	19.81	19.62	19.46	19.80	18.65	18.62	18.62	17.20	18.75
AIRPORT OPERATIONS	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
SHIPPING OPERATIONS	13.21	13.21	13.21	13.21	13.21	13.21	13.21	13.21	13.21	13.21	13.21	13.21	13.21
RAILROAD OPERATIONS	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33
TOTAL	352.51	354.71	351.76	335.93	345.95	370.07	371.03	372.21	356.48	362.78	366.36	317.72	354.79

TABLE E1.28b

Major Off-Grid Emission Sources Included within the South Coast Air Basin Sulfur Oxides Modeling Inventory Early 1980's Test Year 2 (in short tons per day as SO_2)

STATIONARY SOURCES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
FUEL COMBUSTION													
ELECTRIC UTILITIES													
RESIDUAL OIL	46.35	46.46	46.57	39.61	43.28	52.58	53.58	53.90	48.42	51.01	51.99	36.56	47.53
DISTILLATE OIL	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.02	0.02	0.03	0.02	0.02
REFINERY FUEL	---	---	---	---	---	---	---	---	---	---	---	---	---
LOW PRIORITY NATURAL GAS CUSTOMERS	---	---	---	---	---	---	---	---	---	---	---	---	---
HIGH PRIORITY NATURAL GAS CUSTOMERS	---	---	---	---	---	---	---	---	---	---	---	---	---
CHEMICAL PLANTS													
SULFUR RECOVERY	---	---	---	---	---	---	---	---	---	---	---	---	---
SULFURIC ACID	---	---	---	---	---	---	---	---	---	---	---	---	---
OTHER CHEMICALS	---	---	---	---	---	---	---	---	---	---	---	---	---
PETROLEUM REFINING AND PRODUCTION													
FLUID CATALYTIC CRACKERS	---	---	---	---	---	---	---	---	---	---	---	---	---
SOUR WATER STRIPPERS	---	---	---	---	---	---	---	---	---	---	---	---	---
DELAYED COKERS	---	---	---	---	---	---	---	---	---	---	---	---	---
MISC. REFINERY UTNIS	---	---	---	---	---	---	---	---	---	---	---	---	---
OIL FIELD PRODUCTION	---	---	---	---	---	---	---	---	---	---	---	---	---
MISC. STATIONARY SOURCES													
PETROLEUM COKE KILNS	---	---	---	---	---	---	---	---	---	---	---	---	---
GLASS FURNACES	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
NON-FERROUS METALS	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
FERROUS METALS	14.55	14.55	14.55	14.55	14.55	14.55	14.55	14.55	14.55	14.55	14.55	14.55	14.55
MINERAL PRODUCTS	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90
SEWAGE TREATMENT DIGESTERS	---	---	---	---	---	---	---	---	---	---	---	---	---
OTHER INDUSTRIAL PROCESSES	---	---	---	---	---	---	---	---	---	---	---	---	---
PERMITTED INCINERATORS	---	---	---	---	---	---	---	---	---	---	---	---	---
TOTAL OFF-GRID STATIONARY SOURCES	63.09	63.20	63.31	56.35	60.02	69.33	70.33	70.65	65.16	67.75	68.74	53.30	64.27

TABLE E1.29a

Sulfur Oxides Emissions Within the 50 by 50 Mile Square Grid
Early 1980's Test Year 3
(in short tons per day as SO_2)

STATIONARY SOURCES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
FUEL COMBUSTION													
ELECTRIC UTILITIES													
RESIDUAL OIL	139.95	114.63	106.43	95.91	104.17	126.70	137.08	130.43	151.04	147.32	149.40	147.41	129.31
DISTILLATE OIL	2.28	1.87	1.74	1.57	1.70	2.07	2.24	2.13	2.46	2.40	2.44	2.41	2.11
REFINERY FUEL	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00
LOW PRIORITY NATURAL GAS CUSTOMERS	43.34	48.64	44.06	44.94	43.13	44.22	41.44	41.98	44.85	43.53	46.16	42.39	44.01
HIGH PRIORITY NATURAL GAS CUSTOMERS	0.41	0.41	0.35	0.27	0.23	0.21	0.17	0.15	0.16	0.17	0.25	0.35	0.26
CHEMICAL PLANTS													
SULFUR RECOVERY	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51
SULFURIC ACID	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08
OTHER CHEMICALS	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
PETROLEUM REFINING AND PRODUCTION													
FLUID CATALYTIC CRACKERS	44.95	44.95	44.95	44.95	44.95	44.95	44.95	44.95	44.95	44.95	44.95	44.95	44.95
SOUR WATER STRIPPERS	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03
DELAYED COKERS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MISC. REFINERY PROCESSES	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76
OIL FIELD PROCESSES	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30
MISC. STATIONARY SOURCES													
PETROLEUM COKE KILNS	22.82	22.82	22.82	22.82	22.82	22.82	22.82	22.82	22.82	22.82	22.82	22.82	22.82
GLASS FURNACES	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
NON-FERROUS METALS	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
FERROUS METALS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MINERAL PRODUCTS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SEWAGE TREATMENT DIGESTERS	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64
OTHER INDUSTRIAL PROCESSES	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
PERMITTED INCINERATORS	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
MOBILE SOURCES													
CATALYST-EQUIPPED LT. DUTY VEHICLES - SURFACE	6.91	7.19	6.95	7.70	7.98	8.18	8.23	8.19	7.76	8.01	7.58	7.94	7.72
CATALYST-EQUIPPED LT. DUTY VEHICLES - FREEWAY	4.82	5.01	4.84	5.37	5.56	5.70	5.73	5.70	5.40	5.58	5.28	5.53	5.38
NON-CATALYST LT. DUTY VEHICLES	14.24	14.81	14.31	15.87	16.45	16.85	16.96	16.86	15.98	16.50	15.61	16.35	15.91
HEAVY HIGHWAY DIESEL VEHICLES	16.78	17.46	16.87	18.70	19.38	19.85	19.99	19.88	18.83	19.44	18.40	19.27	18.75
AIRPORT OPERATIONS	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
SHIPPING OPERATIONS	13.21	13.21	13.21	13.21	13.21	13.21	13.21	13.21	13.21	13.21	13.21	13.21	13.21
RAILROAD OPERATIONS	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33
TOTAL	358.45	339.74	325.27	320.05	328.32	353.50	361.56	355.04	376.25	372.67	374.84	371.37	353.18

TABLE E1.29b

Major Off-Grid Emission Sources Included within the South Coast Air Basin Sulfur Oxides Modeling Inventory Early 1980's Test Year 3 (in short tons per day as SO_2)

STATIONARY SOURCES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
FUEL COMBUSTION													
ELECTRIC UTILITIES													
RESIDUAL OIL	51.44	42.13	39.12	35.25	38.29	46.57	50.38	47.94	55.51	54.15	54.19	54.18	47.53
DISTILLATE OIL	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.02
REFINERY FUEL	---	---	---	---	---	---	---	---	---	---	---	---	---
LOW PRIORITY NATURAL GAS CUSTOMERS	---	---	---	---	---	---	---	---	---	---	---	---	---
HIGH PRIORITY NATURAL GAS CUSTOMERS	---	---	---	---	---	---	---	---	---	---	---	---	---
CHEMICAL PLANTS													
SULFUR RECOVERY	---	---	---	---	---	---	---	---	---	---	---	---	---
SULFURIC ACID	---	---	---	---	---	---	---	---	---	---	---	---	---
OTHER CHEMICALS	---	---	---	---	---	---	---	---	---	---	---	---	---
PETROLEUM REFINING AND PRODUCTION													
FLUID CATALYTIC CRACKERS	---	---	---	---	---	---	---	---	---	---	---	---	---
SOUR WATER STRIPPERS	---	---	---	---	---	---	---	---	---	---	---	---	---
DELAYED COKERS	---	---	---	---	---	---	---	---	---	---	---	---	---
MISC. REFINERY UNITS	---	---	---	---	---	---	---	---	---	---	---	---	---
OIL FIELD PRODUCTION	---	---	---	---	---	---	---	---	---	---	---	---	---
MISC. STATIONARY SOURCES													
PETROLEUM COKE KILNS	---	---	---	---	---	---	---	---	---	---	---	---	---
GLASS FURNACES	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
NON-FERROUS METALS	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
FERROUS METALS	14.55	14.55	14.55	14.55	14.55	14.55	14.55	14.55	14.55	14.55	14.55	14.55	14.55
MINERAL PRODUCTS	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90
SEWAGE TREATMENT DIGESTERS	---	---	---	---	---	---	---	---	---	---	---	---	---
OTHER INDUSTRIAL PROCESSES	---	---	---	---	---	---	---	---	---	---	---	---	---
PERMITTED INCINERATORS	---	---	---	---	---	---	---	---	---	---	---	---	---
TOTAL OFF-GRID STATIONARY SOURCES	68.16	58.87	55.86	51.99	55.03	63.31	67.12	64.68	72.26	70.90	71.66	70.93	64.27

TOTAL SOX EMISSICNS IN THE EARLY 1980'S: TEST YEAR 1 UNDER CONDITIONS OF LOW NATURAL GAS SUPPLY, IN TONS/DAY AS SO2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	0.C	0.0	0.0	0.1	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.C	0.1	0.1	0.3	C.2	0.1	0.1	2.3	0.0	0.0	0.0	0.0	0.0	0.0	C.C	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.1	0.1	0.1	0.1	0.5	0.2	0.4	0.3	0.1	0.0	0.0	0.1	0.0	0.0	0.C	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	C.1	0.2	C.1	0.1	0.2	0.3	0.2	0.2	0.4	2.4	0.0	0.1	0.0	0.1	0.C	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.1	0.1	0.2	0.2	0.3	0.3	0.3	C.3	C.3	0.3	2.2	0.2	0.0	0.1	C.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.C	0.0	0.0	0.0	C.1	0.C	0.1	0.1	C.2	0.0	0.4	0.1	0.1	0.2	3.C	0.1	0.1	0.1	0.1	0.1	0.4	0.1	0.1	0.C	0.0
19	C.C	0.0	C.0	0.0	0.1	0.0	0.0	0.1	0.5	0.5	0.2	0.5	0.1	0.1	0.1	0.2	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1
18	0.0	0.0	0.0	0.0	0.1	1.8	0.2	0.4	0.4	0.4	0.5	0.8	0.8	0.3	0.3	0.2	0.3	0.6	0.2	0.2	0.1	0.1	0.1	0.1	1.9
17	0.0	0.0	0.0	0.1	0.1	0.7	0.6	0.3	0.4	0.5	1.0	2.4	0.4	0.3	0.2	0.1	0.1	0.2	0.4	0.1	0.0	0.0	0.0	0.2	0.1
16	C.C	0.0	0.0	0.1	0.3	0.4	0.4	0.2	0.2	0.2	0.7	1.9	2.5	1.0	0.4	0.1	0.3	0.1	0.7	0.2	0.1	0.2	0.2	0.1	0.0
15	0.0	0.0	0.0	0.0	0.0	0.2	0.4	C.2	0.1	0.3	0.7	2.8	2.8	1.5	1.4	0.1	0.2	0.0	0.0	0.0	0.2	0.1	0.1	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.C	1.1	0.3	C.2	0.1	0.3	1.4	1.4	0.8	C.2	0.3	0.7	0.2	0.1	0.0	0.0	0.0	0.1	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.7	9.8	0.4	0.4	0.1	0.2	0.5	0.3	0.4	C.3	0.4	3.6	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0
12	0.0	0.0	0.C	0.0	C.0	0.C	23.6	0.5	C.2	0.2	0.3	0.2	0.4	0.4	1.1	0.3	0.4	3.0	0.1	0.0	0.1	0.1	1.5	1.5	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.5	0.3	0.1	0.3	1.5	0.2	0.3	0.2	0.3	0.3	0.7	0.2	0.6	0.2	0.1	0.1
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.5	12.0	2.2	0.5	11.7	0.3	0.1	C.1	0.2	0.1	0.1	0.3	0.4	0.5	0.3	0.2	0.2	0.0
9	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.1	C.1	0.4	C.3	25.5	0.3	0.2	0.3	0.2	0.2	0.1	0.1	0.1	0.4	0.3	0.2	0.1	0.0
8	0.0	0.0	C.C	0.0	0.0	0.C	0.0	0.0	0.1	0.1	18.2	21.0	1.2	0.5	C.1	60.8	0.2	0.2	0.2	0.1	0.1	0.4	0.2	0.2	0.0
7	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	3.1	4.8	1.8	0.1	0.0	0.1	0.2	0.4	0.3	0.2	0.2	0.1	0.5	0.2	0.0
6	0.0	0.0	0.1	0.1	C.0	0.C	0.0	0.0	0.0	0.1	3.2	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.8	0.2	0.1
5	0.1	0.1	0.0	0.0	0.1	0.1	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.C	0.0	0.C	0.0	0.1	0.2	0.5	0.2	0.6	0.0	0.1
4	0.0	0.0	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.3	0.2	0.1	0.1	0.1
3	0.0	0.0	0.0	0.0	C.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	13.9	4.9	0.2	0.1	0.1	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.C	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.C	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0

SOX
TONS/DAY
356.460

Figure E1.45

TOTAL SOX EMISSIONS IN THE EARLY 1980'S: TEST YEAR 2 UNDER CONDITIONS OF LOW NATURAL GAS SUPPLY, IN TONS/DAY AS SO2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	0.0	0.0	0.0	0.1	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.1	0.1	0.3	0.2	0.1	0.1	2.3	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	C.1	0.1	0.1	0.1	C.5	0.2	0.2	0.2	0.1	0.0	0.0	0.1	0.0	0.0	0.C	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.1	0.2	0.1	0.1	0.2	0.3	0.2	0.2	C.3	2.3	0.C	0.1	0.0	0.1	C.C	0.0	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.1	0.1	0.2	0.2	0.3	0.3	0.3	0.3	C.3	0.3	2.2	0.2	0.0	0.1	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.C	0.0	C.0	0.0	0.1	0.0	0.1	0.1	0.2	0.0	0.4	0.1	0.1	0.2	3.C	0.1	0.1	0.1	0.1	0.1	0.4	0.1	0.1	0.0	0.0
19	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.4	0.5	0.2	0.4	0.1	0.1	0.1	0.2	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1
18	0.0	0.0	0.0	0.0	0.1	1.5	0.2	0.3	0.4	0.4	0.5	0.8	0.8	0.3	0.3	0.2	0.3	0.6	0.2	0.2	0.1	0.1	0.1	0.1	1.8
17	C.C	0.0	0.0	0.1	0.1	0.7	0.7	0.3	0.4	0.5	1.0	2.3	0.4	0.3	0.2	0.1	0.1	0.2	0.4	0.1	0.0	0.0	0.0	0.2	0.1
16	0.0	0.0	0.0	0.1	C.3	0.4	0.4	0.2	0.2	0.2	0.6	1.6	2.3	0.8	0.4	0.1	0.3	0.1	0.7	0.2	0.1	0.2	0.2	0.1	0.0
15	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.2	0.1	0.2	0.8	2.9	3.1	1.6	1.4	0.1	0.2	0.0	0.0	0.0	0.2	0.1	0.1	0.0	0.0
14	C.0	0.0	0.0	0.0	0.0	0.0	1.0	0.3	0.2	0.1	0.3	1.5	0.9	0.8	0.2	0.3	0.E	0.2	0.1	0.0	0.0	0.0	0.1	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.7	9.8	0.4	0.4	0.1	0.2	0.5	0.2	0.3	0.3	0.4	3.5	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	23.6	0.4	0.2	0.2	0.3	0.2	0.4	0.4	1.1	0.3	0.4	3.0	0.1	0.0	0.1	0.1	1.5	1.5	0.0
11	0.0	0.0	0.0	0.0	0.0	0.C	0.1	0.1	0.3	0.5	0.3	0.1	0.3	1.6	0.2	0.3	0.2	0.3	0.3	0.7	0.2	0.6	0.2	0.1	0.1
10	0.0	C.0	0.0	0.0	C.0	0.C	0.0	22.5	12.0	2.2	0.5	11.8	0.3	0.1	0.1	0.2	0.1	0.1	0.3	0.4	0.5	0.3	0.2	0.2	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.4	0.3	25.5	0.3	0.2	0.3	0.2	0.2	0.1	0.1	0.1	0.4	0.3	0.1	0.2	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	18.2	21.0	1.3	0.5	C.1	61.0	0.2	0.2	0.2	0.1	0.1	0.4	0.2	0.2	0.0
7	C.1	0.1	0.C	0.0	0.0	0.C	0.0	0.0	0.0	0.1	3.1	4.7	1.8	0.1	0.0	0.1	0.2	0.4	0.3	0.2	0.2	0.1	0.5	0.2	0.0
6	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.1	3.4	0.0	0.0	0.0	0.C	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.8	0.2	0.1
5	0.1	0.1	0.0	0.0	0.1	0.1	0.1	0.0	0.1	0.1	0.C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.5	0.2	0.6	0.0	0.1
4	0.0	0.0	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.3	0.2	0.1	0.1	0.1
3	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	13.9	4.9	0.2	0.1	0.1	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0	0.0	0.1	0.0	0.C	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0
1	0.C	0.0	0.0	0.0	C.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.C	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0

RESEDA
BURBANK
GLENDALE
PASADENA
AZUSA
GLENDORA
WEST COVINA
WEST LA
LOS ANGELES
SANTA MONICA
LENNOX
LYNWOOD
TORRANCE
LONG BEACH
ANAHEIM
GARDEN GROVE
SANTA ANA

SOX
TONS/DAY
354.791

Figure E1,46

TOTAL SOX EMISSIONS IN THE EARLY 1980'S: TEST YEAR 3 UNDER CONDITIONS OF LOW NATURAL GAS SUPPLY, IN TONS/DAY AS SO2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	0.0	0.0	0.0	0.1	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.1	0.1	0.3	0.2	0.1	0.1	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.1	0.1	0.1	0.1	0.5	0.2	0.3	0.2	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.1	0.1	0.1	0.1	0.2	0.3	0.2	0.2	0.3	2.3	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.1	0.1	0.2	0.2	0.3	0.3	0.3	0.3	0.2	0.3	2.2	0.2	0.0	0.1	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.2	0.0	0.4	0.1	0.1	0.2	3.0	0.1	0.1	0.1	0.1	0.1	0.4	0.1	0.1	0.0	0.0
19	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.4	0.5	0.2	0.4	0.1	0.1	0.1	0.2	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1
18	0.0	0.0	0.0	0.0	0.1	1.3	0.2	0.3	0.3	0.4	0.4	0.8	0.7	0.3	0.3	0.2	0.3	0.6	0.2	0.2	0.1	0.1	0.1	0.1	1.6
17	0.0	0.0	0.0	0.2	0.1	0.5	0.6	0.3	0.4	0.5	0.9	1.6	0.4	0.3	0.2	0.1	0.1	0.2	0.3	0.1	0.0	0.0	0.0	0.2	0.1
16	0.0	0.0	0.0	0.1	0.3	0.3	0.4	0.2	0.2	0.2	0.6	1.6	2.2	0.8	0.3	0.1	0.3	0.1	0.7	0.2	0.1	0.2	0.2	0.1	0.0
15	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.2	0.1	0.2	0.7	3.0	3.5	1.5	1.5	0.1	0.2	0.0	0.0	0.0	0.2	0.1	0.1	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.3	0.2	0.1	0.3	1.5	1.3	0.7	0.2	0.3	0.7	0.2	0.1	0.0	0.0	0.0	0.1	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.7	9.8	0.4	0.4	0.1	0.2	0.5	0.2	0.3	0.3	0.4	3.5	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	23.6	0.4	0.2	0.2	0.3	0.2	0.3	0.4	1.1	0.3	0.4	3.0	0.1	0.0	0.1	0.1	1.5	1.5	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.5	0.3	0.1	0.3	1.5	0.2	0.3	0.2	0.2	0.3	0.7	0.2	0.6	0.2	0.0	0.1
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.5	12.0	2.4	0.5	11.8	0.3	0.1	0.1	0.2	0.1	0.1	0.3	0.4	0.4	0.3	0.2	0.2	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.3	25.7	0.3	0.2	0.3	0.2	0.2	0.1	0.1	0.1	0.4	0.3	0.1	0.2	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	18.2	21.1	1.2	0.5	0.1	61.0	0.2	0.2	0.2	0.1	0.1	0.4	0.2	0.2	0.0
7	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	3.0	4.7	1.8	0.1	0.0	0.1	0.2	0.4	0.3	0.2	0.2	0.1	0.5	0.2	0.0
6	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.1	3.3	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.8	0.2	0.1
5	0.1	0.1	0.0	0.0	0.1	0.1	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.5	0.2	0.6	0.0	0.1
4	0.0	0.0	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	[illegible]	0.1	0.1	0.3	0.2	0.1	0.1	0.1
3	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.9	4.9	0.2	0.1	0.1	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0

RESEDA
BURBANK
GLENDALE
PASADENA
AZUSA
GLENDORA
WEST COVINA
WEST LA
LOS ANGELES
SANTA MONICA
LENNOX
LYNWOOD
TORRANCE
LONG BEACH
ANAHEIM
GARDEN GROVE
SANTA ANA

SOX
TONS/DAY
353.179

Figure E1.47

Lennox) on the north to Huntington Beach (opposite Santa Ana) on the south. However, sulfur oxides emissions in the downtown Los Angeles area have grown beyond levels observed in the early 1970's due to increased industrial fuel oil use under conditions of low natural gas supply.

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