EPA-R4-73-012, Vol. d

CR-4-273

IMPACTS OF TRANSPORTATION CONTROL STRATEGIES ON LOS ANGELES AIR QUALITY

Contract No. 68-02-0336

May 1973

J. R. Martinez
R. A. Nordsieck
A. Q. Eschenroeder

Prepared for
Environmental Protection Agency

GENERAL RESEARCH CORPORATION
P.O. BOX 3587, SANTA BARBARA, CALIFORNIA 93105

In addition to approval by the Project Leader and Department Head, General Research Corporation reports are subject to independent review by a staff member not connected with the project. This report was reviewed by W. H. Jago.

The work upon which this publication is based was performed pursuant to Contract 68-02-0336 with the Environmental Protection Agency.

CR-4-273

IMPACTS OF TRANSPORTATION CONTROL STRATEGIES ON LOS ANGELES AIR QUALITY

May 1973

J. R. Martinez
R. A. Nordsieck
A. Q. Eschenroeder

Prepared for
Environmental Protection Agency

ABSTRACT

The General Research Corporation photochemical/diffusion simulation model is employed to evaluate four control strategies for reducing air pollution in Los Angeles. Three representative air trajectories (for which validation tests have been run) serve as baseline cases using 1969 emission levels. Transportation controls are emulated by reducing source emissions in accordance with hypothetical plans worked out with the Division of Meteorology of the Environmental Protection Agency. Straight reductions of vehicle miles traveled do not give ozone reduction percentages that are as large as the emission reduction percentages. Strong influence of initial pollutant load of the air in the morning is noted. Day-to-day pollution carryover must be carefully adjusted through the initial conditions to account for continuous strategies in contrast with intermittent strategies. Ratios of nitrogen oxides to reactive hydrocarbon affect the ozone buildup markedly. It is found that control of the mixture ratio can be more important than straight reduction in emissions.

CONTENTS

SECTION		PAGE
	ABSTRACT	i
1	INTRODUCTION	1
2	STUDY PLAN	3
	2.1 Trajectories for Baseline Cases	3
	2.2 Strategies Tested	3
3	IMPACTS	10
	3.1 The 30 Percent Strategy	10
	3.2 The Reduced Downtown Emissions Strategy	21
	3.3 The EQL Strategy	29
	3.4 Zero Emissions Intermittent Control Strategy	39
4	EFFECT OF INITIAL CONDITIONS SCALING ON THE EQL STRATEGY RESULTS	47
5	CONCLUDING REMARKS	54
	REFERENCES	57

ILLUSTRATIONS

NO.		PAGE
2.1	Trajectory No. 1	4
2.2	Trajectory No. 2	5
2.3	Trajectory No. 3	6
3.1	Comparison of CO Levels for Baseline Case and 30% Reduction Strategy, Trajectory No. 1	11
3.2	Comparison of NO and NO_2 Levels for Baseline Case and 30% Reduction Strategy, Trajectory No. 1	12
3.3	Comparison of Ozone Levels for Baseline Case and 30% Reduction Strategy, Trajectory No. 1	13
3.4	Comparison of CO Levels for Baseline Case and 30% Reduction Strategy, Trajectory No. 2	14
3.5	Comparison of NO and NO_2 Levels for Baseline Case and 30% Reduction Strategy, Trajectory No. 2	15
3.6	Comparison of Ozone Levels for Baseline Case and 30% Reduction Strategy, Trajectory No. 2	16
3.7	Comparison of CO Levels for Baseline Case and 30% Reduction Strategy, Trajectory No. 3	17
3.8	Comparison of NO and NO_2 Levels for Baseline Case and 30% Reduction Strategy, Trajectory No. 3	18
3.9	Comparison of Ozone Levels for Baseline Case and 30% Reduction Strategy, Trajectory No. 3	19
3.10	Comparison of CO Levels for Baseline Case and Reduced-Downtown-Emissions Strategy, Trajectory No. 1	22
3.11	Comparison of NO and NO_2 Levels for Baseline Case and Reduced-Downtown-Emissions Strategy, Trajectory No. 1	23

Illustrations (Cont.)

NO.		PAGE
3.12	Comparison of Ozone Levels for Baseline Case and Reduced-Downtown-Emissions Strategy, Trajectory No. 1	24
3.13	Comparison of CO Levels for Baseline Case and Reduced-Downtown-Emissions Strategy, Trajectory No. 3	25
3.14	Comparison of NO and NO_2 Levels for Baseline Case and Reduced-Downtown-Emissions Strategy, Trajectory No. 3	26
3.15	Comparison of Ozone Levels for Baseline Case and Reduced-Downtown-Emissions Strategy, Trajectory No. 3	27
3.16	Comparison of CO Levels for Baseline Case and EQL Strategy, Trajectory No. 1	30
3.17	Comparison of NO and NO_2 Levels for Baseline Case and EQL Strategy, Trajectory No.1	31
3.18	Comparison of Ozone Levels for Baseline Case and EQL Strategy, Trajectory No. 1	32
3.19	Comparison of CO Levels for Baseline Case and EQL Strategy, Trajectory No. 2	33
3.20	Comparison of NO and NO_2 Levels for Baseline Case and EQL Strategy, Trajectory No. 2	34
3.21	Comparison of Ozone Levels for Baseline Case and EQL Strategy, Trajectory No. 2	35
3.22	Comparison of CO Levels for Baseline Case and EQL Strategy, Trajectory No. 3	36
3.23	Comparison of NO and NO_2 Levels for Baseline Case and EQL Strategy, Trajectory No. 3	37
3.24	Comparison of Ozone Levels for Baseline Case and EQL Strategy, Trajectory No. 3	38
3.25	Comparison of NO and NO_2 Levels for Baseline Case and Zero-Emissions Strategy, Trajectory No. 1	41
3.26	Comparison of Ozone Levels for Baseline Case and Zero-Emissions Strategy, Trajectory No. 1	42

Illustrations (Cont.)

NO.		PAGE
3.27	Comparison of NO and NO_2 Levels for Baseline Case and Zero-Emissions Strategy, Trajectory No. 2	43
3.28	Comparison of Ozone Levels for Baseline Case and Zero-Emissions Strategy, Trajectory No. 2	44
3.29	Comparison of NO and NO_2 Levels for Baseline Case and Zero-Emissions Strategy, Trajectory No. 3	45
3.30	Comparison of Ozone Levels for Baseline Case and Zero-Emissions Strategy, Trajectory No. 3	46
4.1	Effect of Changes in HC/NO_x Ratio and Initial Load Level for Trajectory 1, Zero Emissions Strategy	48
4.2	Effect of Varying Initial Load Level with Constant HC/NO_x Ratio = 2 for Trajectory 1, Zero Emissions Strategy	52

TABLES

NO.		PAGE
2.1	Directory of Air Quality and Meteorological Monitoring Stations in the Los Angeles Basin	7
3.1	Effect of 30% Reduction in Mobile Source Emissions	10
3.2	Ratio of Total Emissions After 30% Reduction on Mobile Source Emissions to Total Emissions Before Controls on Mobile Sources	20
3.3	Ratio of Selected Parameters after 90% Reduction in Miles Traveled in the Downtown Area to the Parameters without Reduction in Miles Traveled	28
3.4	Ratio of Selected Parameters After Application of EQL Strategy to the Baseline Values	29
3.5	Ratio of Selected Parameters Computed Without Emissions to Baseline Values with Initial Conditions Unchanged	40
4.1	HC/NO_x Ratio, Initial Load Level, and Ozone Dosage for Trajectories Used in Transportation Control Strategy Studies	49
4.2	Effect of Changes in Initial Load Level of $(HC+NO_x)$ on Ozone Peak and Dosage with $HC/NO_x = 2$	52

1 INTRODUCTION

In compliance with the Clean Air Act as amended (PL 91-604), each state must submit an implementation plan showing how it proposes to meet air quality standards. An element of the plan must be a control strategy for each region where ambient levels of a pollutant exceed the applicable national standard. The plan submitted by California for the Los Angeles Air Quality Control Region (AQCR) recommends relatively large percentage reductions in mobile source emissions as follows: CO: 80%, NO_x: 57%, and enough hydrocarbon reduction to lower oxidant by 79%. These emission reductions were estimated to produce improvements in air quality as follows: CO concentration reduction >78%, NO_2 concentration reduction ≈45%, and oxidant concentration reduction ≈73%.

Part of the plan proposed by California was disapproved by EPA on the grounds that the proposed reductions in hydrocarbon emissions would not result in oxidant levels which meet the national air quality standards of 0.08 parts per million (ppm) for one hour. Following a court ruling, EPA promulgated its own strategy, which recommends a reduction in hydrocarbon emissions of 87%.[1] The EPA plan has been involved in controversy because it appears that the only way to reduce HC emissions by 87% is by a drastic decrease in the use of vehicles in Los Angeles during the smog season.

The 87% hydrocarbon emissions reduction called for by EPA was obtained by the application of the so-called linear rollback formula. The linear rollback formula assumes that air quality levels are directly proportional to emissions and is based on the equation

$$\text{percent emissions reduction} = \left(1 - \frac{S}{A}\right) \times 100$$

where S = air quality standard

A = actual air quality

It is not the purpose of this report to examine either the State or Federal implementation plans. The latter is evaluated in another report[2] based on the testimony of one of the authors (A. Eschenroeder). This report is basically exploratory and treats four hypothetical transportation control strategies using the General Research Corporation (GRC) photochemical/diffusion simulation model.[3]

In contrast to the oversimplifications of linear rollback, the results we present here are based on a deterministic prediction of expected reduction. Such a prediction is now possible through the application of the GRC simulation model. The method of applying the technique is to establish baseline values for times and conditions for which meteorological and air quality variables have been measured. Then the emission control strategy is imposed on the existing inventories as reductions in certain emission sources with respect to the specific pollutant, the location, and the time. In this manner, changes in air quality can be associated directly with changes in emissions for established conditions of atmospheric transport and sunlight intensity.

The specific objective of these exercises is to determine the effect of various amounts of emission reductions on air pollution levels at selected points in the Los Angeles Basin. Days with high pollution levels were selected for the simulation. The ground rules for the study were established by EPA by selecting the days, the air trajectories, and the emission reductions to be tested. The exercise demonstrates the flexibility and utility of the model approach while providing quantitative information which allows us to evaluate the effectiveness of the various abatement strategies studies.

This report first describes the study plan in terms of the trajectories and the strategies tested. Then it details the results obtained by simulating the strategies.

2 STUDY PLAN

2.1 TRAJECTORIES FOR BASELINE CASES

Three air trajectories were obtained from a previous phase of our studies[4] which gives full details on evaluating the validity of the model for these and 21 other trajectories. Comprehensive discussions on emissions statistics, meteorological inputs, and chemical kinetics are given in Ref. 4 and will not be repeated here. The three trajectories chosen for the study consisted of two trajectories on September 29, 1969, and one on November 4, 1969. The main criterion used in the selection of these trajectories was the presence of high concentrations of ozone. The maps shown in Figs. 2.1-2.3 illustrate the path of the air parcels as they traverse the Los Angeles Basin. Table 2.1 lists the monitoring stations and abbreviations used in the figures. The trajectories shall be identified using the following numbering scheme:

- Trajectory No. 1 for September 29, 1969 starts at 0530 hours* in Downtown Los Angeles and ends at 1230 hours near Pomona in the San Gabriel Valley.
- Trajectory No. 2 for September 29, 1969 starts at 0230 hours near the coast and ends at 1230 hours in Anaheim.
- Trajectory No. 3 for November 4, 1969 starts at 0530 hours in Downtown Los Angeles and ends at 1430 hours near Mission Hills in the San Fernando Valley.

2.2 STRATEGIES TESTED

Four emission control strategies for reducing emissions of carbon monoxide, reactive hydrocarbons, and nitric oxide were applied to each trajectory. These control strategies are:

1. 30% reduction in CO, reactive hydrocarbons, and nitric oxide emissions from mobile sources only. This was believed

*All times are given in Pacific Standard Time.

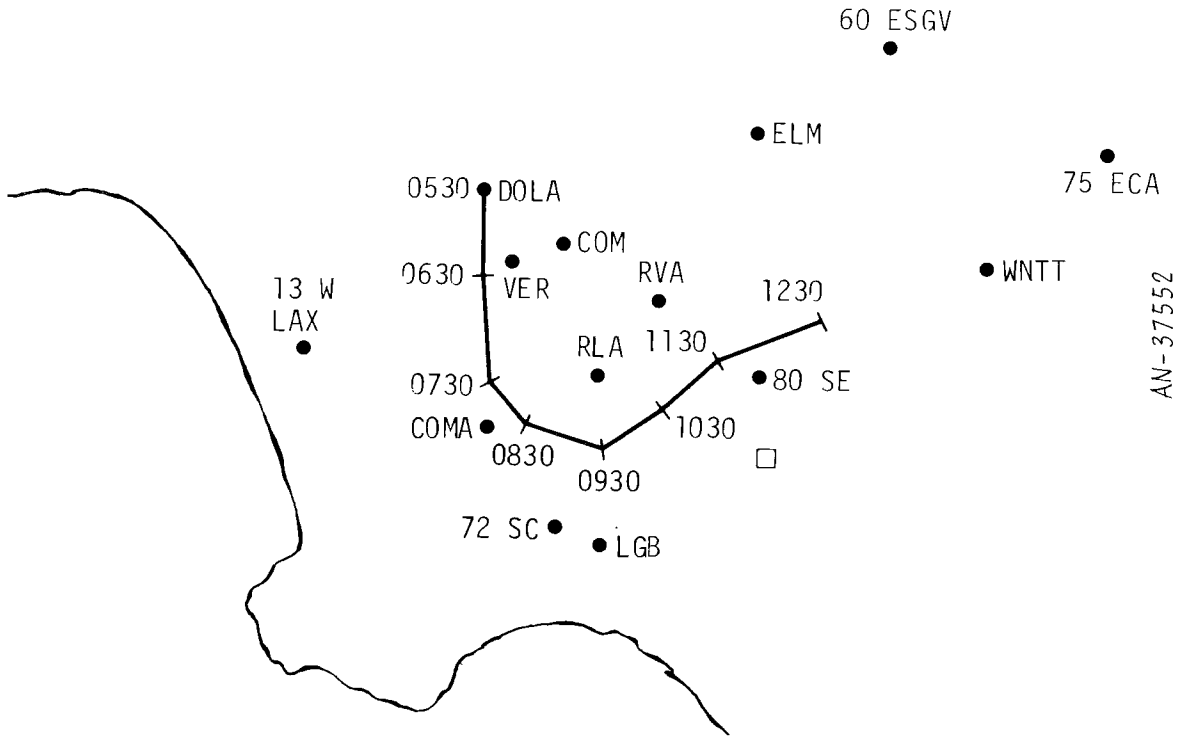
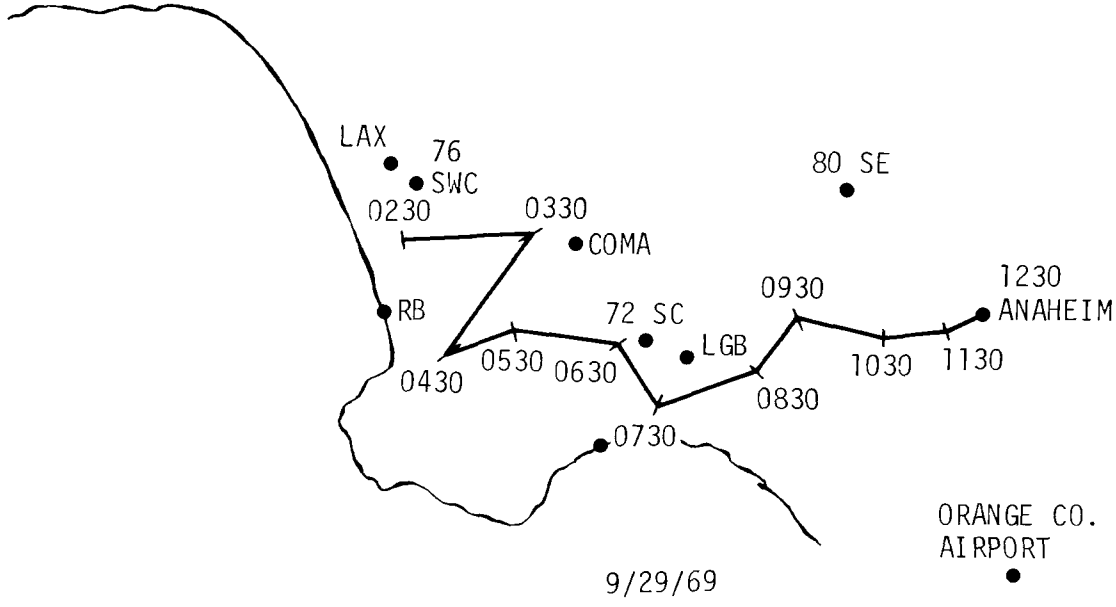


Figure 2.1. Trajectory No. 1



AN-37551

Figure 2.2. Trajectory No. 2

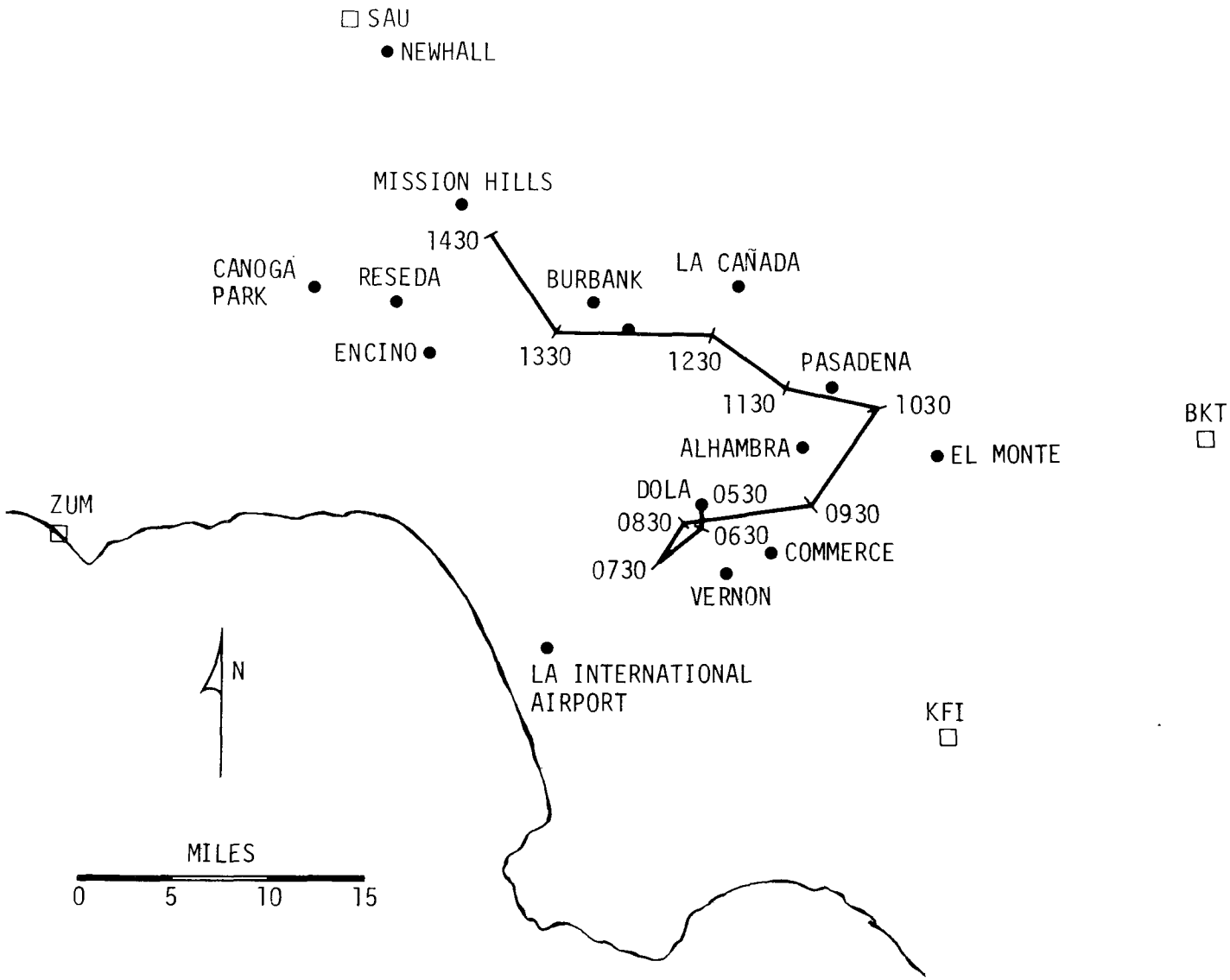


Figure 2.3. Trajectory No. 3

TABLE 2.1

DIRECTORY OF AIR QUALITY AND METEOROLOGICAL MONITORING STATIONS IN THE LOS ANGELES BASIN

Abbreviation	Location
ALMB	Alhambra
AZU	Azusa - East San Gabrial Valley
BRT	Brackett
BUR	Hollywood-Burbank Airport
BURK	Burbank - East San Fernando Valley
COMA	Compton
CPK	Canoga Park
DOLA	Downtown Los Angeles - LAAPCD Headquarters
DOM	Dominguez
ELM	El Monte
ENC	Encino
FOX	Gen. Wm. J. Fox Airfield
HOL	Hollywood
KFI	KFI Transmitter
LACA	La Cañada
LANC	Lancaster
LAX	Los Angeles International Airport
LENX	Lennox
LGB	Long Beach Airport
LONB	Long Beach - South Coast
MALC	Malibu
MDR	Marina del Ray

TABLE 2.1 (Cont.)

Abbreviation	Location
MISH	Mission Hills
MWS	Mount Wilson
NEW	Newhall
NP	Newport Beach
NTB	Los Alamitos Naval Air Station
ONT	Ontario International Airport
PASA	Pasadena - West San Gabriel Valley
PICO	Pico
PMD	Palmdale Airport
POMA	Pomona
RB	Redondo Beach
RESD	Reseda
RLA	Rancho Los Amigos
RVA	Rivera
SAU	Saugus
SM	Santa Monica
SP	San Pedro
VEN	Venice
VER	Vernon
WEST	West Los Angeles
WHTR	Whittier
WNTT	Walnut
ZUM	Zuma Beach

to be a maximum reduction obtainable by placing sanctions on vehicle operations without any technological changes in the vehicle itself.

2. A nearly vehicle-free area involving 90% reduction in mileage traveled in a 60 mi^2 area approximately centered in Downtown Los Angeles.

3. An approximation* to the Environmental Quality Laboratory's (EQL) strategy[5] which consists of:

   a. 62% reduction in CO emissions together with a 50% cut in the initial CO load

   b. 79% reduction in reactive hydrocarbon emissions from mobile sources together with a 63% cut in the initial load

   c. 73% reduction in nitric oxide emissions from mobile sources together with a 58% cut in initial NO_x load

4. The ultimate in intermittent control strategies which is modeled by total elimination of all emissions without changing initial conditions.

Except for the third strategy, all other strategies were tested using the initial concentrations obtained from air monitoring data for each of the three trajectories. The selection of these strategies is motivated by a need to investigate relative effects; therefore, it should not be interpreted as an endorsement of these courses of action.

---

*The numbers are interpretations by EPA of the results of applying the EQL strategy.

3 IMPACTS

3.1 THE 30 PERCENT STRATEGY

Table 3.1 shows the changes obtained in peak ozone, ozone dosage, and CO peak for the first strategy. The numbers shown on Table 3.1 are the ratio of the quantity after the emission controls are applied to the quantity before applying emission controls. Concentration histories along the ground track of the air parcels are shown in Figs. 3.1 through 3.9 for the baseline case and for the 30 percent strategy. It should be noted that the dosage shown in Table 3.1, as well as in subsequent sections, is the integral of the concentration-time curve for ozone. Hence it is the ozone dose that would be experienced by an observer traveling with the air parcel.

TABLE 3.1

EFFECT OF 30% REDUCTION IN MOBILE SOURCE EMISSIONS

(Numbers shown are ratios of the quantity after applying controls to the quantity before controls are applied.)

Trajectory	O_3 Peak	O_3 Dosage	CO Peak
1	0.99	1.04	0.87
2	0.93	0.96	0.79
3	0.84	0.92	0.87

From Table 3.1, it can be seen that CO shows the greatest response to the emission controls. This is to be expected since atmospheric CO concentrations are wholly due to mobile sources and the full force of the controls can be felt by the air parcel. Actually, the response of CO has a one-to-one relationship to uniform changes in emissions. Thus a uniform 30% reduction in CO emissions should result in a 30% decrease in CO peak provided that transient effects due to initial conditions are removed. The results reported in Table 3.1 are based on ratios obtained with initial conditions included, hence the ratio is 0.87 instead of 0.70.

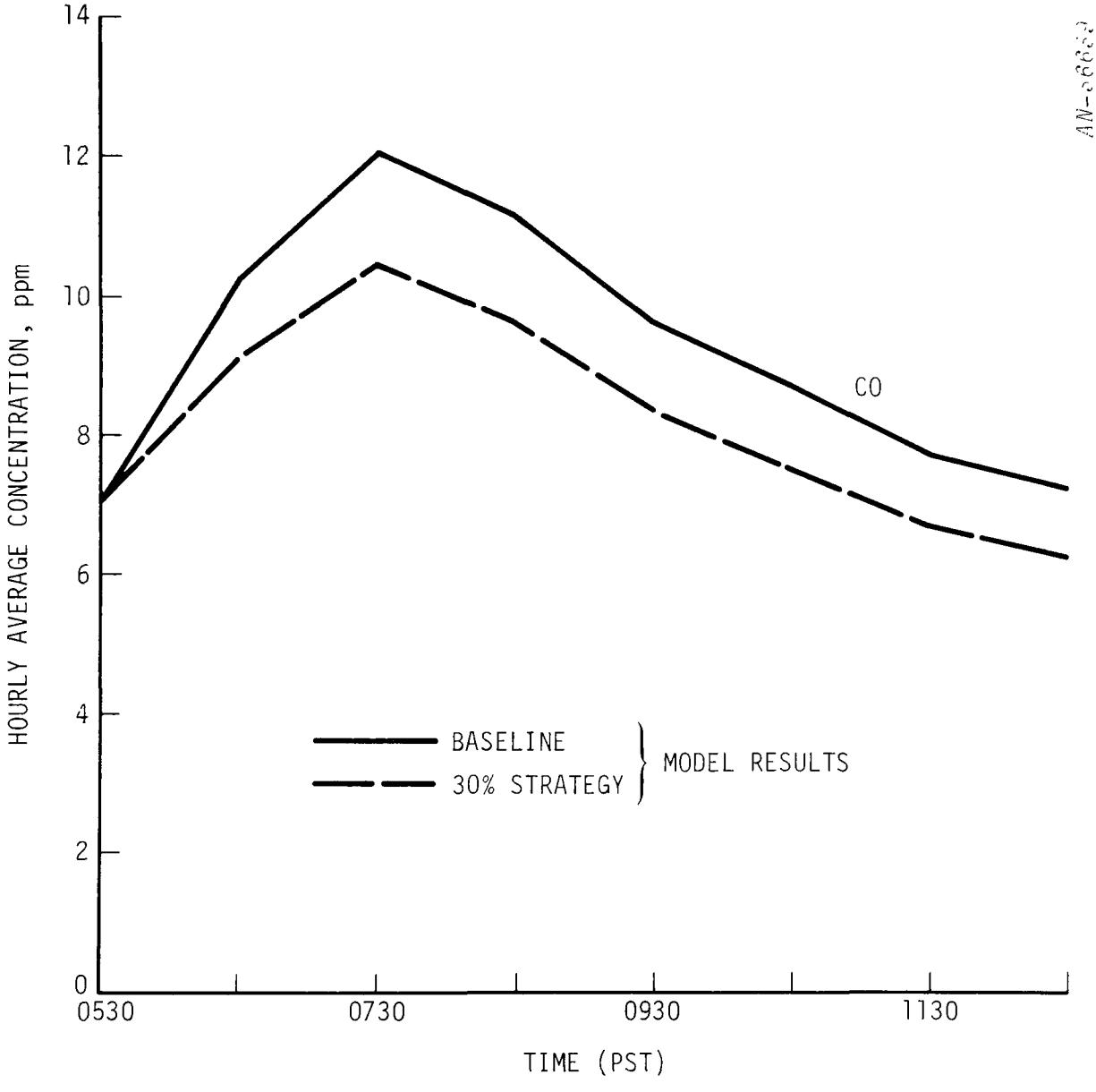


Figure 3.1. Comparison of CO Levels for Baseline Case and 30% Reduction Strategy, Trajectory No. 1

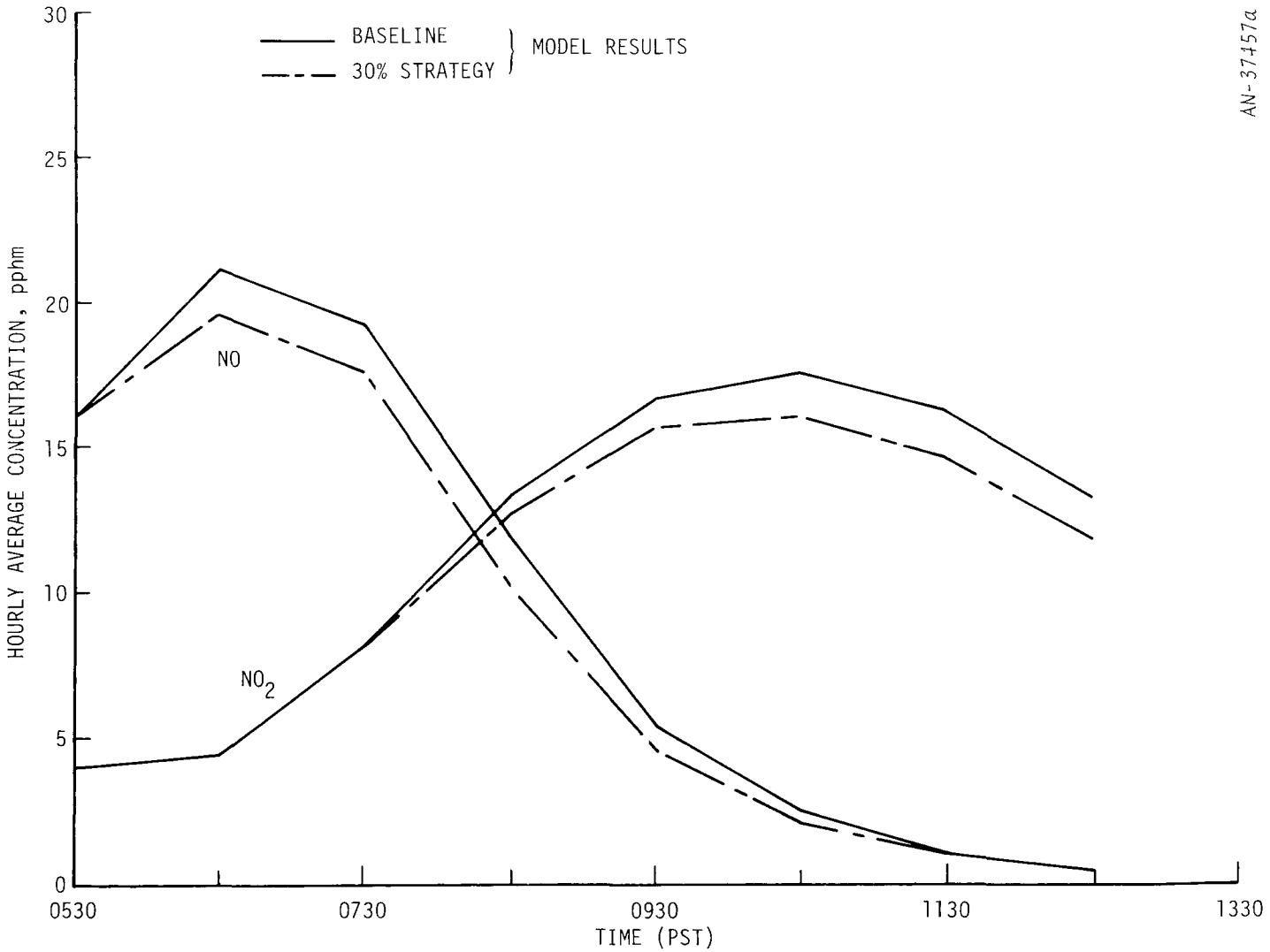


Figure 3.2. Comparison of NO and NO_2 Levels for Baseline Case and 30% Reduction Strategy, Trajectory No. 1

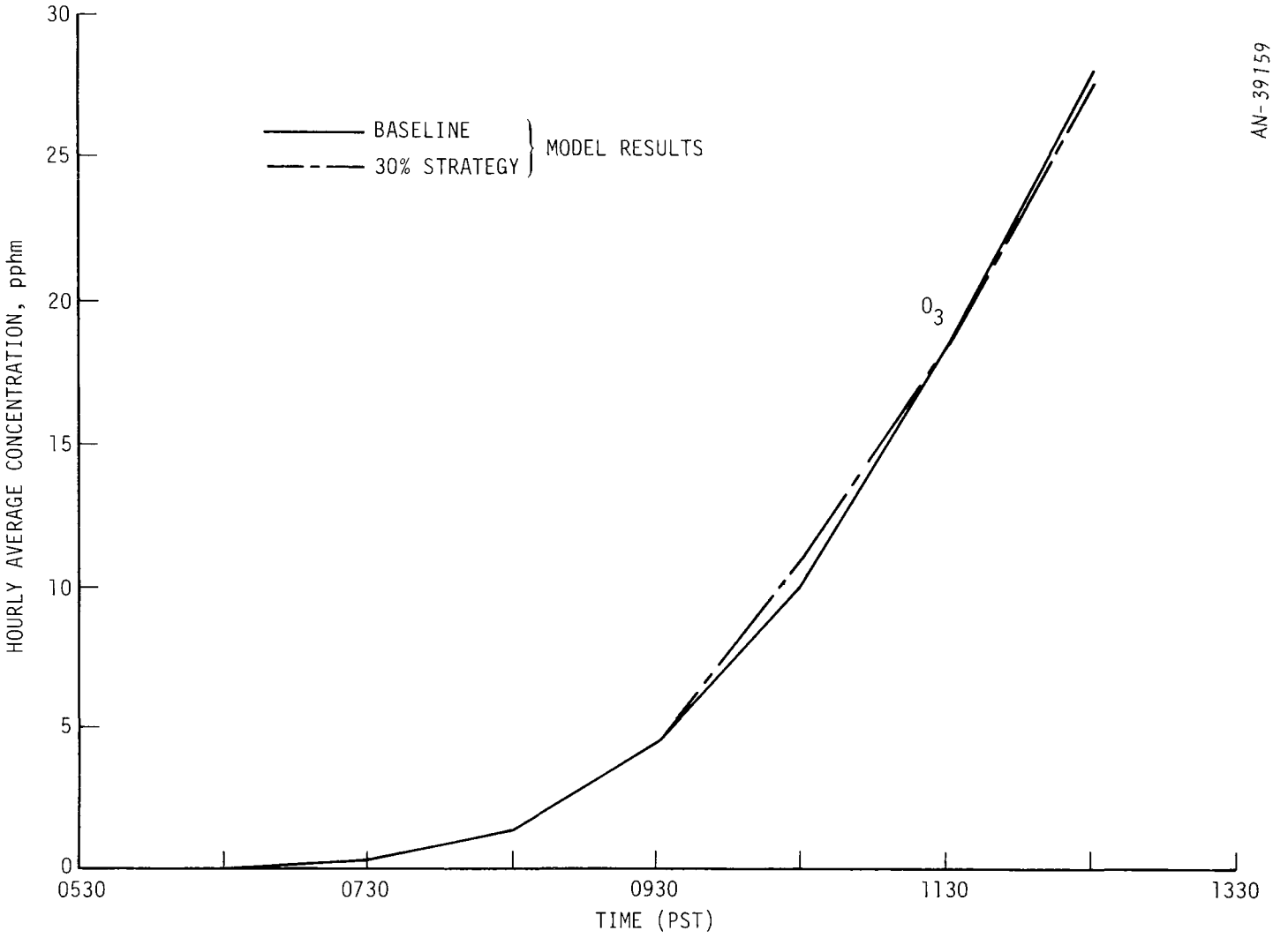


Figure 3.3. Comparison of Ozone Levels for Baseline Case and 30% Reduction Strategy, Trajectory No. 1

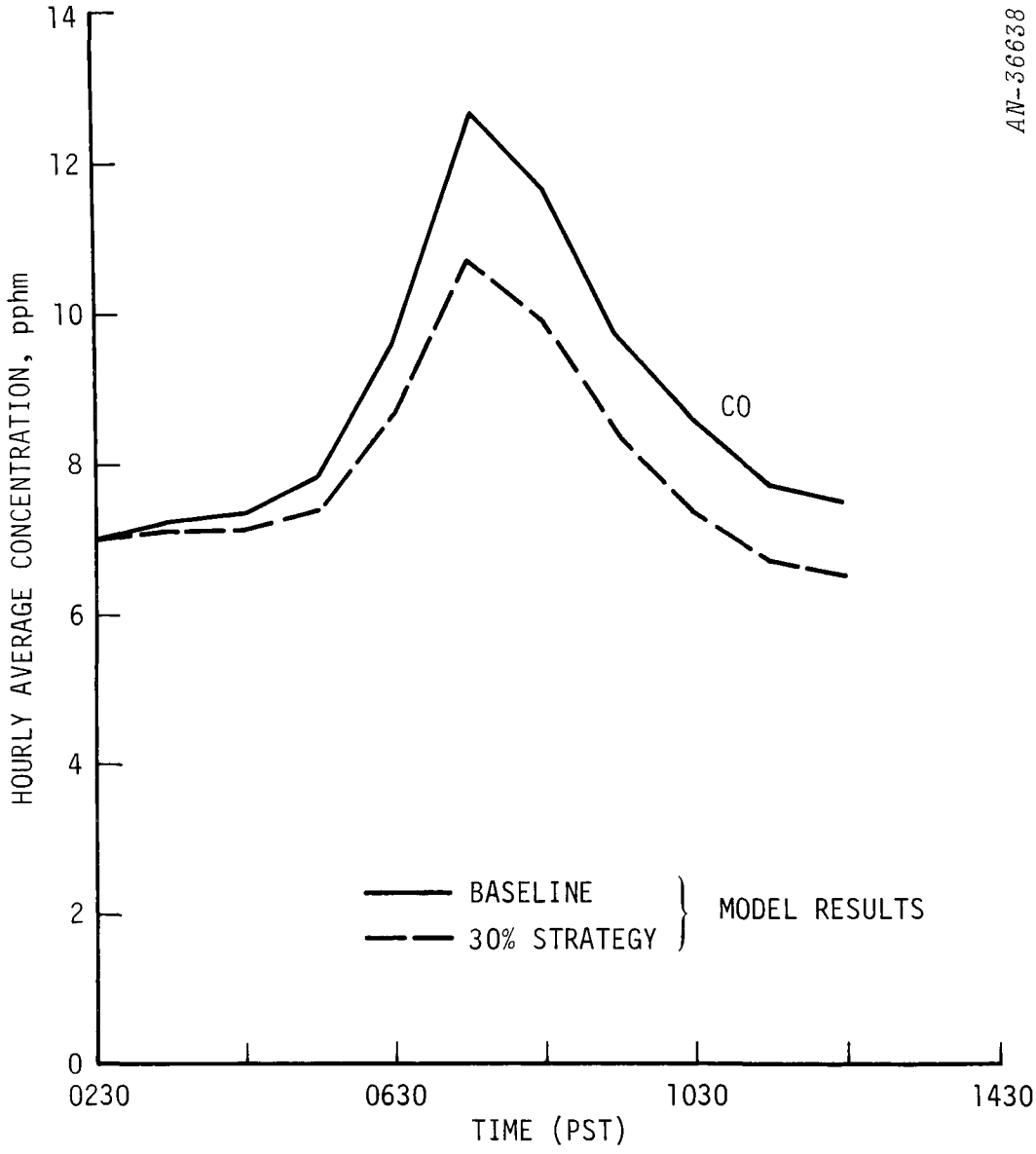


Figure 3.4. Comparison of CO Levels for Baseline Case and 30% Reduction Strategy, Trajectory No. 2

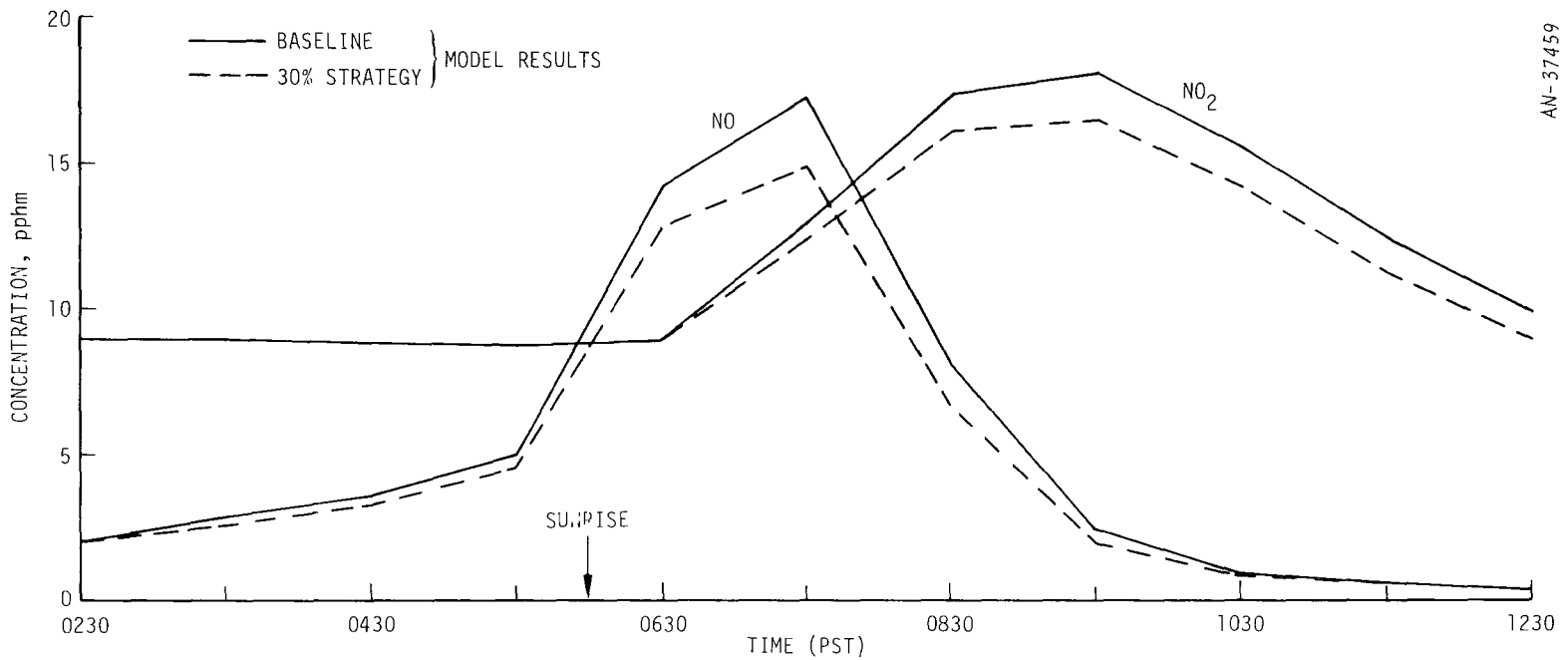


Figure 3.5. Comparison of NO and NO_2 Levels for Baseline Case and 30% Reduction Strategy, Trajectory No. 2

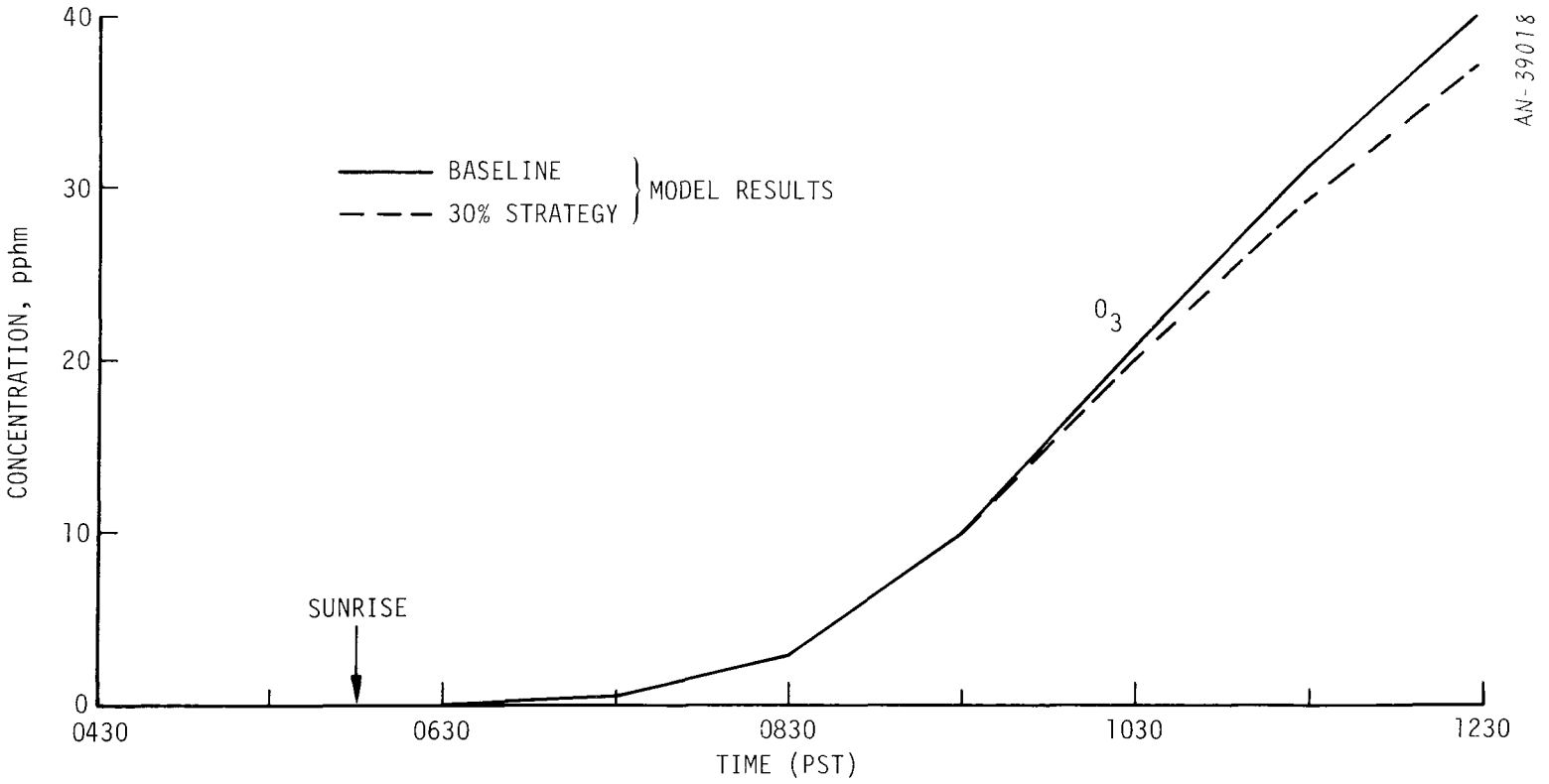


Figure 3.6. Comparison of Ozone Levels for Baseline Case and 30% Reduction Strategy, Trajectory No. 2

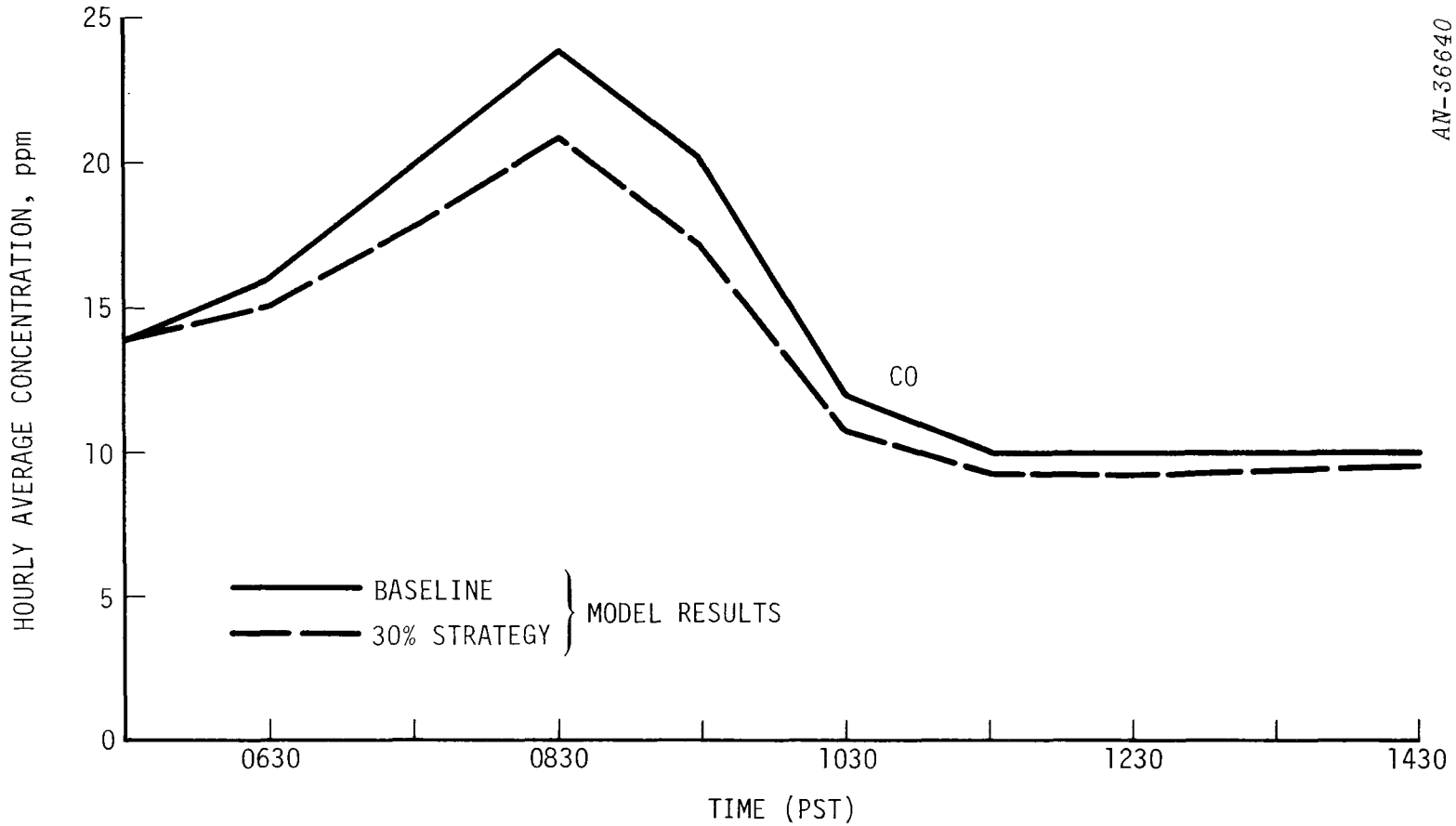


Figure 3.7. Comparison of CO Levels for Baseline Case and 30% Reduction Strategy, Trajectory No. 3

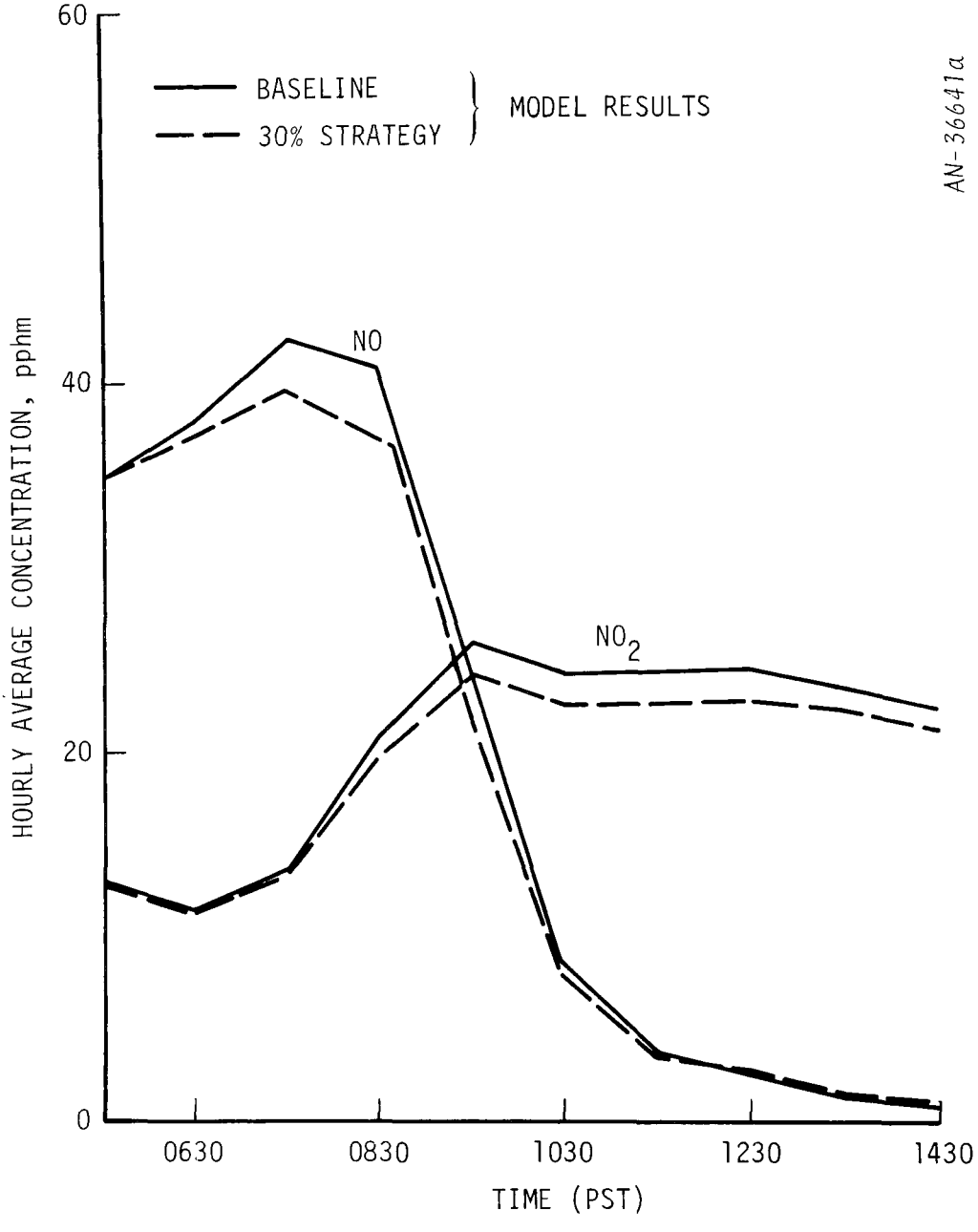


Figure 3.8. Comparison of NO and NO_2 Levels for Baseline Case and 30% Reduction Strategy, Trajectory No. 3

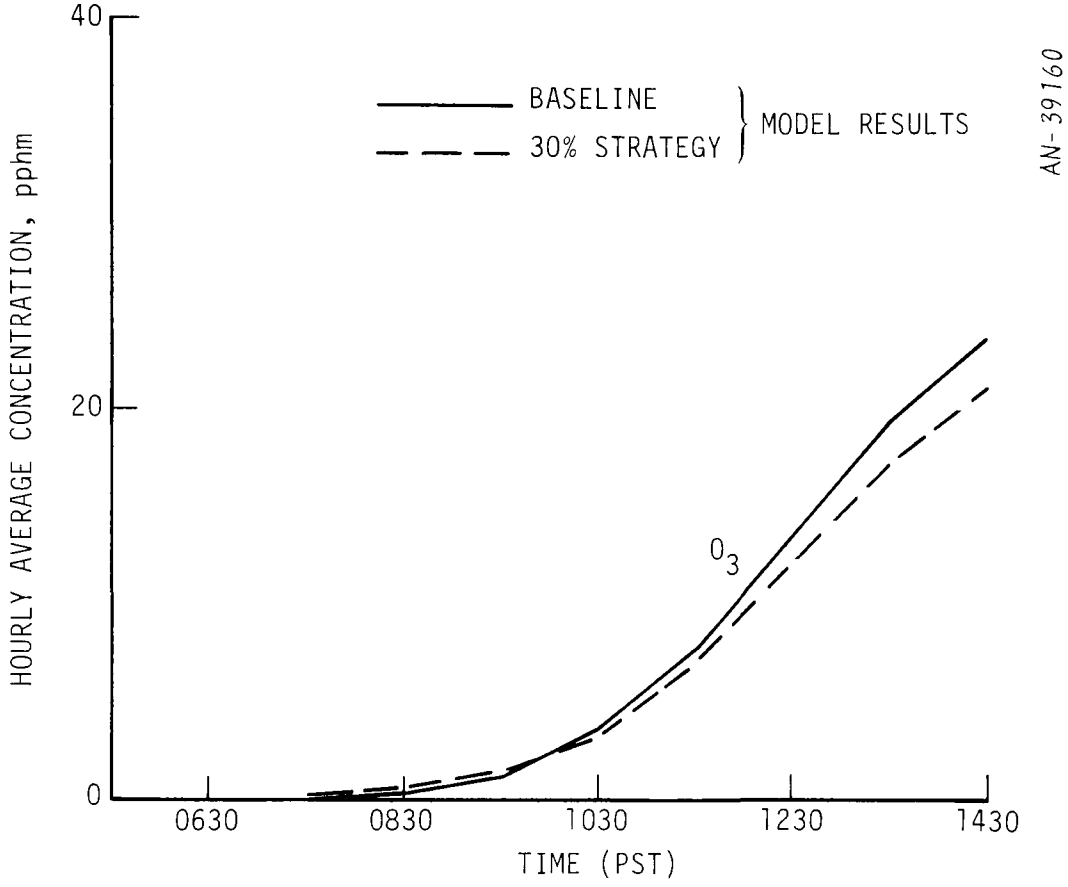


Figure 3.9. Comparison of Ozone Levels for Baseline Case and 30% Reduction Strategy, Trajectory No. 3

Once the system relaxes and the transients have decayed, the ratio of the asymptotic CO concentration with the 30% reduction in emissions to the concentration without the reduction should be found to be 0.70.

The changes in peak ozone and ozone dosage are seen to be so small as to be insignificant. Although the last trajectory shows a 16% decrease in peak ozone, the dosage is only reduced by 8%. As mentioned previously, the first and third trajectories contain relatively large initial loads of reactive pollutants and are not very sensitive to source emissions.

Table 3.2 shows the ratio of emissions after controls to emissions before controls. The emissions considered here and subsequently are the emissions received by the air parcel as it sweeps over the Los Angeles Basin. If the full 30% reduction were in effect for total emissions, all the ratios would be equal to 0.7. From Table 3.2, it is seen that the contribution of stationary sources reduces the impact of the controls for the reactive species: The NO reductions range from 13% to 26% and the hydrocarbon reductions from 19% to 22%. From Tables 3.1 and 3.2 we see that the emissions cutbacks and the peak concentration of ozone and CO are positively correlated, but that the relationship is far weaker than a one-to-one proportionality. This casts some doubt on the validity of linear rollback assumptions for secondary pollutants such as ozone if reduction of vehicle miles travelled is the action contemplated.

TABLE 3.2

RATIO OF TOTAL EMISSIONS AFTER 30% REDUCTION ON MOBILE SOURCE EMISSIONS TO TOTAL EMISSIONS BEFORE CONTROLS ON MOBILE SOURCES

Trajectory	NO	Reactive Hydrocarbons	CO
1	0.87	0.81	0.7
2	0.81	0.78	0.7
3	0.74	0.78	0.7

Table 3.1 also shows that, in the case of the first trajectory, even though the peak ozone concentration decreased slightly, the ozone dosage increased about 4%. Referring to Fig. 3.3, we can see that the reason for the increase in ozone dosage is that the ozone curve for the 30% emissions reduction shows slight increases in concentration during the hours 0930-1130. The cause for these increases is the lower concentration of NO which, through the fast reaction $NO + O_3 \rightarrow NO_2 + O_2$, tends to keep the ozone in check until the NO decays to a low value. Thus the reductions in NO emissions tend to speed up the accumulation of ozone and this results in a slight dosage increase. However, the lower NO emissions also work to lower the amount of NO_2 present, as can be seen in Fig. 3.2. Because the NO_2 concentration is lower, the production rate of ozone will be eventually slowed down and the resulting ozone peak will be reduced. It should be noted that the peak ozone concentration occurs at 1230, the end of the trajectory. Because of the reduced NO_2 levels, the difference in peak ozone and dosage between the baseline and 30% strategy cases should increase if the computation were continued beyond 1230. Finally, we note that initial concentrations also play a large role in the results shown in Table 3.1. A fuller explanation of these effects is given in Sec. 4.

3.2 THE REDUCED DOWNTOWN EMISSIONS STRATEGY

The second control strategy consists of reducing by 90% the vehicle miles traveled in an area of 60 mi^2 approximately centered on Downtown Los Angeles. Only trajectories 1 and 3 could be used to evaluate the effect of this strategy since the second trajectory does not traverse the affected area. It should also be noted from Fig. 2.1 that in the case of trajectory 1 the air parcel does not spend very much time downtown and the observed effects are therefore very small. However, trajectory 3 does spend a considerable amount of time in the downtown area and the effects of the strategy are much more significant. Figures 3.10 through 3.15 compare the ground concentrations along the ground track with and without the strategy applied.

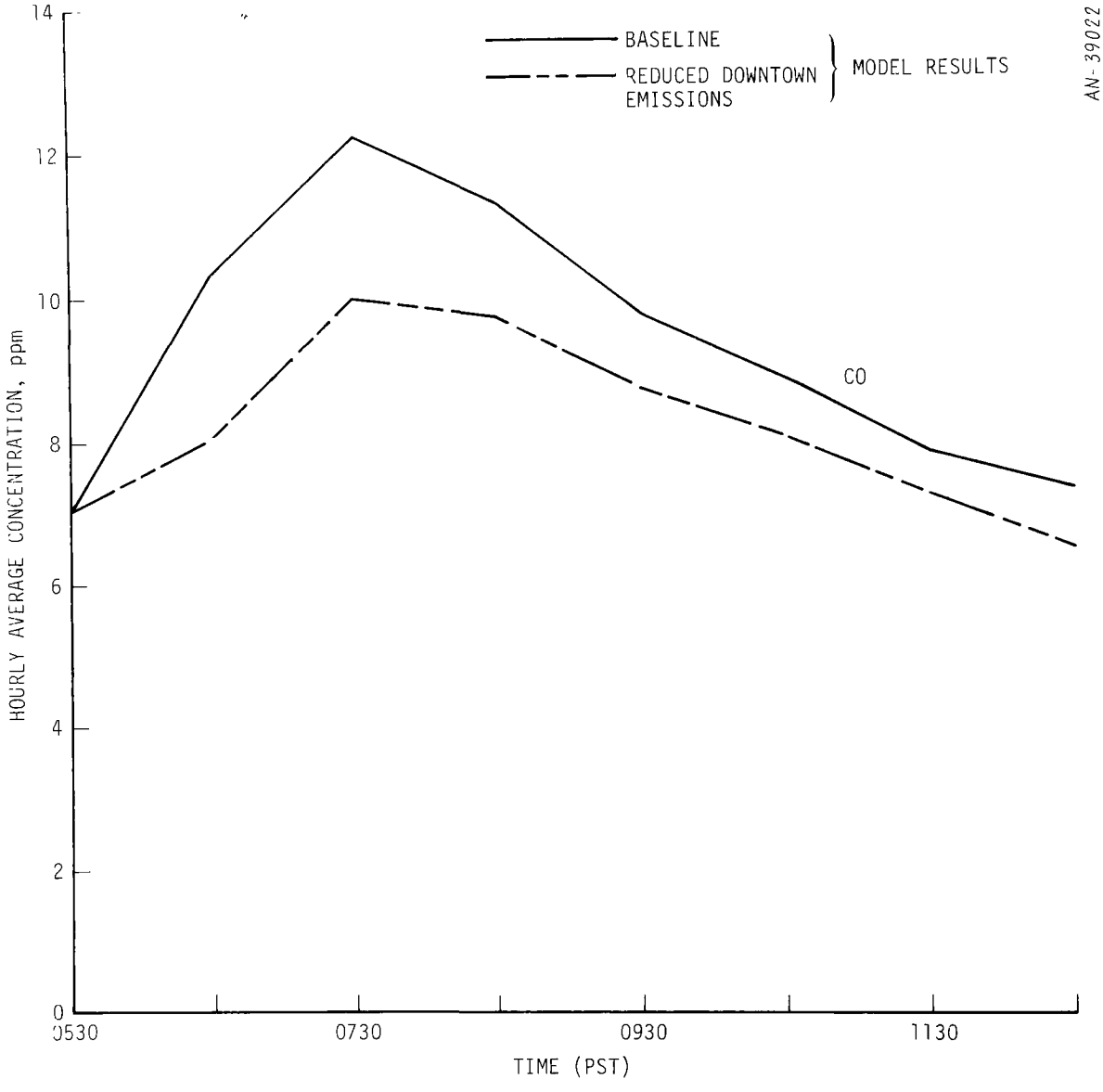


Figure 3.10. Comparison of CO Levels for Baseline Case and Reduced-Downtown-Emissions Strategy, Trajectory No. 1

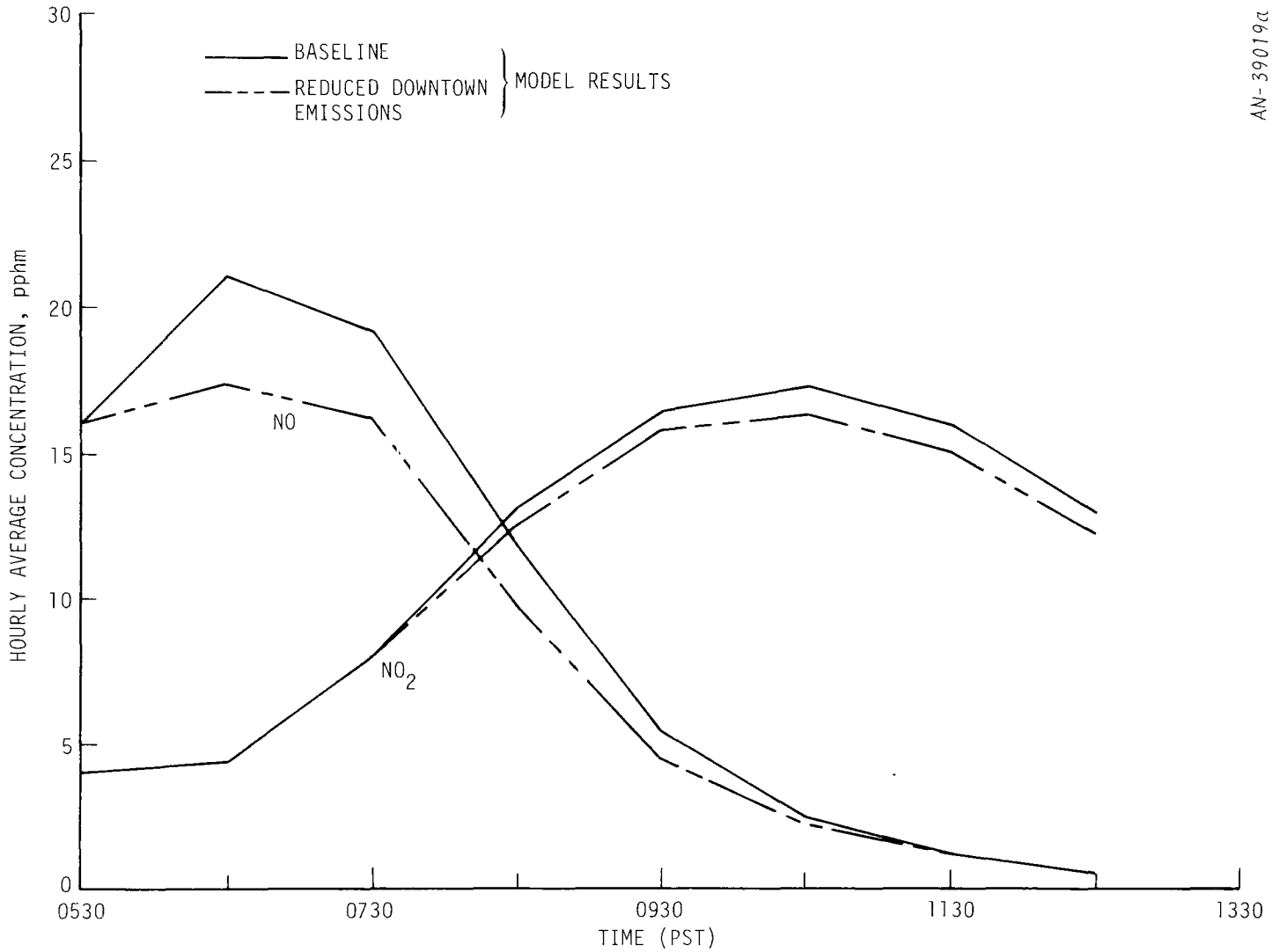


Figure 3.11. Comparison of NO and NO_2 Levels for Baseline Case and Reduced-Downtown-Emissions Strategy, Trajectory No. 1

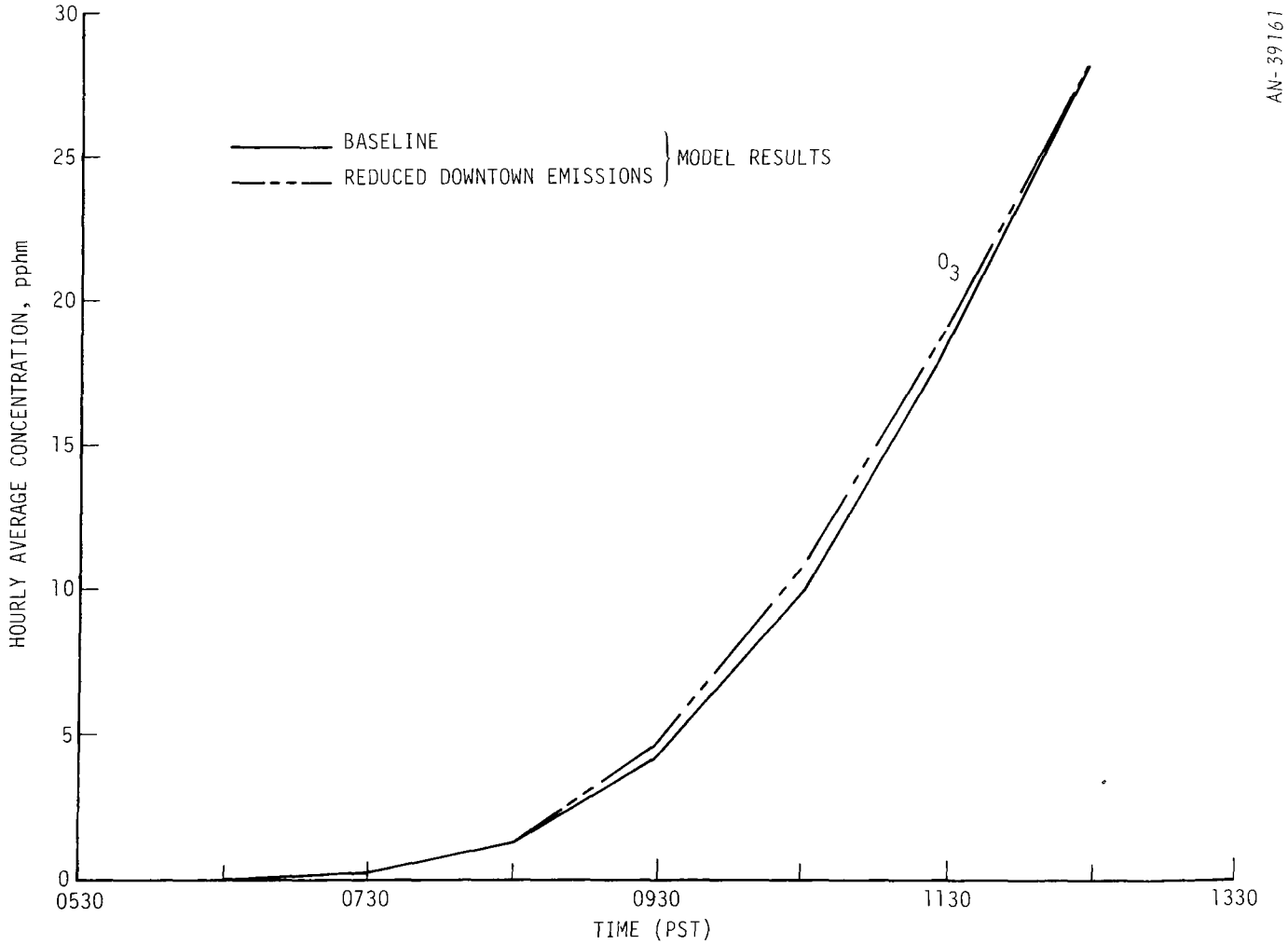


Figure 3.12. Comparison of Ozone Levels for Baseline Case and Reduced-Downtown-Emissions Strategy, Trajectory No. 1

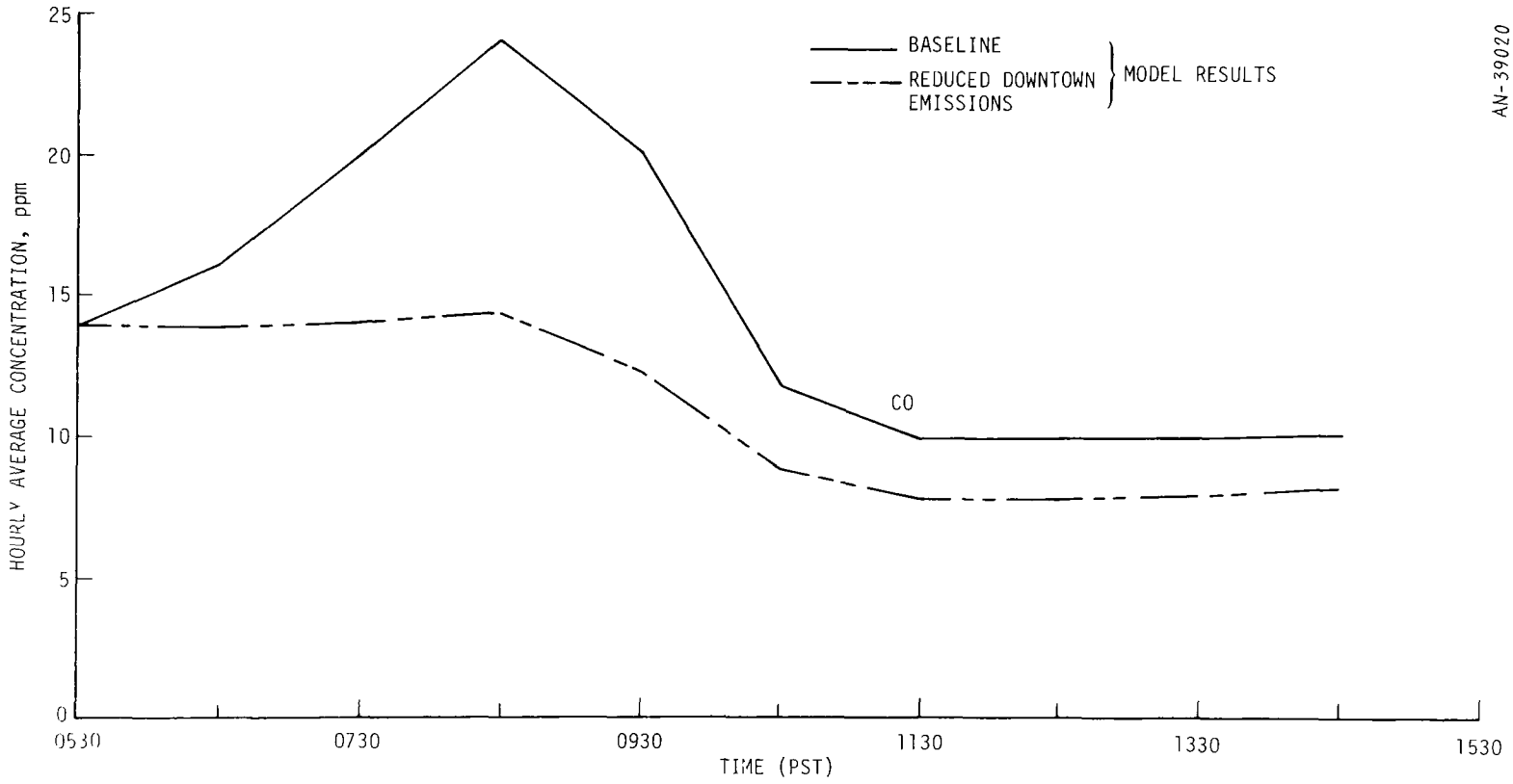


Figure 3.13. Comparison of CO Levels for Baseline Case and Reduced-Downtown-Emissions Strategy, Trajectory No. 3

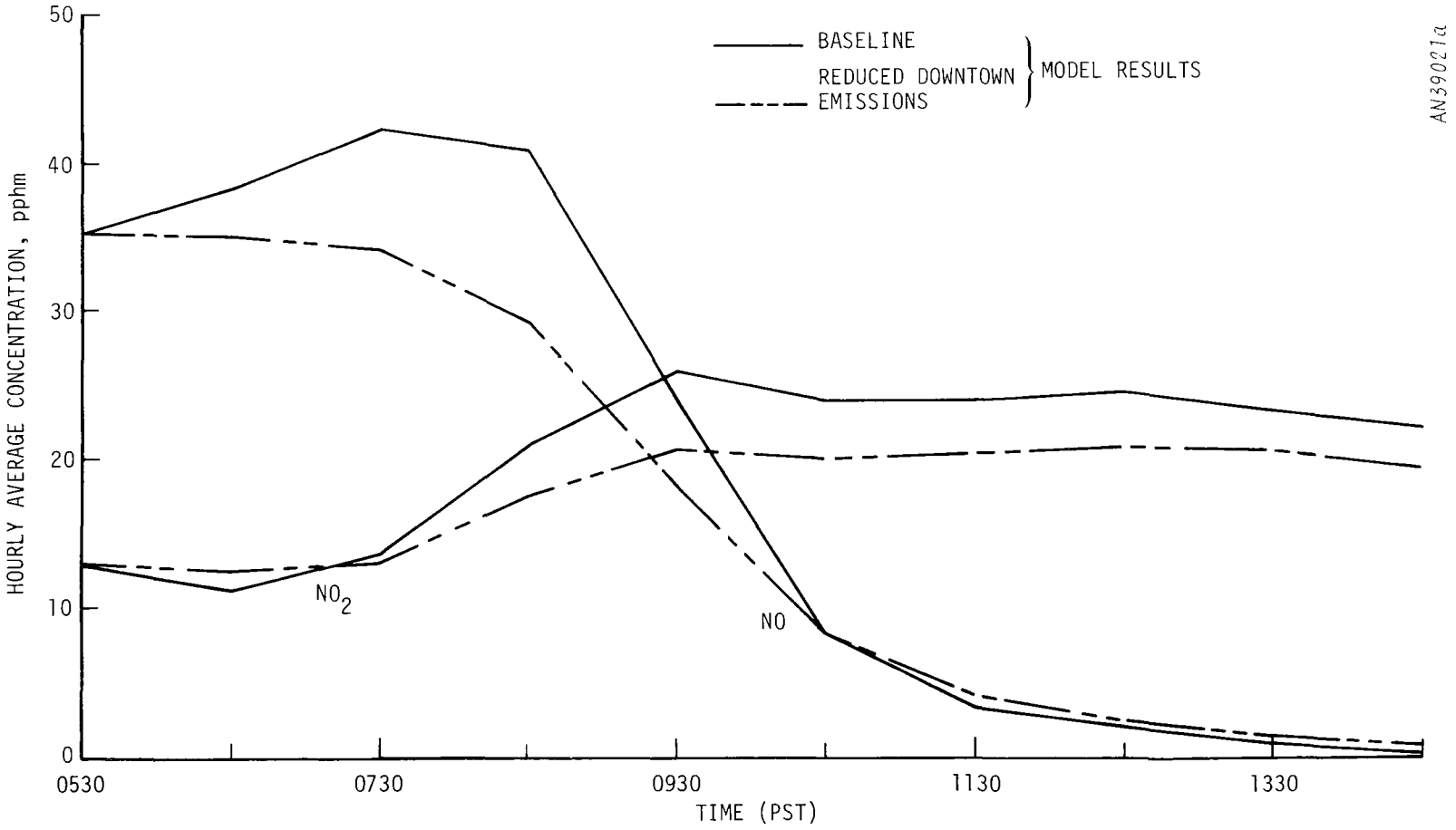


Figure 3.14. Comparison of NO and NO_2 Levels for Baseline Case and Reduced-Downtown-Emissions Strategy, Trajectory No. 3

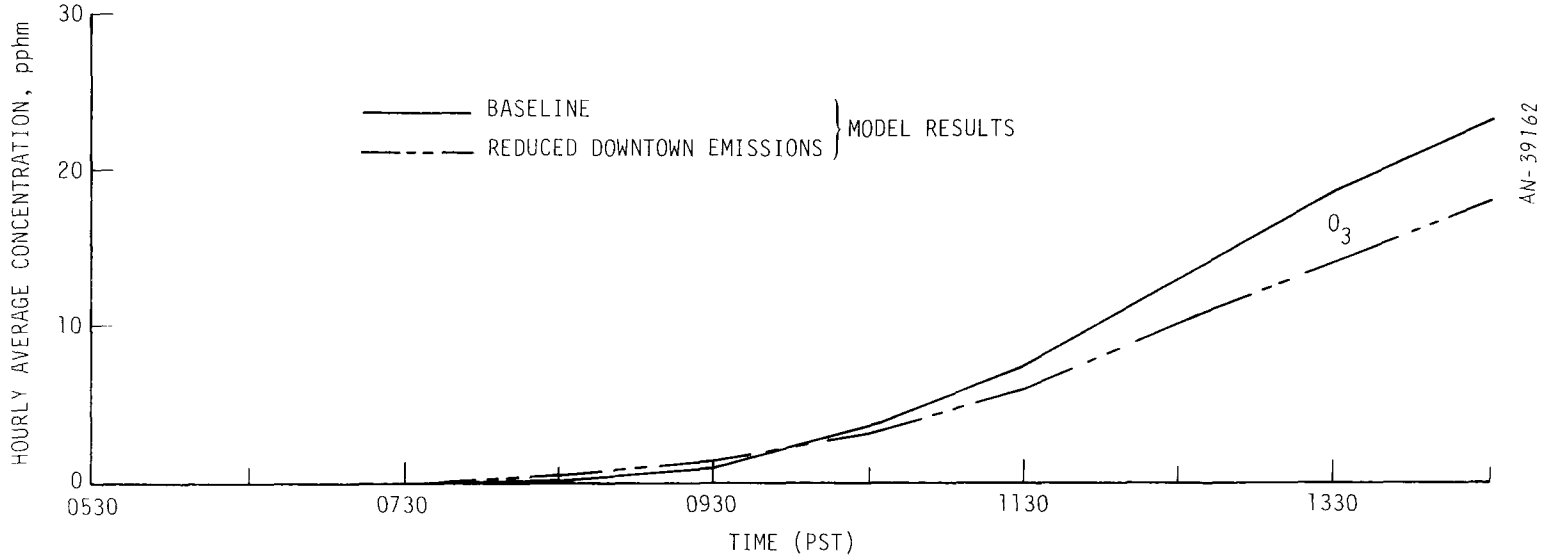


Figure 3.15. Comparison of Ozone Levels for Baseline Case and Reduced-Downtown-Emissions Strategy, Trajectory No. 3

Table 3.3 shows the ratio of the O_3 peak, O_3 dosage, CO peak, and NO, HC, and CO emissions after controls to the quantities before controls. From Table 3.3 it can be observed that for trajectory 1, slight increases in ozone peak and dosage result. For the same trajectory, it is apparent that the emissions reductions are minimal for NO and HC. The increases in ozone peak and dosage can be ascribed to initial condition effects (see Sec. 4 for a detailed explanation of these effects). It should be noted that in this case, the concentration changes expected for CO do not follow a one-to-one relationship with the emissions reductions because the flux changes are not uniform.

TABLE 3.3

RATIO OF SELECTED PARAMETERS AFTER 90% REDUCTION IN MILES TRAVELED IN THE DOWNTOWN AREA TO THE PARAMETERS WITHOUT REDUCTION IN MILES TRAVELED

	Air Quality Effects			Emission Effects		
Trajectory	O_3 Peak	O_3 Dosage	CO Peak	NO	HC	CO
1	1.01	1.04	0.82	0.96	0.90	0.83
3	0.73	0.77	0.66	0.45	0.56	0.39

The increase in peak ozone and dosage shown in Table 3.3 may be somewhat misleading, because in addition to the initial condition effects, the peak ozone concentration occurs at the end of the trajectory. Thus it is possible that if the computation were continued beyond that point that the peak ozone and dosage for the case with reduced emissions would eventually be lower than for the baseline case. This same comment applies to the results discussed in Sec. 3.3. See also the remarks in Sec. 3.1 concerning ozone dosage increases.

For the third trajectory, it is apparent that the emissions reductions are substantial and the air quality improvements are similarly significant. The trajectory spends about 40% of the time in the downtown

area and the reductions in ozone peak and dosage are thus indicative of the influence that is exerted on late-time oxidant formation by reductions in early-morning emissions.

3.3 THE EQL STRATEGY

Table 3.4 shows the ratios of various parameters after abatement is applied to the same quantities before applying controls according to the EQL strategy. Figures 3.16 through 3.24 show concentration comparisons for the EQL case.

TABLE 3.4

RATIO OF SELECTED PARAMETERS AFTER APPLICATION OF EQL STRATEGY TO THE BASELINE VALUES

	Air Quality Effects			Emission Effects		
Trajectory	O_3 Peak	O_3 Dosage	CO Peak	NO	HC	CO
1	1.01	1.35	0.45	0.53	0.51	0.38
2	0.67	0.75	0.45	0.53	0.42	0.38
3	0.90	1.12	0.45	0.53	0.42	0.38

We note that the total NO and HC emissions exceed by considerable margins the expected emissions from mobile sources alone. The expected ratios for mobile source emissions are 0.27 and 0.21 for NO and HC, respectively. Thus we find that the contribution from stationary sources assumes greater importance, generally matching the contributions of the highly controlled mobile sources. Concentrating on the second trajectory, we see significant reductions in both ozone peak and dosage. However, again we note that although total emissions have been essentially halved, the reductions in ozone peak and dosage are 33% and 25% respectively. The reader is referred to Sec. 4 for further elaboration on the other results.

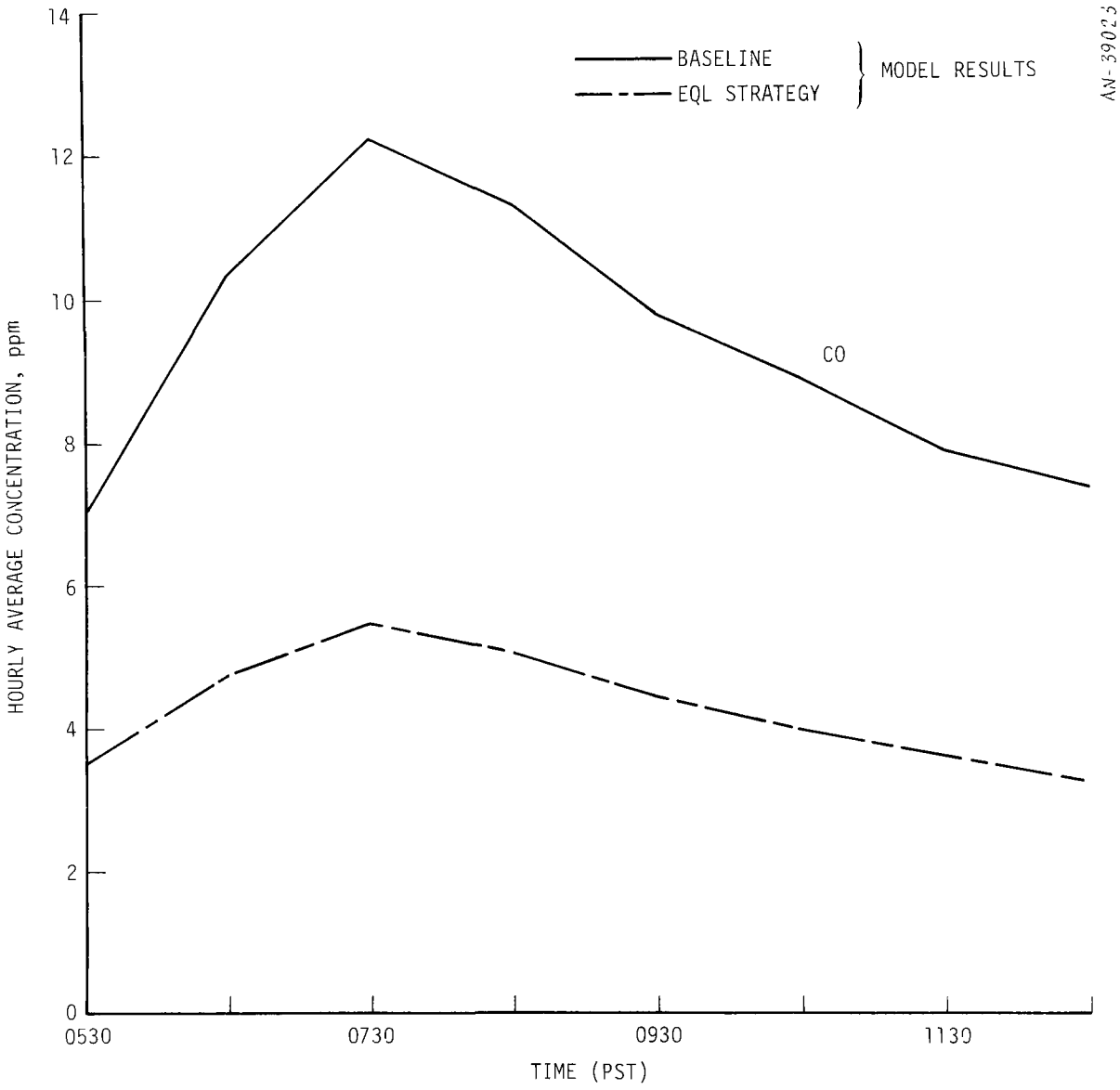


Figure 3.16. Comparison of CO Levels for Baseline Case and EQL Strategy, Trajectory No. 1

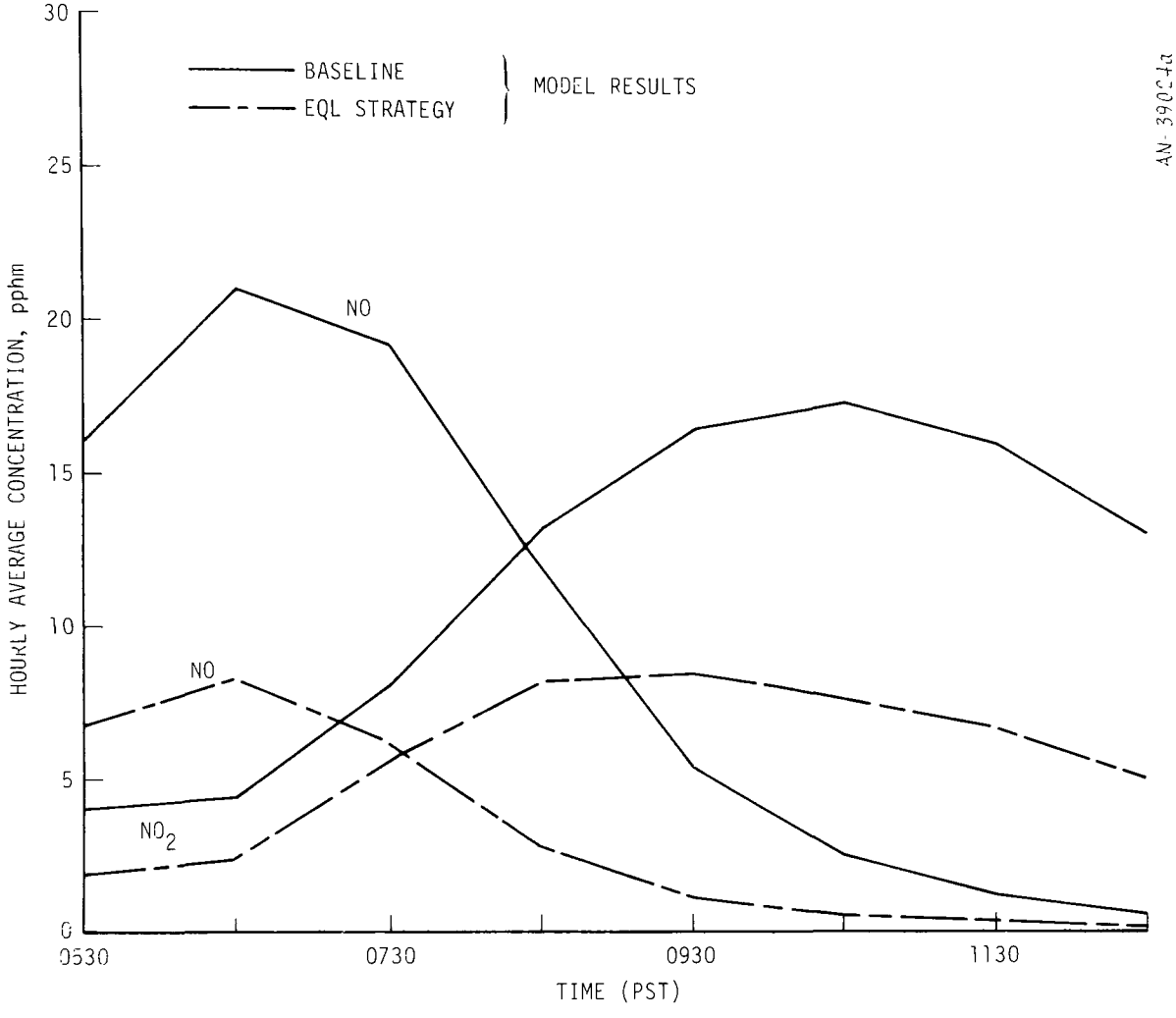


Figure 3.17. Comparison of NO and NO_2 Levels for Baseline Case and EQL Strategy, Trajectory No. 1

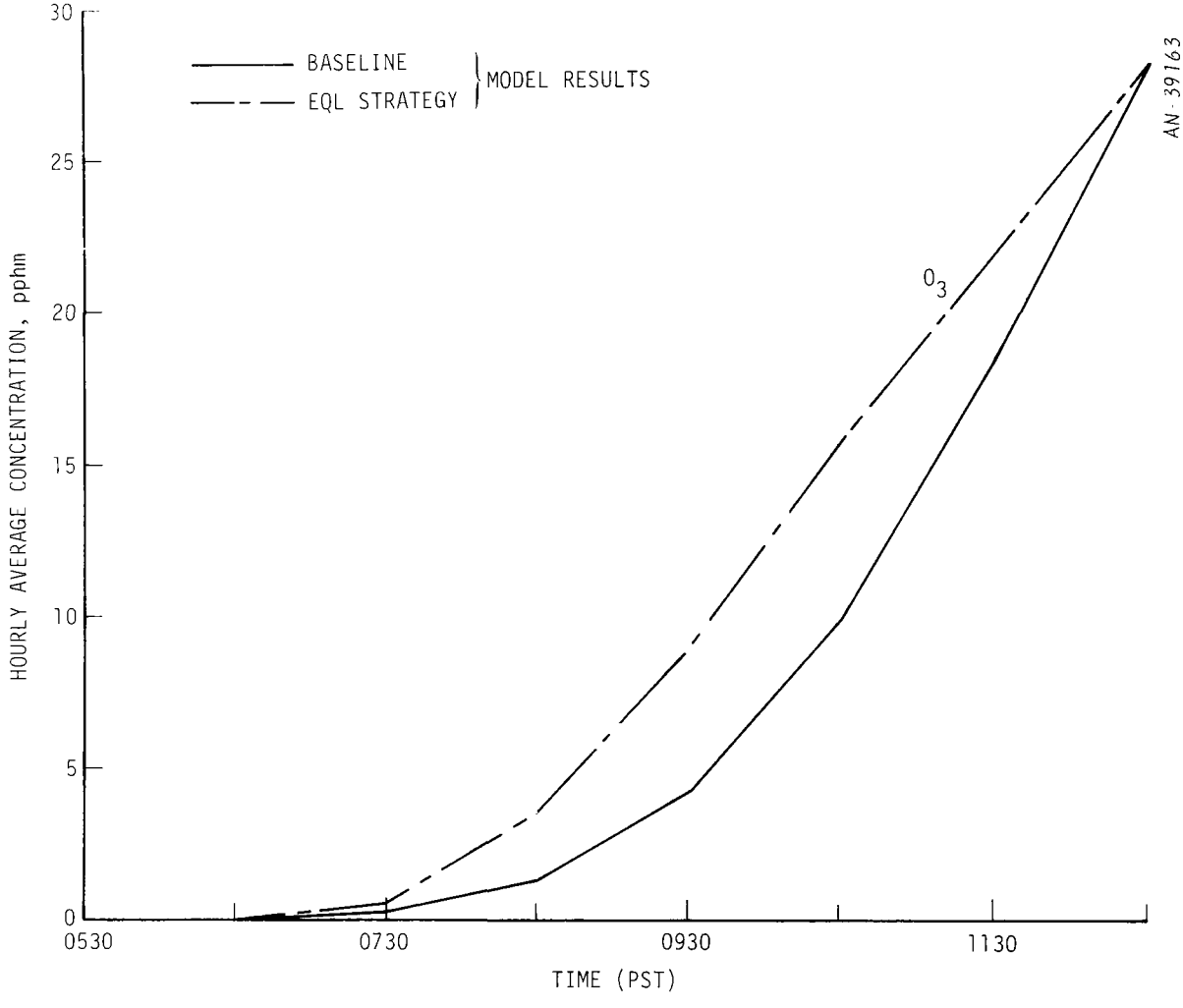


Figure 3.18. Comparison of Ozone Levels for Baseline Case and EQL Strategy, Trajectory No. 1

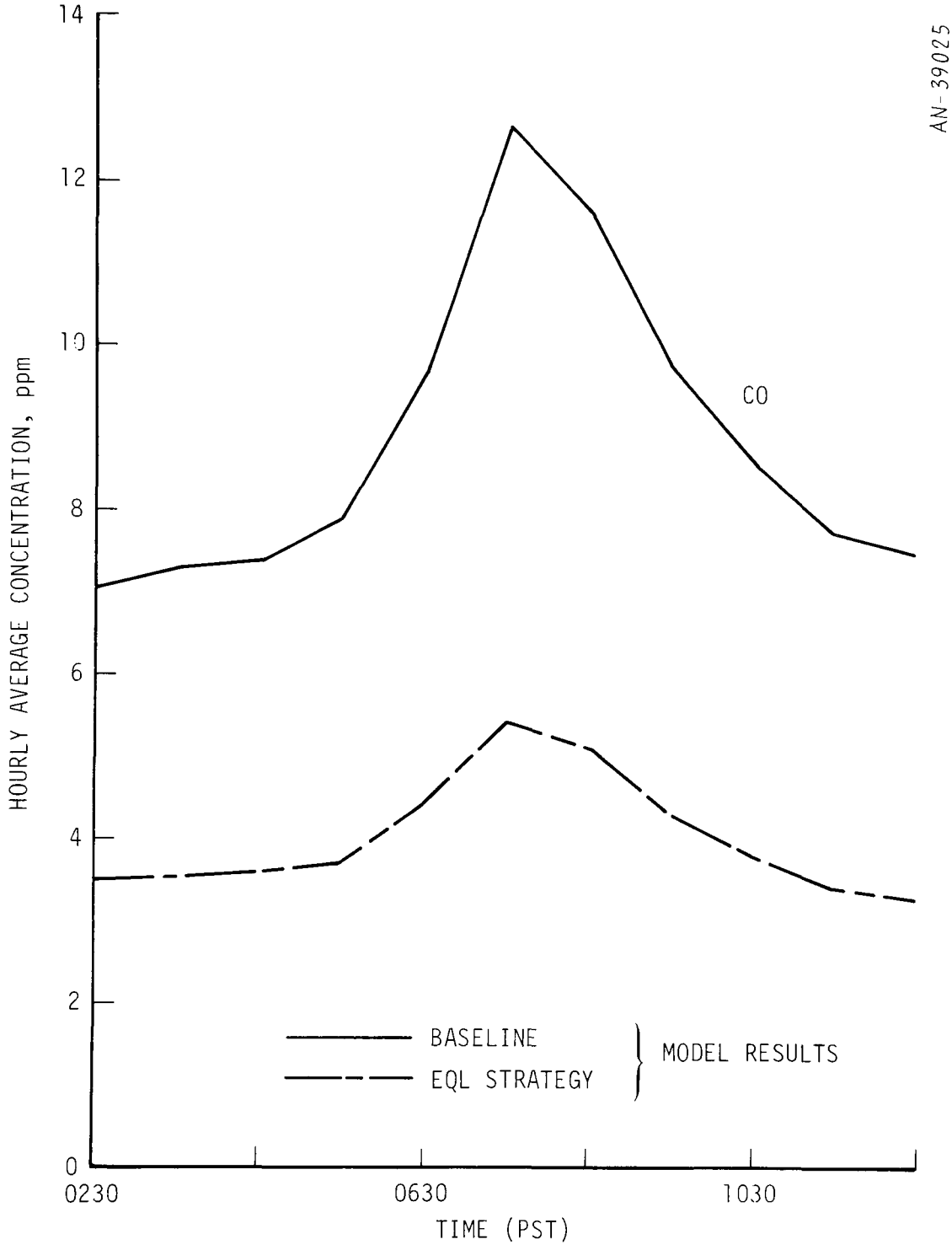


Figure 3.19. Comparison of CO Levels for Baseline Case and EQL Strategy, Trajectory No. 2

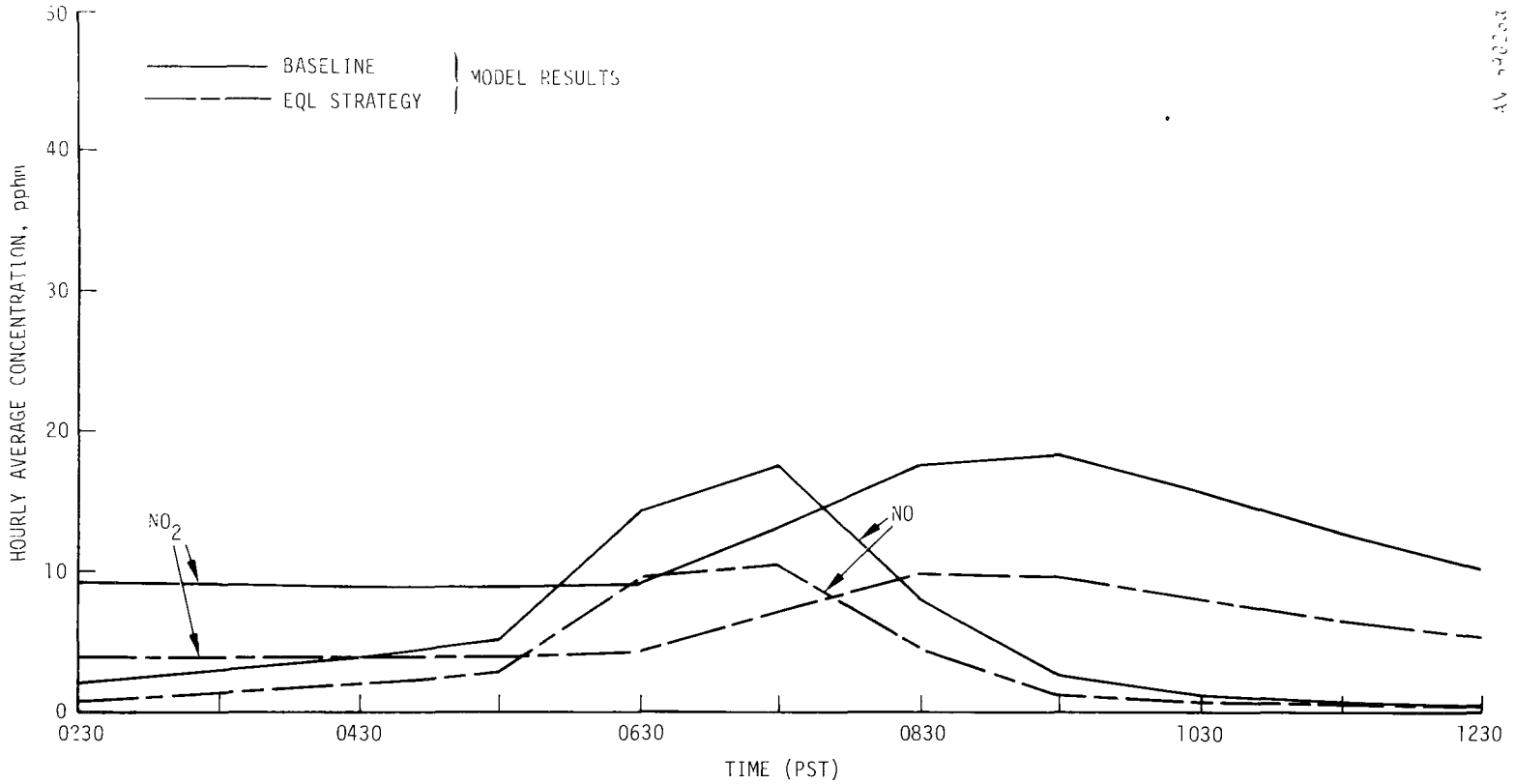


Figure 3.20. Comparison of NO and NO_2 Levels for Baseline Case and EQL Strategy, Trajectory No. 2

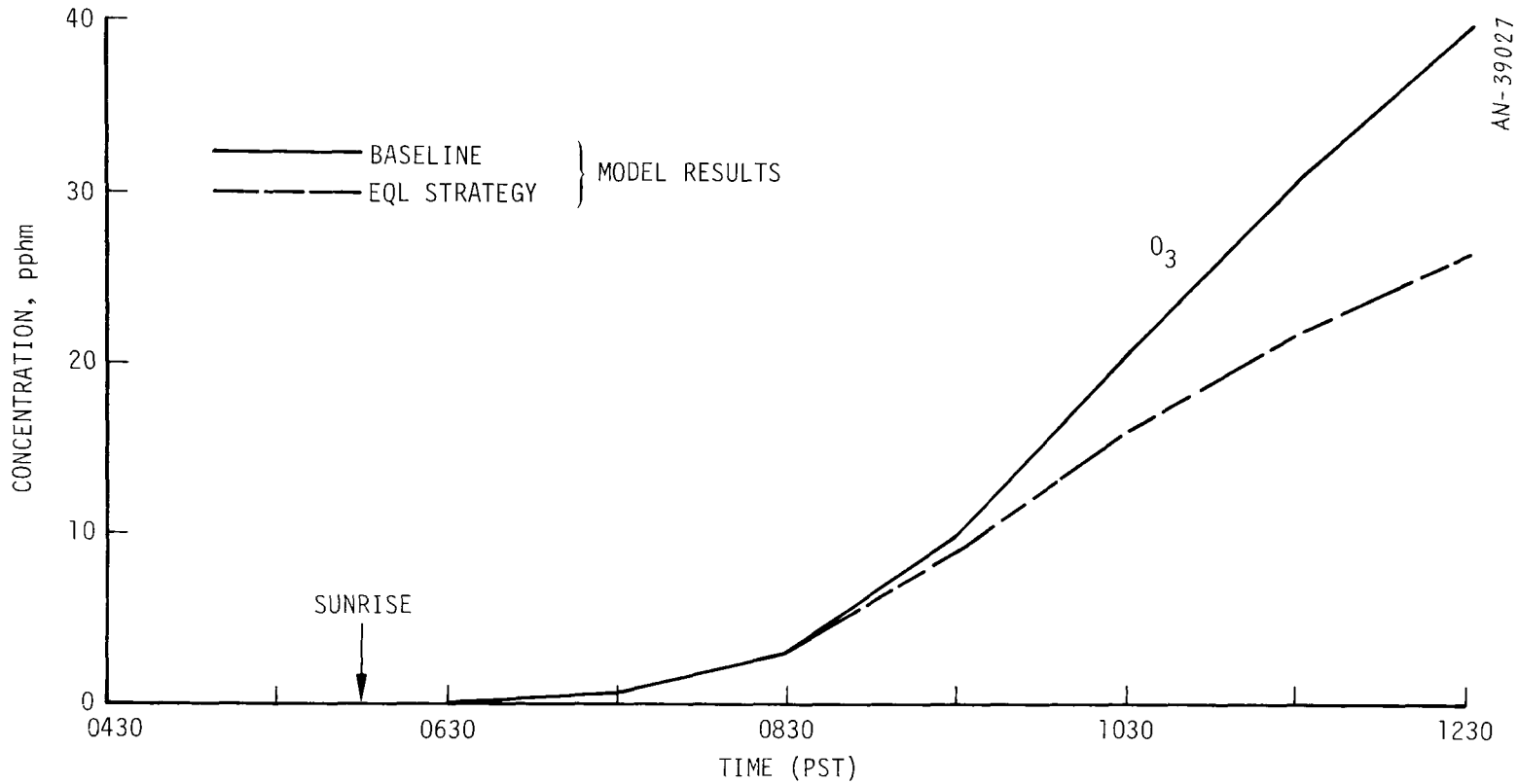


Figure 3.21. Comparison of Ozone Levels for Baseline Case and EQL Strategy, Trajectory No. 2

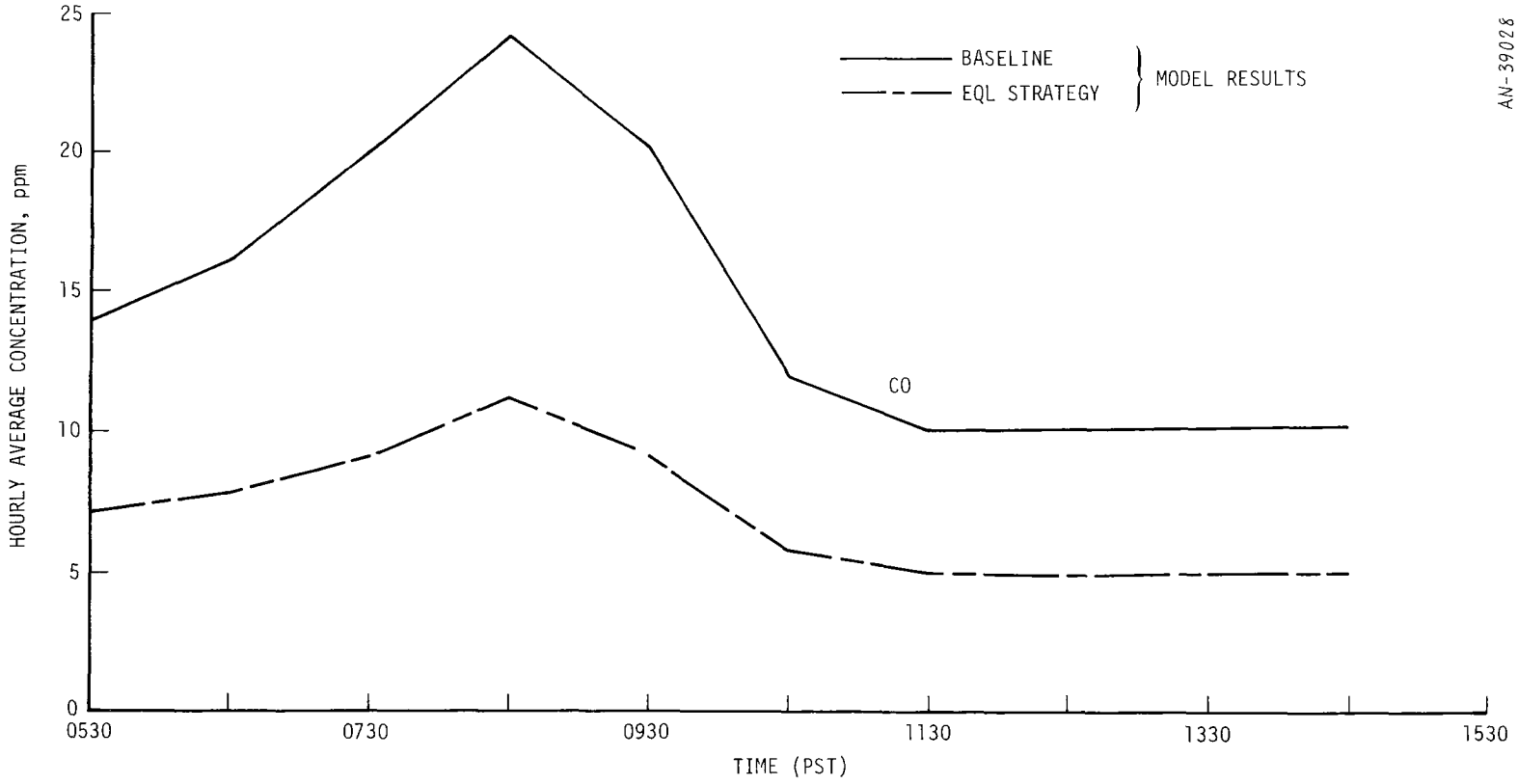


Figure 3.22. Comparison of CO Levels for Baseline Case and EQL Strategy, Trajectory No. 3

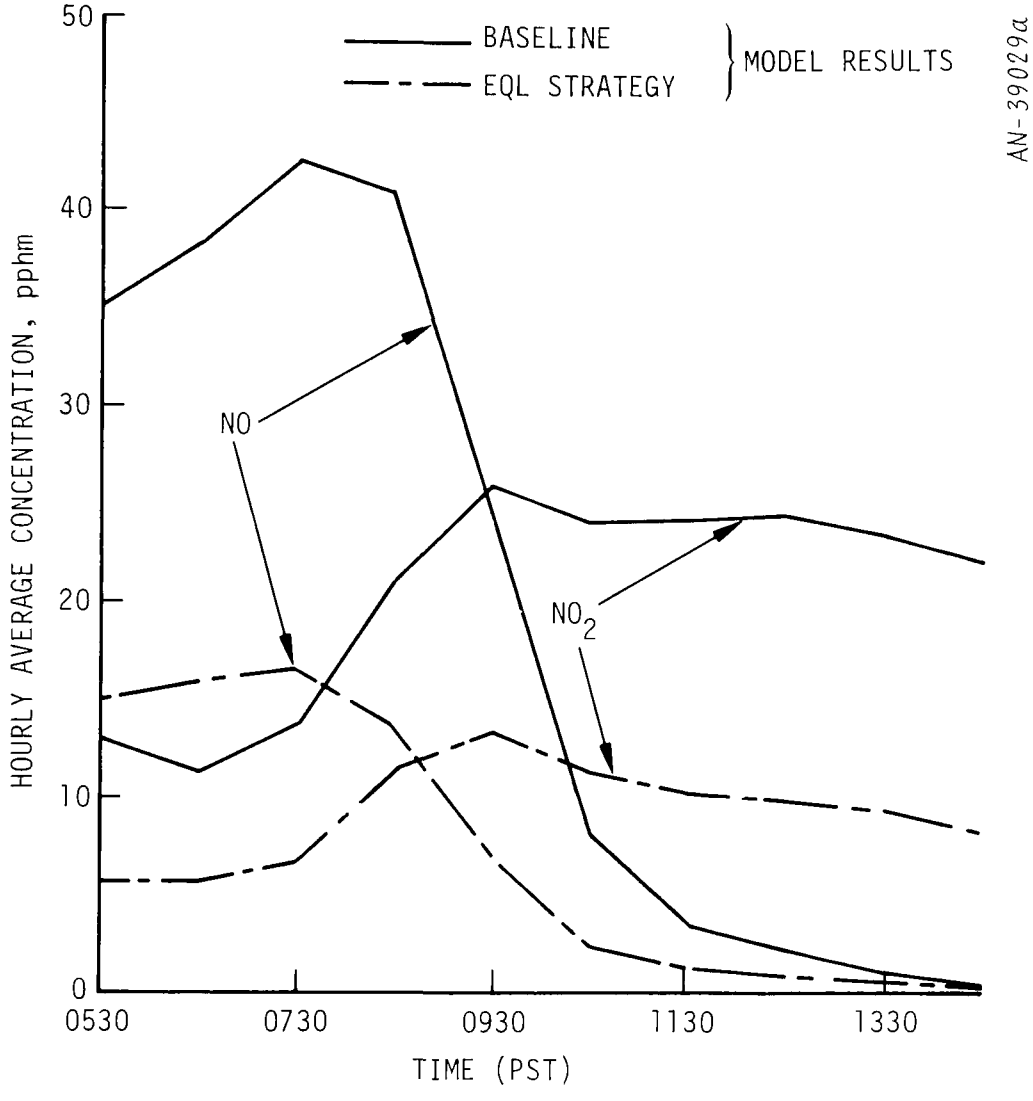


Figure 3.23. Comparison of NO and NO_2 Levels for Baseline Case and EQL Strategy, Trajectory No. 3

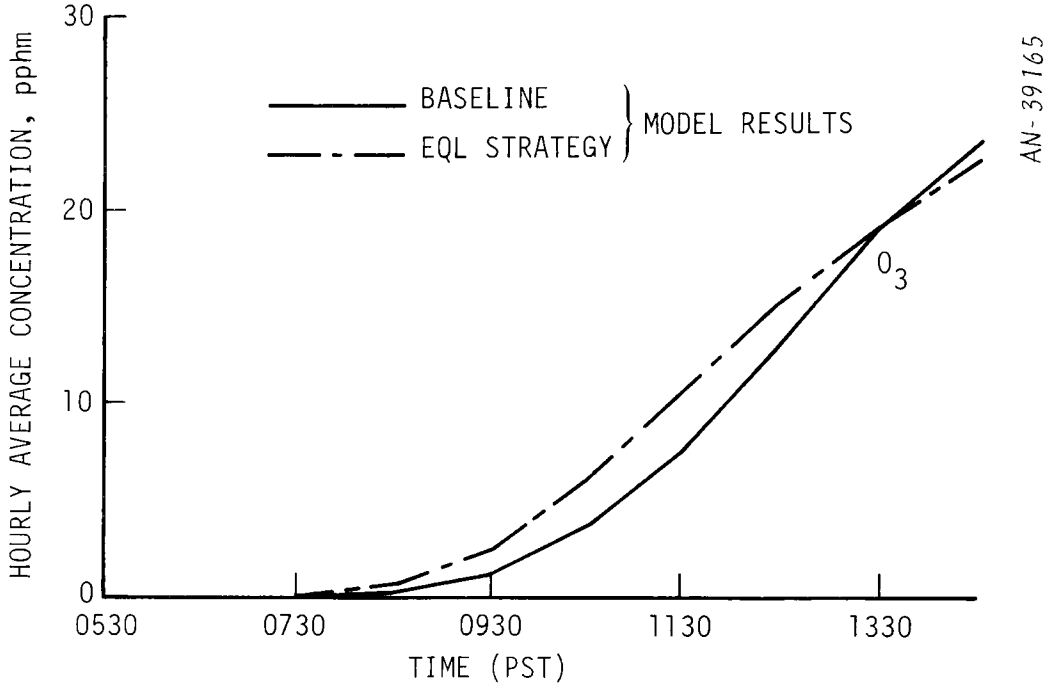


Figure 3.24. Comparison of Ozone Levels for Baseline Case and EQL Strategy, Trajectory No. 3

The comments made about the CO ratios reported in Table 3.1 also apply to the ratios shown on Table 3.4 since the reduction in CO emissions is uniform in the EQL strategy.

The results obtained with the EQL strategy show increases in ozone dosage for trajectories 1 and 3 and in peak ozone for trajectory 1. However, the second trajectory showed marked reductions in both categories. The reasons for the increases found in trajectories 1 and 3 are fully explained in Sec. 4. At this time, it suffices to say that a combination of changes in initial HC/NO_x ratio together with initial concentration levels are the causes for the results obtained with these two trajectories. The same effects did not occur with the second trajectory because the initial concentration levels are very low and this trajectory is thus much more sensitive to changes in the emissions. Consequently, the second trajectory is considered to be a much better test of the effects which this abatement strategy is likely to produce. Let us digress here momentarily to state that any future tests of abatement strategies should involve trajectories which start early enough to have very low initial concentrations and thereby cause the computed concentrations to be sensitive to emissions.

3.4 ZERO EMISSIONS INTERMITTENT CONTROL STRATEGY

Much of the previous day's pollution is carried over in the initial morning conditions during a pollution episode. Testing this highly idealized intermittent strategy gives us an upper-limit optimistic view of the effectiveness of shut-downs after an episode has begun. It is seen from Table 3.5 that for all but the third trajectory, ozone still stays unacceptably high. Figures 3.25 through 3.30 compare the concentration histories for zero emission trajectories with baseline values.

TABLE 3.5

RATIO OF SELECTED PARAMETERS COMPUTED WITHOUT EMISSIONS TO BASELINE VALUES WITH INITIAL CONDITIONS UNCHANGED

Trajectory	O_3 Peak	O_3 Dose
1	0.79	0.93
2	0.77	1.07
3	0.50	0.57

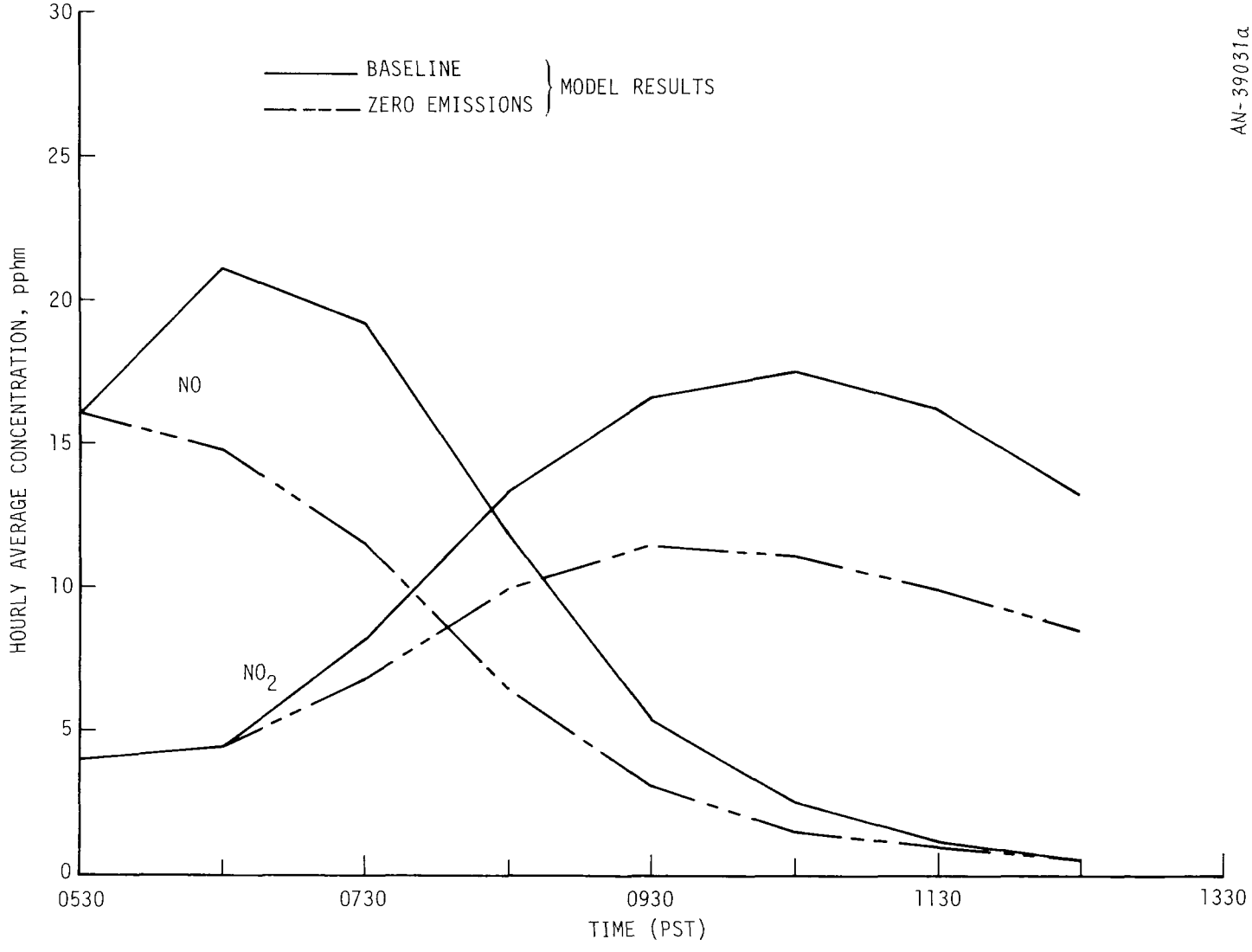


Figure 3.25. Comparison of NO and NO_2 Levels for Baseline Case and Zero-Emissions Strategy, Trajectory No. 1

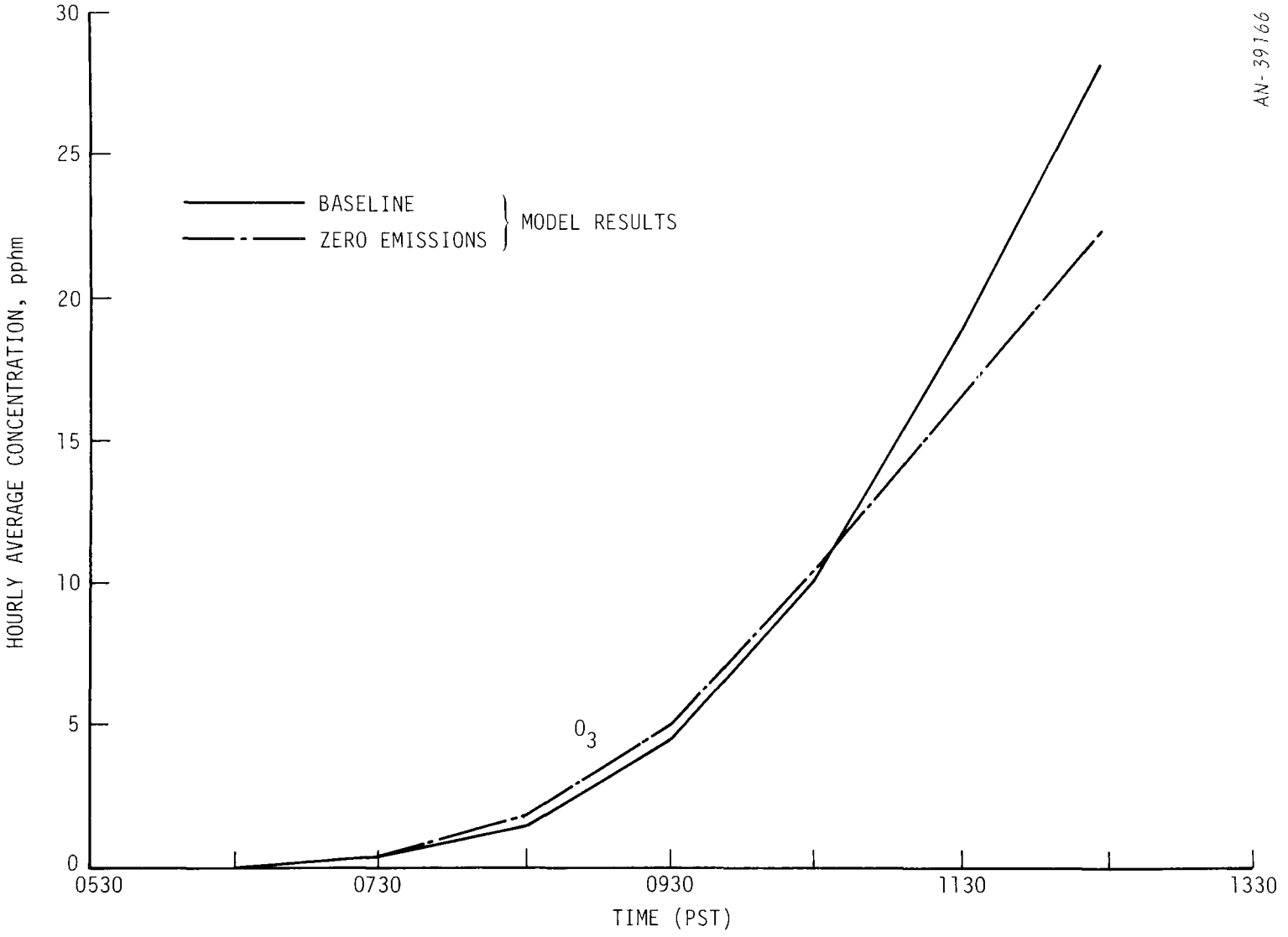


Figure 3.26. Comparison of Ozone Levels for Baseline Case and Zero-Emissions Strategy, Trajectory No. 1

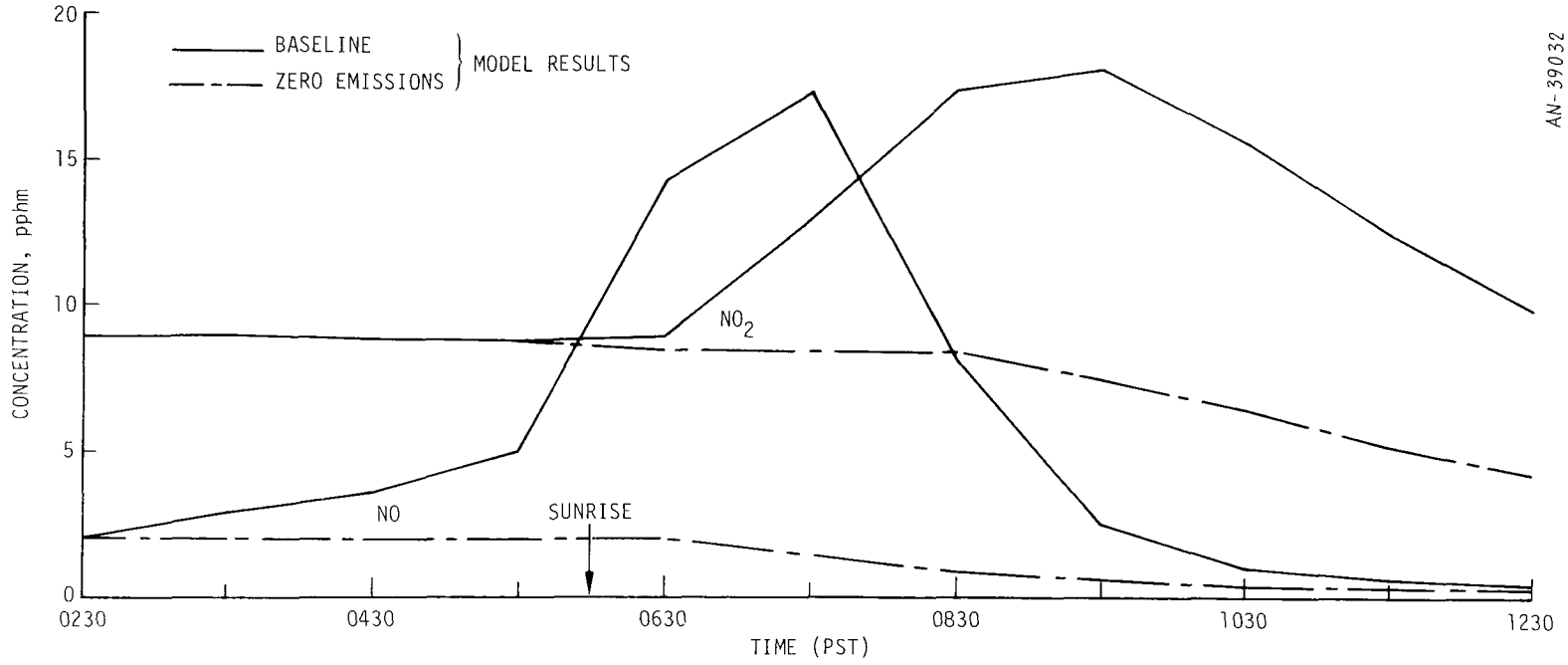


Figure 3.27. Comparison of NO and NO_2 Levels for Baseline Case and Zero-Emissions Strategy, Trajectory No. 2

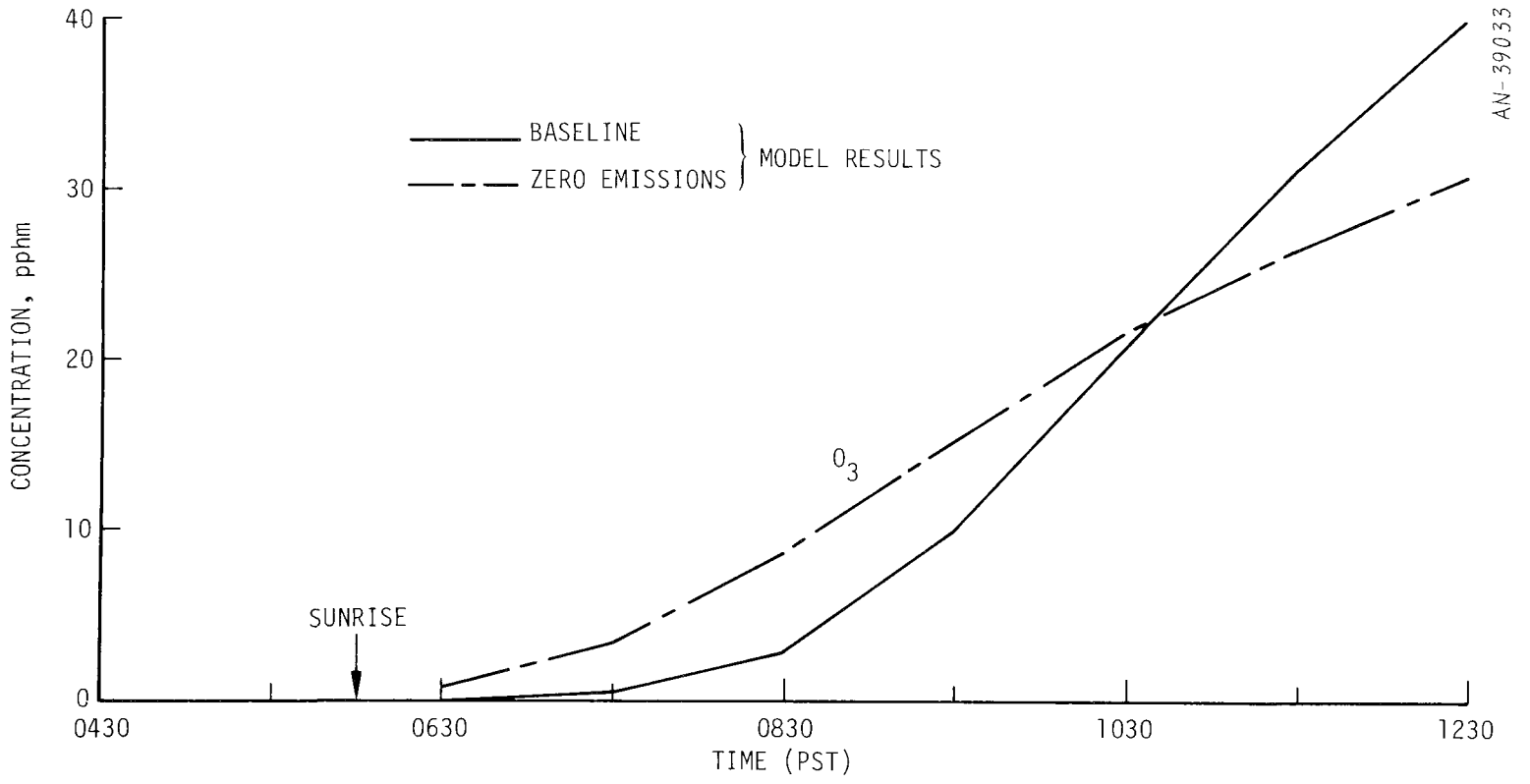


Figure 3.28. Comparison of Ozone Levels for Baseline Case and Zero-Emissions Strategy, Trajectory No. 2

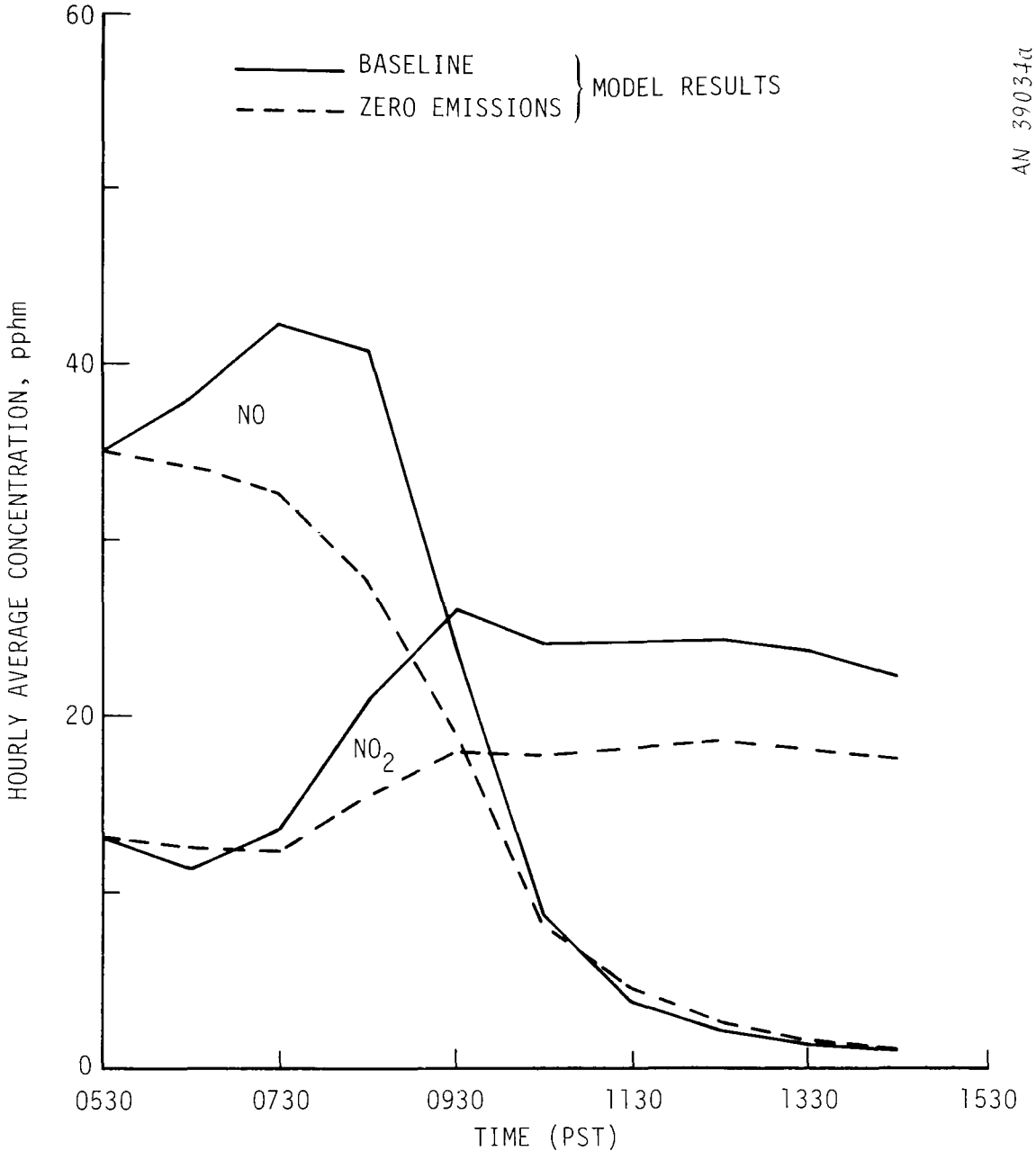


Figure 3.29. Comparison of NO and NO_2 Levels for Baseline Case and Zero-Emissions Strategy, Trajectory No. 3

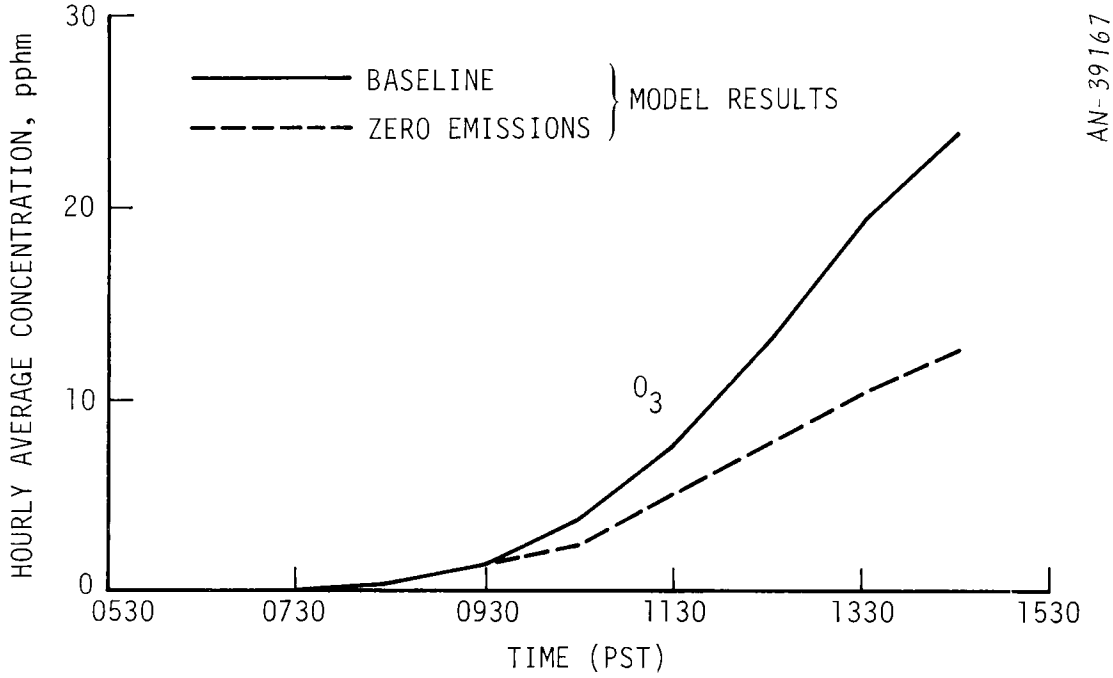


Figure 3.30. Comparison of Ozone Levels for Baseline Case and Zero-Emissions Strategy, Trajectory No. 3

4 EFFECT OF INITIAL CONDITIONS SCALING ON THE EQL STRATEGY RESULTS

The most striking result obtained using the EQL strategy is that the ozone dosage increased in two of the three cases tested: the Sept. 29 and Nov. 4 trajectories, both of which start at 0530 in Downtown Los Angeles. The ozone dosage decreased considerably in the case of the Sept. 29 trajectory which starts at 0230 near the coast and ends at Anaheim at 1230. The following remarks are intended to explain these results.

Two parameters are of paramount importance in the analysis: the initial HC/NO_x ratio and the total initial load level of HC and NO_x. (The load level is defined as the sum of HC and NO_x concentrations.) Since we know that the chemical reaction rate is very sensitive to HC/NO_x ratio as well as concentration, the model's response to changes in these parameters accounts for the results mentioned above.

Figure 4.1 shows the ozone concentration computed by the model in response to changes in HC/NO_x ratio and in initial load level for the Sept. 29 trajectory which starts at 0530 in Downtown Los Angeles. For this set of tests, the emissions have been turned off in order to highlight the effects of the initial conditions. The four cases depicted in Fig. 4.1 correspond to two HC/NO_x ratios and two initial load levels. Case I corresponds to the baseline case with $HC/NO_x = 2$ and load level equal to 60 pphm. Case II corresponds to the EQL strategy, with $HC/NO_x = 1.76$ and load level equal to 23.2 pphm. Cases III and IV represent the remaining combinations of HC/NO_x ratio and initial load level of the first two cases.

Figure 4.1 shows that lowering the HC/NO_x ratio while maintaining a constant initial load level [cases (I, III) and (II, IV)] lowers both the ozone peak and the dosage. However, lowering the initial load level while retaining a constant HC/NO_x ratio has the effect of increasing the ozone peak as well as the dosage [cases (I, IV) and (II, III)]. If both

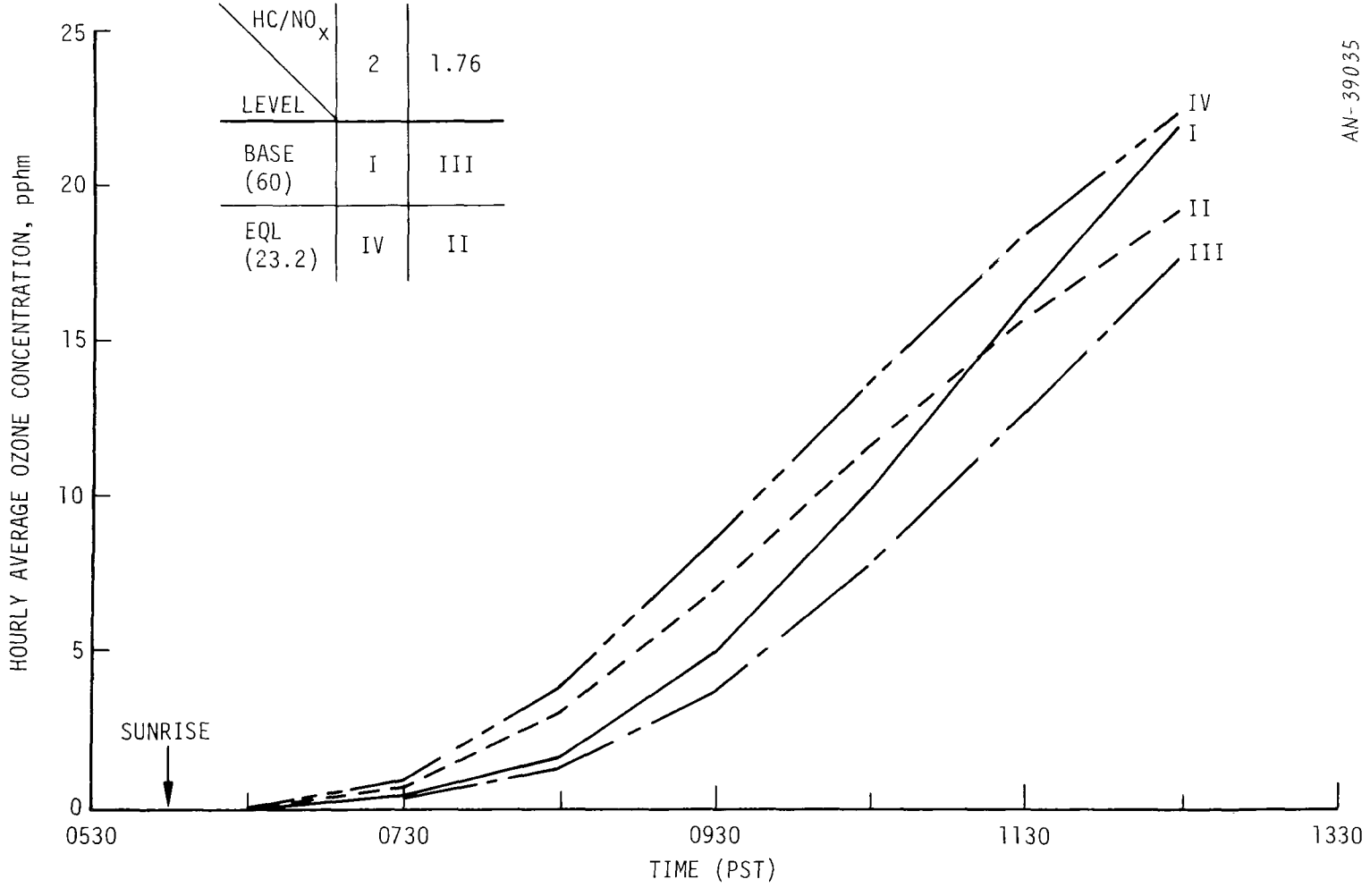


Figure 4.1. Effect of Changes in HC/NO$_x$ Ratio and Initial Load Level for Trajectory 1, Zero Emissions Strategy

the HC/NO_x ratio and the initial level are lowered, as is done in going from case I to case II, then the two changes work against each other and the relative magnitude of the perturbations will determine which way the system goes. In going from case I to II the ozone peak is obviously decreased, but the dosage increases by about 7%. In going from Case III to IV, the changes work in the same direction and we get the expected increases in both peak concentration and dosage.

The results shown in Fig. 4.1 can now be used to explain the increase of ozone dosage in two instances when the EQL strategy was applied. What happens in these two trajectories is that, although the EQL strategy lowers the HC/NO_x ratio, it also lowers the initial load level in such a manner as to increase the ozone dosage. Table 4.1 shows the parameters for the trajectories.

TABLE 4.1

HC/NO_x RATIO, INITIAL LOAD LEVEL, AND OZONE DOSAGE FOR TRAJECTORIES USED IN TRANSPORTATION CONTROL STRATEGY STUDIES

Trajectory	HC/NO_x		$(HC + NO_x)$ pphm		Ozone Dosage Ratio (EQL/Base)
	Base	EQL	Base	EQL	
1	2	1.76	60	23.2	1.35
2	1.64	1.44	29	10.2	0.75
3	0.83	0.73	88	35	1.12

From Table 4.1, we see that the first and third trajectories showed increases in ozone dosage of 35% and 12%, respectively. The second trajectory, on the other hand, showed a decrease in dosage of 25%. Clearly, in all cases we have reductions in HC/NO_x ratio and in initial load level from the baseline case.

A possible explanation for the increase in dosage seen in the first trajectory is that the decrease in HC/NO_x ratio is insufficient to offset the dosage increases caused by the lower initial load levels. In addition, we note that although the EQL strategy under study calls for reductions in automotive emissions of 79% for reactive hydrocarbons and of 73% for nitric oxide, the reductions in total emissions (auto + stationary) achieved for this trajectory are 49% and 47%, respectively. Thus stationary sources play a significant role in the emissions of this trajectory and may also be responsible for part of the dosage increase.

The dosage increase experienced in the Nov. 4 trajectory is small. The smallness of the increase is most probably due to the low value of the HC/NO_x ratio. The ratio is low enough to compensate for the sizable reductions in initial load level. It is likely that the system would show a decrease in ozone dosage if additional reductions in HC/NO_x ratio are implemented. It should also be noted that the total emissions (auto + stationary) were reduced by 58% for reactive hydrocarbons and by 62% for nitric oxide compared to the base case. These reductions more closely approximate the cutbacks prescribed by the strategy for automotive sources. Thus, in this instance we have a situation which is more sensitive to the strategy's goals.

The Sept. 29 trajectory which starts at 0230 near the coast and ends at Anaheim at 1230 showed a 25% decrease in ozone dosage and a reduction in peak ozone of 33%. These reductions are due to the fact that the initial load level has been made too low to sustain the reaction. In the two cases discussed previously, the lower initial levels remained large enough to sustain the reaction. However, as is explained below, it appears that there is a threshold level below which we get reduced production of secondary pollutants and that in this trajectory the initial load level is below the threshold. Finally, it should be noted that the reductions in total emissions obtained in this trajectory were 58% for reactive hydrocarbons and 45% for nitric oxide.

The threshold effect is illustrated in Fig. 4.2 and Table 4.2. Figure 4.2 shows the ozone concentration for three different initial load levels and HC/NO_x held constant at a value of two. Reducing the level from 60 to 23.2 increases both peak ozone and dosage. Further reducing the level to 5 lowers the peak and the dosage. Table 4.2 shows the pertinent quantities.

Table 4.2 shows that the dosage for the highest and lowest level is almost the same, in spite of the fact that the peak concentration has been cut in half. The existence of a threshold region raises some difficulties in evaluating control strategies, because it emphasizes an effect of initial conditions which are assumed rather than modeled and it underscores the need to consider nonlinearities by the use of models instead of simple rollback.

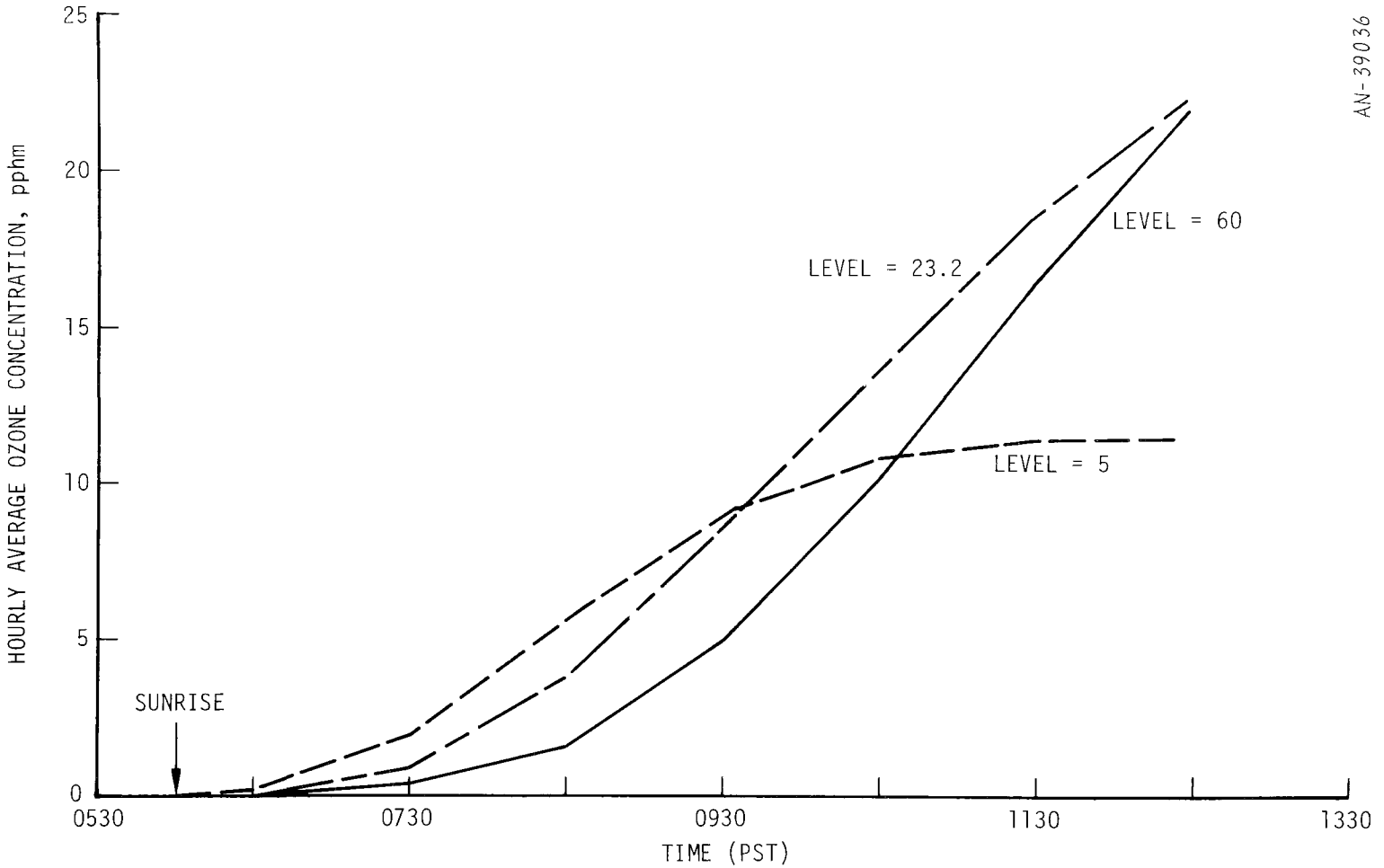


Figure 4.2. Effect of Varying Initial Load Level with Constant HC/NO_x Ratio = 2 for Trajectory 1, Zero Emissions Strategy

TABLE 4.2

EFFECT OF CHANGES IN INITIAL LOAD LEVEL OF ($HC + NO_x$) ON OZONE PEAK AND DOSAGE WITH $HC/NO_x = 2$

Level	Peak Ozone Concentration, pphm	Ozone Dosage, pphm-min
60	22.1	2681
23.2	22.3	3401
5	11.4	2679

5 CONCLUDING REMARKS

The work presented shows the utility of applying simulation modeling to the problem of implementation planning. The need for considering many receptor points in the basin becomes obvious in examining the results. Also, it is apparent that HC/NO_x-ratio effects can be as important as total loadings or emissions.

The effects of the controls vary widely according to pollution sources encountered by the air mass and to details of the initial loading of pollutants in the air mass. In particular, the 30% cutbacks produced relatively small reductions in peak ozone concentration and in ozone dosage. However, it should be noted that the first and third trajectories are dominated by initial pollutant loading. Hence, reductions in emissions without concurrent decreases in initial concentration lowers the system's sensitivity to the abatement strategy.

The reduced downtown emission strategy (nearly vehicle-free zone) only has an effect on areas swept out by the downtown plume. In a city like Los Angeles, there is such a wide dispersion of intense sources that a blanket strategy must be applied. In a highly centralized urban region, perhaps vehicle-free zones might have a better chance of improving overall air quality.

The need for sweeping reductions across the board is underscored by the relative success of the EQL strategy for the Los Angeles Air Quality Control Region. This is the only case where we felt justified in decreasing initial loadings of pollutants in the morning air. Even with large cutbacks in emissions, however, surprising things happen with ozone buildup because of peculiarities of hydrocarbon/nitrogen oxides mixture effects. The zero emission intermittent strategy scenario shows the extreme sensitivity to initial condition and mixture effects.

Future work using photochemical/diffusion simulation models for abatement evaluation should consider periods of several days and should inject statistical variations about the mean input quantities. These requirements may involve geometric increases in computing expenditures; however, the large costs of controls should justify a more elaborate analysis.

REFERENCES

1. Federal Register, Vol. 38, No. 14, Jan. 22, 1973, pp. 2194-2200.

2. A. Eschenroeder, Comments on California Air Quality Standards: Transportation Control Strategy, General Research Corporation IM-1741, April 1973.

3. A. Eschenroeder, J. Martinez, "Concepts and Applications of Photochemical Smog Modeling," "Advances in Chemistry," Series No. 113 entitled Photochemical Smog and Ozone Reactions, American Chemical Society, Washington, December 1972, pp. 101-168.

4. A. Eschenroeder, J. Martinez, R. Nordsieck, Evaluation of a Diffusion Model for Photochemical Smog Simulation, General Research Corporation CR-1-273, October 1972.

5. Smog: A Report to the People of the South Coast Air Basin, California Institute of Technology Environmental Quality Laboratory, Report No. 4, January 1972.