Appendix B

Modeling for the Houston/Galveston
Ozone Attainment Demonstration

1.0 INTRODUCTION

On May 19, 1998, the commission submitted a modeling demonstration to the EPA which estimated the levels of reduction required for the HGA nonattainment area to attain the one-hour ozone NAAQS. This modeling was based on an ozone episode occurring in September of 1993 with emissions projected to 2007, the HGA area's attainment date for the one-hour standard. The modeling, which relied heavily on the rich COAST collection of meteorological, aerometric, and emissions data, was conducted using the variable-grid version of the UAM (UAM-V). The major conclusions are as follows:

- In order for the area to reach attainment, reductions of NO_x emissions of oxides by 65 to 85 percent will be necessary.

- Concurrent reductions of VOC will help to mitigate a potential rise in peak ozone as emissions of NO_x are reduced ("NO_x disbenefit") by up to 50%. This disbenefit disappears for NO_x reductions above 50%.

- Reductions will be required in all categories of NO_x emissions in order for the HGA area to reach attainment.

Details of the previous modeling work can be found in the SIP revisions dated May 6, 1998 (TNRCC 1998a), which is available from TNRCC upon request.

EPA notified the commission that the May 19, 1998 SIP revision was not approvable as submitted, because no specific control strategies had been modeled. The modeling performed in the current SIP revision remedies this deficiency by modeling several candidate reduction scenarios. In addition, several enhancements to the modeling process have been incorporated into the modeling described herein. These include:

- Use of CAMx, a freely-available advanced photochemical model with capabilities similar to those of the UAM-V.

- New biogenic emissions based on a comprehensive survey of biomass in the HGA and BPA nonattainment areas.

- Revised and enhanced 2007 projected onroad mobile source emissions for the HGA nonattainment counties.

- New emissions growth projections for point and nonroad mobile sources based on, respectively, a TNRCC industry survey and EPA's new Nonroad model.

- Emissions modeling using the SMOKE emissions modeling system.

- Future initial and boundary conditions derived from regional modeling conducted with

CAMx (replacing similar initial and boundary conditions based upon UAM-V modeling).

These modifications to the modeling process will be detailed in following sections of this Appendix B and in several supplemental appendices. Other elements of the modeling are unchanged from the previous SIP submittal, and will not be discussed in detail in this document. The reader is referred to the May 6, 1998 SIP for additional details.

Most of the modeling reported in this SIP was conducted by MCNC-North Carolina Supercomputing Center Environmental Programs under contract to TNRCC. The TNRCC modeling staff wishes to acknowledge Dr. Neil Wheeler and his staff, particularly Jeff Vukovich and Pat Dolwick, for their responsiveness and attention to detail in carrying out this work.

2.0 MODELING PROTOCOL

The modeling described in this document was performed in accordance with a protocol dated December 14, 1988 (TNRCC, 1998c), although some aspects of the modeling were modified subsequent to the latest protocol revision. This report documents the modeling as actually implemented, and supersedes the modeling protocol in cases where the two differ.

3.0 DEVELOPMENT OF THE REVISED 1993 BASE CASE

This section details the migration from UAM-V to CAMx, modifications made to the base case modeling inventory for the current round of modeling, and model performance evaluation of the revised base case, including diagnostic and sensitivity analyses.

3.1 Migration to CAMx from UAM-V

Many stakeholders in the HGA area have expressed interest in the modeling conducted by TNRCC, and some have indicated a desire to perform ancillary modeling. Because the UAM-V is a proprietary model, these stakeholders urged TNRCC to adopt a model which is freely available to interested users. After surveying the available alternatives, including UAM-IV and SAQM, TNRCC selected CAMx as the most suitable replacement for the UAM-V in its current modeling applications. TNRCC has previously used CAMx in modeling for the DFW ozone nonattainment area (TNRCC, 1998b).

The migration from UAM-V to CAMx was accomplished by TNRCC's contractor - hereinafter referred to as MCNC - and is documented in detail in Appendix C. The following excerpt from Appendix C summarizes the results of the comparison:

> As has been seen in previous comparisons of the CAMx and UAM-V models, the CAMx model generally produces more ozone over the domain. When averaged over the entire domain, CAMx model ozone concentrations are generally 4-9 ppb higher than UAM-V.

Four potential causes for the differences in pollutant concentrations have been identified:

1) There are other known differences in the formulations of CAMx and UAM-V. For instance, the treatment of deposition has been improved within CAMx. Most importantly, the chemical solver in CAMx has been modified to become more flexible (easier to upgrade code when chemical mechanism is revised) and more computationally efficient. Both models use the CB4 chemical mechanism.

2) Treatment of point source plumes differs between the two photochemical models. CAMx appears to generate more ground-level ozone in the plumes emanating from large NO_x sources.

3) There appear to be significant differences in the algorithms governing exchange of mass between the coarse and fine grids in the two models. Although neither model features "box-like" ozone patterns along the interface between the coarse and fine grids, the ozone difference plots do feature such a pattern at times.

4) Differences occur in the first hour of the simulation. The model output data diverge especially strongly over the nested grid. There is some indication that the 16km initial condition file is interpolated slightly differently between the two models.

However, the difference in model performance between the two models was determined to be fairly small over the HGA airshed for the 6-11 September 1993 COAST episode. The mean normalized bias for those observed-model pairs greater than 60 ppb is slightly higher and more biased than what was previously seen in the UAM-V modeling (8% overestimation vs. 1% underestimation). The gross error and peak accuracy values are more closely aligned between the two sets of results. All surface ozone statistics (for non-rampup days) fell within EPA acceptability criteria. This cursory evaluation of model performance indicates that both the UAM-V and the CAMx results are plausible base case scenarios.

In summary, then, these comparisons show that the HGA modeling results do not vary greatly as a function of the model employed. The similarity of the new CAMx outputs with the original UAM-V results affirms the continued relevance of the previous HGA UAM-V modeling analyses.

Table 1 shows the base-case model performance of CAMx compared to EPA acceptability criteria, based on monitors in the HGA eight-county area. Also shown (in parentheses) are the corresponding UAM-V model performance statistics. Values within EPA recommended performance specifications are shown in **bold**:

Table 1. CAMx Performance Statistics for September 6-11, 1993										
Episode Date	Normalized Bias (+/- 5-15%)		Gross Error (30-35 %)		Unpaired Peak Accuracy (+/-15-20%)		Simulated Peak Ozone		Measured Peak Ozone
9/6/93	**7.9**	**(1.3)**	**17.8**	**(15.0)**	**20.7**	**(14.5)**	164	(156)	136.
9/7/93	**10.6**	**(0.3)**	**21.5**	**(19.6)**	50.8	(39.4)	167	(155)	111.
9/8/93	**9.2**	**(2.9)**	**24.8**	**(24.0)**	**-15.0**	**(-13.1)**	182	(186)	214.
9/9/93	**11.4**	**(4.3)**	**28.2**	**(26.1)**	**-7.9**	**(-8.5)**	180	(179)	195.
9/10/93	**-4.2**	**(-10.0)**	**24.4**	**(22.7)**	**9.7**	**(10.7)**	178	(179)	162.
9/11/93	**8.4**	**(-1.1)**	**23.6**	**(21.4)**	**-1.8**	**(-1.29)**	186	(185)	189.

Figure 1 shows a set of three plots. The first two show predicted ozone concentrations for September 8, 1993 at the time of peak predicted ozone (16:00), developed using, respectively, CAMx and UAM-V. Also shown is a plot showing the differences in predicted concentrations across the COAST modeling domain. These plots illustrate the general tendency of CAMx to predict higher ozone concentrations than UAM-V.

3.2 Revised Biogenic Emissions in Southeastern Texas

TNRCC commissioned a study in 1993 to determine the biogenic emissions in southeastern Texas (Radian and VRC, 1994). The results of that study indicated that leaf biomass densities for the urban residential areas of Houston and Beaumont were very high compared to values seen in other areas (Wilkinson et al., 1996; Geron et al., 1994). Commission staff were concerned that the unusually high values of leaf biomass could result in an overestimation of biogenic VOC, which could have serious consequences in determining the proper directional guidance for emission controls. The areas in and near the urban core could be VOC-limited (Sillman, 1999; TNRCC, 1998a), and an improper accounting of biogenic VOC could lead to erroneous decisions about the appropriate ozone control strategies (Chameides et al., 1988; Geron et al., 1995). Therefore, TNRCC commissioned a new field study of the urban areas in Houston and Beaumont in order to properly determine the magnitude and spatial variation of urban leaf biomass densities, and the urban species composition. In addition, cropland emissions were reevaluated using an improved method, the remainder of the rural areas were reclassified according to a system compatible with other biogenic studies that have taken place in Texas (Yarwood et al., 1997; ENVIRON, 1998; TNRCC, 1998b), and the latest emission factors from the Biogenic Emissions Inventory System, ver. 2 (BEIS-2) biogenic emissions model (EIIP, 1996; Geron et al., 1994) were incorporated into revised biogenic emissions modeling for southeastern Texas. The surveys that formed the basis for the revised biogenic emissions inventory are described in detail in “Leaf biomass density data for southeast Texas,” Yarwood et al., 1999. The EMS-95 biogenic emissions model, BIOME, was again used for the revised inventory, since it was used to create the original 1993 inventory (Estes et al., 1996).

The 1993 survey, on which the original biogenics inventory was based, used a single leaf biomass density value and a single plant species composition for the entire urban residential plant community in Houston (Estes et al., 1996; Wilkinson et al., 1996). In the revised biogenics inventory, the urban residential areas in Houston were divided into six sectors, each of which was assigned a different leaf biomass density and species distribution, based upon the findings of the new field surveys. A total of 68 sites were surveyed in the HGA urban area, using the methodology established in a similar study in the DFW area by Klinger and Wiedinmyer (Yarwood et al., 1997). Table 2 shows the leaf biomass density assigned to each land use type.

Table 2. Urban leaf biomass density assignments: total density, oak species (*Quercus*), and pine species (*Pinus*), from Yarwood et al., 1999.

Land use	Total leaf biomass density (g/m^2)	*Quercus* species leaf biomass density (g/m^2)	*Pinus* species leaf biomass density (g/m^2)
Northwest Houston residential	93	36	18
Southwest Houston residential	123	48	38
North Loop Houston residential	81	31	1
South Loop Houston residential	136	69	8
Southeast Houston residential	61	27	8
Northeast Houston residential	76	26	15
Galveston residential	144	53	1
Institutional	37	25	3
Rice University	70	56	2
University of Houston	71	52	7
UT Anderson Medical Center	14	8	0
Astrodome	0	0	0
Parks	196	94	79
Memorial Park	308	79	155
Big Park	200	20	10
North Houston forested	556	70	415
South Houston forested	80	29	0
North Houston undeveloped	278	35	208
South Houston undeveloped	80	29	0
Industrial	0	0	0
Commercial	15	5	0
Multi-family residential	37	18	1
Transportation	0	0	0

In the 1993 study, each type of cropland (cotton, soybeans, etc.) was assumed to be a monoculture, i.e., planted 100% with crops. In the 1998 survey, the researchers recognized from their field surveys that many areas described in land use databases as cropland are actually a mixture of cropland, rangeland, forest, wetland, and grassland. USGS Land Cover Characteristics (LCC) data (derived from satellite imagery) were used to allocate the proper mix of different vegetation types to the "cropland" land use category. Marshland was assumed to have zero emissions in the 1993 biogenics inventory; for the revised inventory, TNRCC used the BEIS-2 emission factor for salt marsh (EIIP, 1996). The biogenic NO_x emissions inventory was not revised. The same meteorological files (i.e., photosynthetically-active solar radiation and ambient temperature fields) used in earlier modeling (TNRCC, 1998a) were used in preparation of the revised inventory.

The results of the new biogenic emissions modeling are described in detail in Appendix D, "Effects of Revised Biogenic and Future-Year Mobile Emissions Estimates on Ozone in the Houston/Galveston Region." Briefly, the following changes in emissions were noted:

1. Much lower biogenic emissions in the urban areas of Houston and Beaumont;
< Higher isoprene emissions along the Trinity River bottomlands;
< Lower isoprene emissions along the Brazos River bottomlands;
< Increase in marsh emissions, leading to increases in biogenic emissions in Brazoria County especially; and
< Increase in pine-hardwood forest emissions.

A comparison of the original and revised emissions for each of the eight counties in the HGA nonattainment area is presented in Table 3.

Table 3. Comparison of biogenic CB-IV hydrocarbon emissions inventories: September 10, 1993		
County	Original inventory (tons/day)	Revised inventory (tons/day)
Brazoria	123	240
Chambers	77	85
Fort Bend	45	113
Galveston	44	41
Harris	366	263
Liberty	348	381
Montgomery	367	363
Waller	78	85
HGA Total	1448	1573

The revised inventory has higher emissions in some of the rural counties, and lower emissions in the urban counties, which confirms the TNRCC modeling staff's concerns about the previous study. Appendix D contains detailed tileplots of the biogenic emissions, which show how emissions increased, decreased, or were redistributed by the revised inventory. Changes in the photochemical modeling results due to the revised biogenics inventory were relatively minor, as illustrated in Figure 2 for one hour of the episode, and are described in detail in Appendix D.

3.3 Model Performance Evaluation

As seen in the section "Migration to CAMx from UAM-V" above, model performance for the September 8-11, 1993 episode using CAMx was similar to that obtained earlier using UAM-V. In addition to migrating from UAM-V to CAMx, TNRCC made another significant change to the base case modeling: replacement of the COAST biogenic emissions inventory with a new inventory based on an extensive field survey of biomass and plant species characterizations. See "Revised biogenic emissions in southeastern Texas" above for details. This section examines CAMx model performance for the September 8-11 episode using the new biogenic emissions. A detailed discussion of the base case model performance is provided in Appendix D.

Table 4 below summarizes model performance relative to EPA standard criteria for the entire COAST modeling domain. Table 5 shows a similar performance comparison, but for monitors in the eight-county HGA nonattainment area only. Values within recommended EPA ranges are shown in **bold**.

Table 4. Domain-wide CAMx Performance Statistics, Sept. 6-11, 1993					
Episode Date	Normalized Bias (+/- 5-15%)	Gross Error (30-35 %)	Unpaired Peak Accuracy +/-15-20%	Simulated Peak Ozone (ppb)	Measured Peak Ozone (ppb)
9/6/93	**12.7**	**19.9**	**20.7**	164	136
9/7/93	**12.5**	**19.6**	50.8	167	111
9/8/93	**12.0**	**24.2**	**-15.0**	182	214
9/9/93	**11.2**	**23.9**	**-7.9**	180	195
9/10/93	**0.02**	**22.7**	**9.7**	178	162
9/11/93	**10.8**	**22.4**	**-1.8**	186	189

Table 5. CAMx Performance Statistics for HGA 8-County Area, Sept. 6-11, 1993					
Episode Date	Normalized Bias (+/- 5-15%)	Gross Error (30-35 %)	Unpaired Peak Accuracy +/-15-20%	Simulated Peak Ozone (ppb)	Measured Peak Ozone (ppb)
9/6/93	**7.9**	**17.8**	**20.7**	164	136
9/7/93	**10.6**	**21.5**	50.8	167	111
9/8/93	**9.2**	**24.8**	**-15.0**	182	214
9/9/93	**11.4**	**28.2**	**-7.9**	180	195
9/10/93	**-4.2**	**24.4**	**9.7**	178	162
9/11/93	**8.4**	**23.6**	**-1.8**	186	189

Model performance clearly meets all recommended EPA performance specifications on all days, except for the unpaired peak accuracy on September 7, which is a ramp-up day and is not part of the actual episode. Additionally, large positive values of the unpaired peak accuracy do not necessarily indicate poor model performance, since the model could be accurately simulating a peak concentration which occurred in an area that has no monitor. In general, model performance using CAMx and the revised biogenic emissions is similar to model performance reported in the previous round of modeling (TNRCC, 1998a), except that the normalized bias has shifted in the positive direction by 6 to 7 percent on all days except the second ramp-up day (when bias increased ~ 10%), and gross error is slightly larger (~2%). Figure 3 shows modeled ozone at 16:00 on September 9, a day the model showed very good performance. Similar figures, along with time series plots and ozone scatter plots, can be viewed in Appendix D.

3.4 Sensitivity and Diagnostic Model Analyses

The previous round of modeling (TNRCC, 1998a) included a series of diagnostic and sensitivity analyses which were conducted as part of model performance evaluation. Diagnostic tests are conducted to verify that the model performs as expected under extreme situations, such as zero emissions, while sensitivity analyses are conducted to assess the model's response to specific perturbations to the input data. The diagnostic tests conducted earlier were:

- Zero anthropogenic emissions, and
- Zero initial and boundary conditions.

The sensitivity analyses conducted earlier were:

- Alternative boundary conditions (derived from the Gulf of Mexico Air Quality Study modeling),
- One-half wind speed,
- Alternative emissions inventory I, and
- Alternative emissions inventory II.

The latter two analyses involved modifications to the emissions input based on comparisons to ambient data; the only difference between Alternative I and Alternative II is in the treatment of biogenics; see (TNRCC 1998a).

In the current application, new diagnostic and sensitivity analyses were conducted to ensure that the new model formulation functions appropriately. In addition to the sensitivity analyses described in other sections of this report (CAMx vs. UAM-V and original vs. revised biogenic emissions), the following diagnostic runs were performed:

- Zero emissions (anthropogenic and biogenic), and
- Zero initial and boundary conditions.

Sensitivity runs performed with the current model are:

- One-half wind speed, and
- One-half biogenic emissions.

The results of these analyses are discussed in contained in Appendix D. The conclusions of that report are summarized for each of the four diagnostic and sensitivity analyses below:

Zero emissions:

Zeroing out emissions from the CAMx modeling has the following effects:

1) Daily peak ozone values over the Texas domain are sharply reduced (40-120 ppb). After the first 24 hours, the only concentrations greater than 60 ppb in the domain were attributable to inflow from the eastern or northern boundaries.

2) In some urban areas, there were some ozone increases on the order of 10-40 ppb at night without emissions.

3) The response of the model was exactly what was expected. This particular diagnostic test did not reveal any flaws in the CAMx model formulation.

Zero initial and boundary conditions:

Zeroing out initial and boundary conditions from the CAMx modeling has the following effects:

1) Daily peak ozone values over the Texas domain are sharply reduced (40-120 ppb) on the initial day of the simulation and slightly less on September 7.

2) Generally, model ozone concentrations were lower (10-50 ppb) in the scenarios without initial condition carryover or boundary condition transport.

3) The response of the model was exactly what was expected. This particular diagnostic test did not reveal any flaws in the CAMx model formulation.

One-half wind speed

Reducing the input wind speeds by a factor of two over the COAST CAMx modeling has the following effects:

1) Daily peak ozone values over the Texas domain are sharply increased (20-100 ppb).

2) Simulated ozone was increased domainwide, especially close to the urban areas. The only areas to exhibit ozone decreases with the new wind field were those locations affected by urban ozone plumes late in the day.

3) From a model performance standpoint, model bias would be prohibitive with this particular wind field.

4) It is concluded that the model base year simulations are highly sensitive to wind magnitudes.

One-half biogenic emissions

Reducing biogenic VOC emissions by 50% in the COAST CAMx modeling has the following effects:

1) Daily peak ozone values over the domain are reduced (15-40 ppb).

2) There is a regional ozone response as domain-wide ozone is reduced by about 5-10 ppb on average. The majority of the model response took place downwind of urban NO_x plumes.

3) The response of the model was exactly what was expected. In fact, the results were quite similar to the sensitivity run in which urban biogenic emissions were reduced.

Overall, the diagnostic and sensitivity analyses conducted in this application showed the model behaves as expected, which is consistent with results seen in the previous round of modeling.

Comparing the results of the diagnostic and sensitivity runs performed with the current modeling setup with those performed earlier helps give confidence that conclusions about control strategies will have a consistent basis in both rounds of modeling. Two analyses are directly comparable between the two sets of modeling results, and a useful comparison can be made for an additional case (zero emissions/zero anthropogenic emissions). The inventory modifications analyzed in the previous round of modeling were significantly different from the half-biogenic emissions case modeled in the current SIP, and no attempt is made to compare the results in this case.

Comparing the zero anthropogenic emissions diagnostic run performed in the last round with the zero emissions run performed in the current application shows that both analyses reduce predicted ozone dramatically (over 100 ppb in all cases). As expected, the current runs consistently show lower peak ozone, due to removing all emissions instead of only removing anthropogenic emissions as was done previously. Table 6 compares daily peak predicted ozone between the two cases:

Table 6: Daily Peak Ozone Predictions (ppb) for Two Rounds of Modeling - Zero Emissions

Case:	Episode day			
	9/8/93	9/9/93	9/10/93	9/11/93

Previous round (zero anthropogenic emissions)	131	106	127	100
Current round (zero) emissions	114	92	123	90

Comparing the modeling analyses wherein the initial and boundary conditions were set to zero shows that the results of the two rounds of modeling produce very similar ozone predictions in this case, with daily peak ozone predictions differing by 4 ppb or less between the two rounds. However, the CAMx model suffered an abnormal termination on the last episode day, so no results are reported for the current round on September 11. Table 7 compares daily peak predicted ozone between the two cases:

Table 7: Daily Peak Ozone Predictions (ppb) for Two Rounds of Modeling - Zero Boundary and Initial Conditions				
Case:	Episode day			
	9/8/93	9/9/93	9/10/93	9/11/93
Previous round	113	115	140	148
Current round	114	115	136	N/A

In the half-wind sensitivity, again the model results were quite similar between the two rounds, with a difference of 12 ppb or less for each primary day. Table 8 compares daily peak predicted ozone between the two cases:

Table 8: Daily Peak Ozone Predictions (ppb) for Two Rounds of Modeling - One-half Wind Speed				
Case:	Episode day			
	9/8/93	9/9/93	9/10/93	9/11/93
Previous round	216	236	247	225
Current round	210	230	235	227

4.0 DEVELOPMENT OF THE 2007 FUTURE BASE

After establishing that the base case modeling performs acceptably, the next phase of the modeling process is the development of a future inventory, which is subsequently used to develop emissions reduction programs leading to attainment of the NAAQS. Several significant changes from the previous round of modeling were incorporated into the current application, including correction of an error in the 2007 onroad mobile source emissions, new growth assumptions, incorporation of several federal and state controls into the future base inventory, and development of new future boundary conditions using the CAMx model. The next few sections of this report discuss the steps required to create the 2007 future base case.

4.1 Revised 2007 Onroad Mobile Source Emissions

During the public comment period of the 1998 SIP revision for HGA, an error was discovered in the future onroad emissions used in the analysis. This error resulted in emissions on some roadways being overestimated by a factor of 24. The Commission contracted with TTI, a branch of Texas A&M University, to develop a new gridded, hourly 2007 emissions inventory for the 8-county area which corrected the above error. The new emissions estimates incorporated output from an updated travel-demand model, and accounted for several emissions reductions not explicitly modeled heretofore. These include:

- NLEVs
- Texas Motorist's Choice I/M program
- New national HDDV standards
- Phase II RFG

Details of the development of the revised 2007 onroad mobile source emissions can be found in the following appendices to this SIP:

> Appendix F is a Scope of Services excerpted from the contract executed between TNRCC and TTI to produce the revised inventory, and describes the enhancements made to the modeling process and data collection performed.
>
> Appendix G is a report produced by TTI which documents most of the modeling parameters, and details the seasonal and HPMS adjustments applied to the inventory. Note that the MOBILE5a-h input files listed in this report do not reflect the actual setups used in the modeling.
>
> Appendix H lists MOBILE5a-h input and output mock-up files which depict the actual parameterizations used in the modeling preformed by TTI.

After delivery to the commission's modeling staff, the data were reformatted into records suitable for input into the MEDUAM program, a utility that is functionally equivalent to components of the Emissions Preprocessor, Version 2 (EPS-2), but is designed to process gridded onroad mobile source emissions data (rather than link-based data). Use of MEDUAM obviated the need to create pseudo-links, as was done in previous modeling for the area. The same chemical speciation was used as in the previous modeling.

Table 9 shows projected 2007 emissions for the eight HGA nonattainment counties for September 8, a typical weekday. Emissions for the 1993 base case are also shown. For comparison purposes, note that the eight-county totals for NO_x and VOC in the previous modeling application were 462 and 210 tons/day, respectively (remember that the previous totals did not account for I/M and RFG). Note that the revisions described above did not affect emissions in counties outside the HGA nonattainment area.

Table 9. Onroad mobile emissions summary within the COAST domain

	Sept. 8, 1993 (tons/day)		**Projected 2007 (tons/day)**	
Region	**NO_x**	**VOC**	**NO_x**	**VOC**
Brazoria Co.	19	8	18	7
Chambers Co.	9	3	6	2
Fort Bend Co.	23	11	23	10
Galveston Co.	17	9	13	6
Harris Co.	310	153	190	74
Liberty Co.	7	3	5	2
Montgomery Co.	25	10	23	9
Waller Co.	5	2	4	2
HGA 8-County Total	**416**	**199**	**282**	**112**

Some additional adjustments to the onroad mobile sources were subsequently incorporated into the future base case to reflect federal initiatives including Tier 2 vehicle standards and low sulfur requirements. Since the initiatives apply nationally, these changes applied to emissions throughout the modeling domain. TNRCC emissions inventory staff developed adjustment factors which were applied across-the-board to reflect these reductions. However, since the HGA area was already modeled with RFG-2 (which already has reduced sulfur), NLEV, and new HDDV standards, the factors applied within the HGA area were different from those applied elsewhere. The reduction factors were applied to the model-ready emissions data files through use of a masking operation which selectively applied reduction factors to selected groups of grid cells. Table 10 shows the reduction factors applied to the onroad mobile source emissions in developing the 2007 future base case.

Table 10: Onroad mobile source emission adjustments - 2007 future base case								
Region	Tier 2		Low Sulfur		NLEV+HDDV		Combined Factors	
	NO_x	VOC	NO_x	VOC	NO_x	VOC	NO_x	VOC
HGA 8 Counties	.980	.930	.965	1.00	1.00	1.00	.945	.930
Elsewhere	.980	.930	.885	.963	.958	.974	.823	.867

4.2 Revised Point Source Emissions for 2007 Future Base

The projected 2007 point source emissions used in the modeling reported here differed in two aspects from those in the last round of modeling. First, growth was modeled by projecting actual emissions, rather than economic growth, and second, NO_x RACT regulations were applied to affected sources.

Point source growth

In the previous round of modeling, emissions for point, area, and nonroad mobile sources were projected from 1993 base levels to the 2007 attainment year using econometric forecasts from REMI. These forecasts were applied using the EPA's EGAS to forecast future emissions (TNRCC 1998a). Unfortunately, the REMI/EGAS system only forecasts economic growth, which may differ significantly from future emissions for several reasons, principally because newer units tend to be inherently less polluting due to newer technology. In the case of point sources, which are inventoried annually, emissions have in fact been decreasing across the state, even though the REMI/EGAS model indicates strong economic growth in some regions of Texas.

For the current modeling, the TNRCC used a more representative growth methodology for point source emissions. Instead of using the EGAS and REMI models for point source growth estimates the TNRCC emissions inventory staff developed growth factors from industrial survey data collected by the TNRCC. To remove artificial ("paper") reductions and one-time events from the trend calculations, the survey asked industrial sources for the reasons behind changes in reported point source emissions between 1990 and 1996. Annual emission factors for NO_x and VOC were developed individually for three areas in Texas: the HGA nonattainment area (eight counties), the BPA nonattainment area (three counties), and counties in Central and East Texas. Because the Central and East Texas area includes all but a small fraction of Texas attainment counties included in the COAST domain, the growth values derived for Central and East Texas were applied to all Texas attainment counties. These factors were also applied to all but one Louisiana parish (Calcasieu Parish was treated like the neighboring BPA counties). No growth was assumed for offshore sources. CO emissions were assumed to grow in a manner similar to NO_x.

Because the survey did not provide enough information to develop individual growth factors by SCCs, the same growth was assumed for all sources in each region. Commission modeling and emissions inventory staff are currently involved in an effort to develop industry-specific emissions growth models for the most significant emissions categories in Texas, but there is insufficient information at this time to refine the growth methodology beyond that presented here. It should be noted that in each area, the surveyed growth factors are in fact negative, reflecting a general decline in emissions of NO_x, VOC, and CO statewide.

A detailed summary of the methods used to develop the 1990-1996 growth factors is provided as Appendix I. Table 11 presents a summary of the survey results and the calculated point source growth factors used for each region and pollutant. Note that surveyed annual growth is expressed as a percentage of the 1990 emissions, while the 1993-2007 growth factor is a multiplicative factor applied to the 1993 base year emissions.

Table 11. Point Source Growth Factors

	Surveyed Annual Growth		**1993 - 2007 Growth Factor**		
Region	**NO_x**	**VOC**	**NO_x**	**VOC**	**CO**
HGA	-0.58%	-1.00%	0.9218	0.869	0.9218
BPA	-1.72%	-2.10%	0.7844	0.743	0.7844
Central and East Texas	-0.59%	-0.93%	0.9205	0.8774	0.9205
LA Parishes (ex. Calcasieu)	N/A	N/A	0.9205	0.8774	0.9205
Calcasieu Parish	N/A	N/A	0.7844	0.743	0.7844

Key:
BPA - 3 county Beaumont/Port Arthur nonattainment area
HGA - 8 county Houston Galveston nonattainment area

As an example, the calculation of the 1993-2007 NO_x growth factor for HGA is:

$$(1 - (0.58/100))^{14} = 0.9218$$

The resulting factor was multiplied by the 1993 modeled NO_x emissions from each point source in the eight-county HGA area to provide the 2007 projected emissions of NO_x.

NO_x RACT reductions

As a result of modeling reported in the May, 1998 SIP revision (TNRCC 1998a), The commission requested, and EPA approved, the rescission of the state's temporary waiver of NO_x RACT regulations granted under §8.18 of the 1990 Federal Clean Air Act Amendments for the HGA and BPA nonattainment areas. Texas will thus be implementing NO_x RACT requirements in these areas under 30 TAC Chapter 117. Controls required under the current Chapter 117, with a compliance date of November 15, 1999, are included in the base case emissions for HGA and BPA. The Chapter 117 control efficiencies, which were calculated by TNRCC Air Policy staff, are presented in Table 12 below. Appendix J provides a cross reference to the SCCs that are included in each of the point source

Table 12. Chapter 117 (NO_x RACT) control efficiencies used in 2007 future base

Source Category	Chapter 117 Control Efficiency in HGA and BPA
Utility Boiler, Gas Wall-fired	14%
Utility Boiler, Gas Tangential-fired	0%
Utility Boiler, Coal Wall-fired	0%
Utility Boiler, Coal Tangential-fired	0%
Gas Turbines	17%
Boilers, coal-fired	10%
Boilers, gas-fired	10%
Boilers, oil-fired	10%
Boilers, process gas-fired	10%
Boilers, wood-fired	10%
Solid Waste-Fired Boiler	10%
IC Engines (weighted rich & lean burn efficiency)	30%
Gas-Fired Process Heater or Furnace	0%
Oil-Fired Process Heater or Furnace	0%
Process Gas-Fired Process Heater or Furnace	0%
Miscellaneous Dryer	0%
Other	0%
Nitric Acid Plant	0%
Metallurgical heaters	0%
Incinerators	0%
Fluid Cat Cracker	0%
Oil Fired Turbines	0%
Flares	0%
Mineral Products, Glass Furnaces	0%
Mineral Products, Cement & Lime Kilns	0%
Other heaters	0%

The 2007 base case also included a number of ROP measures implemented between 1993 and 1999. The reductions associated with the ROP controls are unchanged from the previous round of modeling, and are described in Appendix E of the previous SIP revision (TNRCC, 1998a).

4.3 Revised Area and Nonroad Mobile Source Emissions in 2007 Future Base

Like point sources, emissions from nonroad mobile sources such as construction equipment, locomotives, pleasure boats, and lawn and garden equipment are declining because of improved technologies and new federal standards governing their manufacture. These declines are offset, at least partially, by growth in activity primarily related to population growth. The new Nonroad model (EPA, 1998) accounts for both activity growth and equipment replacement, and is thus the ideal tool for forecasting emissions for the sources it covers. (Unfortunately, the current version of the Nonroad model does not include shipping, locomotives, or aircraft.) The Nonroad model is available from EPA, but is still considered a draft version and is not yet approved for use in emissions inventory SIP development. To take advantage of the Nonroad model's capabilities, the commission adopted a compromise implementation whereby the model was used to develop growth factors only, using the model's default activity growth assumptions. These growth factors, which account for older equipment being replaced by units manufactured under new federal standards, were then applied to the base 1993 emissions inventory to produce the 2007 base emissions. The files containing the Nonroad model-derived growth factors are quite large and are not included in this document, but may be obtained from commission staff upon request.

The nonroad mobile sources not modeled by Nonroad, as well as the stationary area sources, were projected to 2007 using the REMI/EGAS factors described in the previous SIP revision (TNRCC, 1998a). Two nonroad mobile source categories, ships and locomotives, are affected by new federal standards and additional controls were applied to these categories, as shown in Table 13.

Table 13. Reduction factors applied to locomotives and commercial marine vessels in 2007 future base

Source	NO_x Reduction	VOC Reduction
Locomotives	0.67	0.92
Commercial marine vessels	0.93	0.97

4.4 Future Base Emissions Summary

Table 14 presents a summary of emissions by category for the eight HGA nonattainment counties for September 8, a typical ozone-season weekday, for both the 1993 base case and the 2007 future base. The future base emissions include both growth and controls. Because area and nonroad mobile source emissions were processed together, Table 14 lists emissions only for the combined category. Note that biogenic emissions were assumed to be unchanged from 1993 to 2007.

Table 14. HGA nonattainment area emissions for 1993 base case and 2007 future base, September 8					
County	Emission Category	1993 Base Case (tons/day)		2007 Future base (tons/day)	
		NO_x	VOC	NO_x	VOC
Brazoria	Biogenic	4	252	4	252
	Area/nonroad	16	22	15	20
	Point	107	56	86	36
	Onroad mobile	19	8	17	7
	County total	146	338	122	315
Chambers	Biogenic	2	84	2	84
	Area/nonroad	14	13	15	13
	Point	56	17	44	7
	Onroad mobile	9	3	5	2
	County total	81	117	66	106
Fort Bend	Biogenic	4	119	4	119
	Area/nonroad	8	16	7	14
	Point	87	4	78	3
	Onroad mobile	23	11	22	9
	County total	122	150	111	145
Galveston	Biogenic	1	42	1	42
	Area/nonroad	26	26	28	23
	Point	108	69	88	39
	Onroad mobile	17	9	12	5
	County total	152	146	129	109
Harris	Biogenic	4	270	4	270
	Area/nonroad	149	202	146	160
	Point	305	253	247	152

County	Emission Category	1993 Base Case (tons/day)		2007 Future base (tons/day)	
		NO_x	VOC	NO_x	VOC
	Onroad mobile	310	153	180	69
	County total	768	878	577	651
Liberty	Biogenic	2	385	2	385
	Area/nonroad	5	10	4	9
	Point	4	4	3	2
	Onroad mobile	7	3	5	2
	County total	18	402	14	398
Montgomery	Biogenic	>1	369	>1	369
	Area/nonroad	7	22	6	19
	Point	21	4	15	3
	Onroad mobile	25	10	21	8
	County total	53	405	42	399
Waller	Biogenic	2	88	2	88
	Area/nonroad	2	4	2	4
	Point	6	3	4	1
	Onroad mobile	5	2	4	1
	County total	15	97	12	94
HGA 8-county	Biogenic	19	1608	19	1608
	Area/nonroad	226	318	222	263
	Point	695	411	564	243
	Onroad mobile	416	199	267	103
	HGA Total	1356	2536	1072	2217

4.5 Revised Future Boundary Conditions

The initial and lateral boundary conditions for the COAST CAMx modeling were extracted from the Texas regional ozone modeling results. In the previous COAST ozone modeling activity, TNRCC used the Texas regional ozone modeling results provided by ENVIRON (ENVIRON, 1996) to obtain the initial and lateral boundary conditions. For the current COAST ozone modeling exercise, TNRCC used the same meteorological inputs as before, but made changes in the ozone photochemical model, emission inventory inputs, and the episode selection in the new Texas regional ozone modeling runs. These changes were made to ensure compatibility with regional modeling currently being conducted in the state, and to provide a basis for comparison with control scenarios modeled assuming regional reductions. Details of the modeling conducted to develop future boundary conditions are found in Appendix L.

4.6 Future Base Modeled Ozone

The 2007 future base case shows significant reductions in modeled ozone compared to the 1993 base case. Figure 4 shows daily peak modeled ozone for the 1993 base case and for the 2007 future base for September 11, and shows the difference between the two. A comparison of the images clearly shows the decrease in the spatial extent of the highest ozone concentrations, and the peak domain-wide ozone concentration also shows a substantial decrease from the 1993 base. Table 15 compares domain-wide peak ozone concentration between the 1993 base case and the 2007 future base.

Table 15: Peak modeled ozone, 1993 base case and 2007 future case (ppb)

	September 8	September 9	September 10	September 11
1993 base case	181.9	179.7	177.8	185.7
2007 future base	171.1	166.0	164.9	170.6

5.0 DIRECTIONAL GUIDANCE MODELING

After the future base case was finalized, modeling was conducted to verify the directional guidance established in the previous round of modeling. In this modeling, emissions of VOC and NO_x in the eight-county area were reduced across-the board to see which pollutant (or a combination of both pollutants) is most effective in controlling ozone formation. Three series of model runs were conducted to test the response of peak modeled ozone to reductions of NO_x, VOC, and NO_x plus VOC, as follows:

- Reduce emissions of NO_x from the 2007 projected levels by 25%, 50%, 75%, and 100%

for all anthropogenic sources in the eight-county HGA nonattainment area.

C Reduce emissions of VOC from the 2007 projected levels by 25%, 50%, 75%, and 100% for all anthropogenic sources in the eight-county HGA nonattainment area.

C

Simultaneously reduce emissions of NO_x and VOC from the 2007 projected levels by 25%, 50%, 75%, and 100% for all anthropogenic sources in the eight-county HGA nonattainment area.

The conclusions of this exercise, not surprisingly, are similar to those reached in the earlier round of modeling: namely, that VOC reductions alone, although beneficial, are not sufficient to bring modeled peak ozone concentrations below the NAAQS (125 ppb), and that NO_x reductions in excess of 75% from the future base will be necessary to reduce modeled ozone below the standard. Details of the directional guidance modeling are provided in Appendix L.

However, ozone formation depends upon the release height, spatial location, and timing of releases of NO_x, so across-the-board reduction modeling is not sufficient to evaluate specific controls. Additional model runs were thus required to assess the effectiveness of specific reduction scenarios.

6.0 CONTROL SCENARIO MODELING

In cooperation with stakeholders and local governmental bodies in the HGA nonattainment area, the commission designed a total of seven control scenarios designed to provide significant ozone reductions in the area. These scenarios combined federal, state, and local measures. Since the federal measures are common to all scenarios, for convenience they were all included in the 2007 future base emissions, as described above. Additional state and local measures were then applied to the 2007 future base as follows:

6.1 Control Scenarios

Scenario I

Adds the following State Measures to the **Future Base**:

Stationary Sources, eight-county nonattainment area:
Tier II point source controls (flue-gas cleanup)

Scenario II

Adds the following State Measures to **Scenario I**:

Stationary Sources, Central and East Texas counties (excluding HGA nonattainment counties):
50% reduction of all utilities (permitted and grandfathered)

30% reduction from remaining grandfathered sources

Onroad Mobile Sources, Central and East Texas counties (excluding HGA and BPA nonattainment counties):
Cleaner gasoline

Nonroad Mobile Sources, Central and East Texas counties (excluding HGA and BPA nonattainment counties):
Cleaner gasoline

Scenario III

Adds the following State Measures to the **Future Base**:

Stationary Sources, eight-county nonattainment area:
Tier III point source controls (flue-gas cleanup plus burner modification)

Adds the following Local Measures to the **Future Base**:

Onroad Mobile Sources, eight-county nonattainment area:
California RFG fuel standards
California diesel fuel standards
Additional transportation control measures

Nonroad Mobile Sources, eight-county nonattainment area:
California RFG fuel standards
California diesel standards
California recreational vehicle standards

Area Sources
Low NO_x standards for new water heaters and furnaces

Scenario IV

Adds the following State Measures to **Scenario III**:

Stationary Sources, Central and East Texas counties (excluding HGA nonattainment counties):
50% reduction of all utilities (permitted and grandfathered)
30% reduction from remaining grandfathered sources

Onroad Mobile Sources, Central and East Texas counties (excluding HGA and BPA nonattainment counties):
Cleaner gasoline

Nonroad Mobile Sources, Central and East Texas counties (excluding HGA and BPA nonattainment counties):
Cleaner gasoline

Scenario VI

Adds the following Local Measures to **Scenario IV**:

Onroad Mobile Sources, eight-county nonattainment area:
IM240 Inspection and Maintenance program

Scenario VII

Adds the following Local Measures to **Scenario IV**:

Onroad Mobile Sources, eight-county nonattainment area:
55 mile/hour maximum speed limit

Scenario VIII

Adds the following Local Measures to **Scenario IV**:

Onroad Mobile Sources, eight-county nonattainment area:
IM240 Inspection and Maintenance program
55 miles/hour maximum speed limit

Note that emissions from Scenario I and II are identical within the eight-county HGA nonattainment area, since the state measures listed apply only in attainment counties in Central and East Texas. Because much of this area lies outside the COAST modeling domain, a new set of future initial and boundary conditions was developed using the same methodology as described above, but assuming the state measures apply in Central and East Texas counties. These future initial and boundary conditions were also used for Scenarios IV, VI, VII, and VIII.

6.2 Description of Control Measures used in Modeling Scenarios

Table 16 below presents a summary of each of the modeled control scenarios that were described above, and includes the modeled reduction assumed for non-point source controls. Tier II and Tier III point source controls are described separately in the next section.

Table 16. Summary of HGA Modeling Scenarios

Controls Applied to 2007 Base	Where applied	NO_x change	VOC change	Scenario							
				I	II	III	IV	V	VI	VII	VIII
Point								not used in HGA Modeling			
Tier II	HGA	See section 6.3 for description of point source controls		X	X						
Tier III	HGA					X	X		X	X	X
50% all utilities, 30% grandfathered non-utility	Central and East Texas, BPA				X		X		X	X	X
Onroad mobile											
Cleaner gas	Central and East Texas	.-8.5%	-14.3%		X		X		X	X	X
Calif. RFG fuel standards	HGA	-8.8%	-17%			X	X		X	X	X
Calif. diesel fuel standards	HGA	-1.5%	0%			X	X		X	X	X
Additional TCMs	HGA	-1%	0%			X	X		X	X	X
8 county IM240 program	Harris County	-18.8%	-14.9%						X		X
	Other HGA counties	-30.3%	-40.5%						X		X
55 mph max. speed limit	HGA	-6.7%	-4.0%							X	X
Off-Road Mobile											
Cleaner gas	Central and East Texas	0%	-3%		X		X		X	X	X
Calif. RFG fuel standards[1]	HGA	0%	0%			X	X		X	X	X
Calif. diesel fuel standards	HGA	-8.0%	0%			X	X		X	X	X
California RV standards[1]	HGA	0%	0%			X	X		X	X	X
Area											
Low NO_x water heaters[1]	HGA	0%	0%			X	X		X	X	X

[1]No reductions could be quantified for these controls, so they were not modeled. They are listed here since they were included in the original control scenario descriptions.

Key:
BPA = 3 county Beaumont/Port Arthur nonattainment area
HGA = 8 county Houston/Galveston nonattainment area

6.3 Point Source Controls

Three classes of point source control were defined for the HGA nonattainment area sources, although only the latter two were modeled specifically in the seven control scenarios. These controls are:

Tier I: burner modification controls, such as low-NO_x burners.

Tier II: “flue gas cleanup” controls such as selective catalytic reduction (SCR).

Tier III: the application of both Tier I and Tier II controls.

The development of reduction percentages for each of the three tiers of control are documented in Appendix I of the 1998 SIP (TNRCC, 1998). Recently, Tier I reductions for coal-fired utility boilers were updated as a result of pending permit applications filed with the commission, and these updates are reflected in the reduction factors listed below.

In addition to controls in the eight-county HGA nonattainment area, some scenarios assume significant reductions for sources in Central and East Texas counties. These point source reductions were assumed to result in a 50% NO_x reduction on all utility boilers and a 30% NO_x reduction on all non-utility grandfathered sources (sources built or designed prior to 1971).

Because of the difficulty in identifying those sources which are grandfathered, an overall reduction factor for non-utility sources was developed based on a grandfathered emission study that was performed by the commission emissions inventory staff in 1998. The study indicated that in Central and East Texas counties, 144 tons per day of NO_x emissions were emitted by grandfathered non-utility sources, and 187 tons per day of NO_x emissions by permitted non-utility sources. Applying the 30% control efficiency to just the grandfathered emissions results in a 13% overall reduction.

Table 17 summarizes the reductions for each group of categories in the inventory. Appendix J provides a cross reference between the Source Categories listed and the EPA ten-digit SCCs used to classify individual sources in the emissions inventory.

Table 17: Summary of modeled point source reductions

Source Category	HGA nonattainment area reductions			Central and East Texas reductions
	Tier I	Tier II	Tier III	
Utility Boiler, Gas Wall-fired	0.50	0.90	0.95	0.50
Utility Boiler, Gas Tangential-fired	0.30	0.90	0.85	0.50
Utility Boiler, Coal Wall-fired	0.42	0.80	0.88	0.50
Utility Boiler, Coal Tangential-fired	0.52	0.80	0.90	0.50
Gas Turbines	0.50	0.90	0.95	0.13

Source Category	HGA nonattainment area reductions			Central and East Texas reductions
	Tier I	Tier II	Tier III	
Boilers, coal-fired	0.50	0.90	0.95	0.13
Boilers, gas-fired	0.50	0.90	0.95	0.13
Boilers, oil-fired	0.50	0.90	0.95	0.13
Boilers, process gas-fired	0.50	0.90	0.95	0.13
Boilers, wood-fired	0.50	0.90	0.95	0.13
Solid Waste Boiler	0.50	0.90	0.95	0.13
IC Engines (weighted rich & lean burn efficiency)	0.30	0.86	0.90	0.13
Gas-Fired Process Heater or Furnace	0.25	0.80	0.85	0.13
Oil-Fired Process Heater or Furnace	0.25	0.80	0.85	0.13
Process Gas-Fired Process Heater or Furnace	0.25	0.80	0.85	0.13
Other heaters	0.25	0.80	0.85	0.13
Miscellaneous Dryer	0.25	0.80	0.85	0.13
Other	0.10	0.50	0.55	0.13
Nitric Acid Plant	0.10	0.50	0.55	0.13
Metallurgical heaters	0.10	0.50	0.55	0.13
Incinerators	0.10	0.50	0.55	0.13
Fluid Cat Cracker	0.10	0.50	0.55	0.13
Oil Fired Turbines	0.00	0.00	0.00	0.13
Flares	0.00	0.00	0.00	0.13
Mineral Products, Glass Furnaces	0.25	0.75	0.81	0.13
Mineral Products, Cement & Lime Kilns	0.20	0.85	0.88	0.13

6.4 Emissions Summary for Control Scenarios

Table 18 summarizes anthropogenic emissions by category for the eight-county HGA area for September 8 for each control scenario. Also included for comparison are the 1993 and 2007 base emissions. Because biogenic emissions are assumed to remain constant, they are not included in the table. Note that emissions within the eight-county area are the same for Scenarios I and II, and also for Scenarios III and IV, since Scenarios II and IV add reductions outside the nonattainment area.

Table 18. Emissions by category for HGA control scenarios (8-county area), September 8								
Scenario	NO_x emissions (tons/day)				VOC emissions (tons/day)			
	point sources	area/nonroad sources	onroad mobile sources	Total	point sources	area/nonroad sources	onroad mobile sources	Total
1993 base	695	226	416	1337	411	318	199	928
2007 future base	564	222	266	1052	243	263	103	609
I	93	222	266	581	243	263	103	609
II	93	222	266	581	243	263	103	609
III	64	209	236	509	243	263	85	591
IV	64	209	236	509	243	263	85	591
VI	64	209	183	456	243	263	66	572
VII	64	209	221	494	243	263	82	588
VIII	64	209	170	443	243	263	63	569

6.5 Results of Control Scenario Modeling

Modeling was conducted to assess the effectiveness of each of the above control scenarios. For scenarios involving state measures in Central and East Texas (II, IV, VI, VII, and VIII), new future initial and boundary condition files were generated by additional runs of the regional CAMx model. Details of this regional modeling are found in Appendix K. Table 19 below summarizes the results of modeling each scenario, listing peak modeled ozone, geographic extent of exceedance, which is the number of grid cells where modeled ozone > 124 ppb at any time during the day, times the area of a grid cell (16 km^2), and area-hours, which accumulates hours over the 124 ppb threshold across the area of exceedance.

Table 19. Results of control scenario modeling												
	Peak daily O_3 (ppb)				Exceedance area (km^2)				Exceedance-hours (km^2-hrs)			
Scenario	9/8	9/9	9/10	9/11	9/8	9/9	9/10	9/11	9/8	9/9	9/10	9/11
1993 base	182	180	178	186	9,856	7,696	11,488	7,456	43,584	31,328	51,360	28,144
2007 fut. base	171	166	165	171	7,280	4,352	8,880	5,424	26,128	16,464	28,096	19,376
I	172	163	163	165	4,544	2,912	5,280	4,032	14,016	10,528	14,624	13,024
II	171	160	162	164	4,528	2,512	4,768	3,968	13,808	8,608	12,960	12,464
III	170	161	162	161	4,160	2,576	4,176	3,728	11,696	8,912	11,184	11,328
IV	170	158	160	160	4,064	2,176	3,808	3,600	11,440	7,232	9,904	10,560
VI	168	156	159	155	3,728	1,968	3,072	3,312	10,000	6,224	7,600	8,944
VII	169	158	160	158	3,984	2,128	3,632	3,552	11,120	7,056	9,200	10,080
VIII	167	155	158	154	3,680	1,936	2,912	3,200	9,664	6,000	7,088	8,608

Figures 5, 6, and 7 plot the data from the above table, showing the response of ozone metrics to the various levels of control. Detailed information on the outcome of modeling each control scenario is found in Appendix M.

6.6 Additional Control Scenario Modeling

A glance at the bottom row of Table 19 shows that Scenario VIII provides very substantial air quality benefits compared to both the 1993 base case and the 2007 future base, but still exhibits modeled ozone concentrations well in excess of the one-hour standard. To demonstrate attainment, additional scenarios would have to be considered. The TNRCC Policy and Modeling staffs thus devised a series of additional model runs to model attainment. These additional runs were based on Scenario VI described above, with incremental reductions applied in addition to those already modeled. The additional scenarios were named by appending a letter to the scenario's Roman numeral; for example, Scenario VIc is the third in the series of additional scenarios based on Scenario VI. Some additional control scenario runs based on Scenarios VI and VIII were also performed, but the results of these runs did not differ greatly from those based upon Scenario VI and are not reported here (these results may be obtained from the commission upon request).

The additional control scenarios are defined as follows:

Scenario VIa

Updates **Scenario VI** as follows:

Regional reductions, applied to pollutants transported into the modeling domain:
Account for widespread NO_x reductions resulting from EPA's NO_x SIP call.

Onroad Mobile Sources, entire modeling domain:
Update Tier II, low sulfur assumptions based on new information from EPA.

Onroad Mobile Sources, eight-county nonattainment area:
Increase I/M compliance rate due to registration denial

Scenario VIb

Adds the following <u>Federal Measures</u> to **Scenario VIa**:

Nonroad Mobile Sources, eight-county nonattainment area:
Reduce NO_x emissions from all categories by 50%

Scenario VIc

Adds the following <u>Federal Measures</u> to **Scenario VIb**:

Onroad Mobile Sources, entire modeling domain:
Assume Tier II penetration at 2015 level (accelerated fleet turnover)

Scenario VId

Adds the following <u>Federal Measures</u> to **Scenario VIc**:

Point Sources, Gulf of Mexico:
Tier III point source controls

Nonroad Mobile Sources, Gulf of Mexico:
Reduce NO_x emissions from all categories by 50%

Adds the following <u>State Measure</u> to **Scenario VIc**:

Area Sources, Central and East Texas counties (excluding HGA and BPA nonattainment counties):
Stage I refueling

Scenario VIe

Adds the following Federal Measures to **Scenario VIc**:

Stationary sources, Central and East Texas counties (excluding HGA nonattainment counties):
90% reduction of all utilities (permitted and grandfathered)
30% reduction from remaining grandfathered sources
Point Sources, Central and East Texas counties:
Tier III point source controls

Nonroad Mobile Sources, Gulf of Mexico:
Reduce NO_x emissions from all categories by 50%

Adds the following State Measure to **Scenario VIc**:

Area Sources, Central and East Texas counties (excluding HGA and BPA nonattainment counties):
Stage I refueling

Scenario VIf

Adds the following State Measures to **Scenario VIc**:

Nonroad Mobile Sources, HGA nonattainment counties:
Shift construction activity from 7 a.m.-7 p.m. to noon-midnight

Area Sources, Central and East Texas counties (excluding HGA and BPA nonattainment counties):
Stage I refueling

Note that Scenario VIa does not specifically apply additional control measures. Rather, it adjusts Scenario VI to account for new information on the Tier II/federal low sulfur proposal and to account for the NO_x SIP call. Additionally, it adjusts the I/M compliance rate from 84% to 96%, since higher compliance is expected in the future due to the implementation of registration denial. In effect, these modifications could have been applied to the future base, but time constraints prevented re-running the future base and Scenarios I through VIII. Details of modeling conducted to develop the NO_x SIP call boundary conditions can be found in Appendix K.

Scenario VIb applies a 50% across-the-board reduction to area and nonroad mobile source NO_x emissions in Scenario VIa. As shown in Table 18, this inventory category remained largely unchanged from the 1993 base through Scenario VIII, and is in fact the largest category of NO_x emissions in Scenarios VI and VIII. Clearly, reductions in this category are important to demonstrating attainment, although it is unclear whether these emissions are accurately characterized in the base (hence future) modeling inventories. Some evidence indicates that the area and nonroad mobile source NO_x emissions may be overstated in the modeling inventory.

Additionally, the 2007 emissions are likely concentrated too tightly near the center of Houston, since the spatial allocation is based on land-use data from the early 1990's or before. This artificial concentration of the emissions may overplay their actual impact on ozone formation. Thus, this scenario may be thought of as an emissions sensitivity analysis. On the other hand, if the emissions are accurately characterized, then this scenario represents the application of unspecified controls to the sources in this category. In fact, proposed federal (and, for ships, international) regulations will eventually bring about very large reductions in this category, but this will not occur until many years beyond the HGA area's 2007 attainment date. A program designed to promote highly accelerated fleet turnover in heavy equipment might be employed to bring about some early reductions. Other avenues of possible control include use of cleaner fuel for marine vessels. The combined effect of emissions inventory improvements and the implementation of control strategies is likely to approach the 50% reduction assumed in this scenario. The reduction strategies for this category will be more specifically quantified in the next SIP. Meanwhile, the TNRCC staff, along with several interested stakeholders, are currently studying the sources in this category, and hope to more accurately characterize the emissions in modeling for the 2000 SIP submittal.

Scenario VIc adds the assumption of a 2015 implementation of federal Tier II and heavy-duty vehicle standards (but not accounting for VMT growth to 2007) to Scenario VIb. Again, programs designed to accelerate fleet turnover might be employed to bring additional reductions by 2007. The TNRCC staff plan to assess the feasibility of broad-scale programs to accelerate fleet turnover, as well as alternative methods for reducing onroad mobile source emissions, and will quantify the achievable levels of reductions in the year 2000 SIP.

Scenario VId is designed to test the effectiveness of reductions in the Gulf of Mexico. It also adds the assumption of Stage I refueling in Central and East Texas counties, a program which was inadvertently left out of earlier model runs. These reductions were applied to Scenario VIc.

Scenario VIe is designed to test the effectiveness of more stringent reductions applied to electric utility sources in Central and East Texas region. It also includes Central and East Texas Stage I refueling. These reductions were applied to Scenario VIc.

Scenario VIf tests the effectiveness of delaying the start of construction activity by five hours. It also includes Central and East Texas Stage I refueling. These reductions were applied to Scenario VIc.

Table 20a summarizes the reductions applied in the additional control scenarios.

Table 20a. Summary of additional HGA Modeling Scenarios									
Controls Applied to Scenario VI	**Where applied**	**NO_x change**	**VOC change**	**Scenario**					
				VIa	**VIb**	**VIc**	**VId**	**VIe**	**VIf**
Point									
Approx. Tier II	Offshore	-89%	0%				X		
Tier II utilities, 30% grandfathered non-utility	Central and East Texas, BPA	See Sect. 6.3						X	
Onroad mobile									
Update Tier II, Federal Low Sulfur	HGA	-12%	+2%	X	X	X	X	X	X
	Central and East Texas, BPA	-2.5%	+4.5%						
Adjust I/M compliance rate	Harris County	0%	-6%	X	X	X	X	X	X
2015 Tier II, HDDV	Harris County	-51%	-56%			X	X	X	X
	HGA 7-counties	-50%	-54%						
Off-Road Mobile									
50% NO_x cut	HGA	-50%	0%		X	X	X	X	X
5-hour delay start time	HGA	0%	0%						X
Area									
Stage I refueling	Central and East Texas	0%	-1%				X	X	X

Table 20b summarizes emissions of VOC and NO_x by category for the additional control scenarios (the 1993 base case, 2007 future base, and original control scenario VI are included for comparison). Note that emissions within the eight-county area are identical for scenarios VIc through VIf, since scenarios VId and VIe apply reductions outside the nonattainment area, and Scenario VIf shifts emissions temporally, but does not change the daily total.

Table 20b. Emissions by category for additional HGA control scenarios (8-county area), September 8								
	NO_x emissions (tons/day)				VOC emissions (tons/day)			
Scenario	**point sources**	**area/non road sources**	**onroad mobile sources**	**Total**	**point sources**	**area/nonr oad sources**	**onroad mobile sources**	**Total**
1993 base	695	226	416	1337	411	318	199	928
2007 future base	564	222	266	1052	243	263	103	609
VI	64	209	183	456	243	263	66	572
VIa	64	209	161	434	243	263	67	573
VIb	64	105	161	330	243	263	67	573
VIc	64	105	80	249	243	263	30	536
VId	64	105	80	249	243	263	30	536
VIe	64	105	80	249	243	263	30	536
VIf	64	105	80	249	243	263	30	536

Table 21 shows the results of the additional control strategy modeling, with the 1993 base case, 2007 future base, and Scenario VI included for comparison. These results indicate that a 50% reduction in area/nonroad NO_x emissions, coupled with the assumption of a 2015 implementation of Tier II and federal heavy-duty standards (Scenario VIc) brings the area near to attainment of the one-hour ozone standard, although attainment is not quite reached on any day. Regional reductions in the Gulf of Mexico (Scenario VId) and in the Central and East Texas area (Scenario VId) are helpful, but neither significantly affect peak ozone. The construction activity time shift (Scenario VIf) does significantly reduce peak ozone and the other metrics tabulated in Table 21, and in fact brings one day (September 11) below the standard, and another day (September 9) very close. Figure 5 compares predicted ozone on September 9 under the assumptions of Scenario VIf with the predictions for the 2007 future base. The comparison shows a vast improvement in both extent and concentration of predicted ozone resulting from the application of Scenario VIf controls.

Table 21. Results of additional control scenario modeling												
	Peak daily O_3 (ppb)				Exceedance area (km^2)				Exceedance-hours (km^2-hrs)			
Scenario	9/8	9/9	9/10	9/11	9/8	9/9	9/10	9/11	9/8	9/9	9/10	9/11
1993 base	182	180	178	186	9,856	7,696	11,488	7,456	43,584	31,328	51,360	28,144
2007 fut. base	171	166	165	171	7,280	4,352	8,880	5,424	26,128	16,464	28,096	19,376
VI	168	156	159	155	3,728	1,968	3,072	3,312	10,000	6,224	7,600	8,944
VIa	165	154	157	153	3,504	1,824	2,752	3,120	8,608	5,456	6,576	8,032
VIb	155	143	148	141	2,096	1,120	1,328	1,952	4,080	2,800	2,912	3,728
VIc	143	131	132	127	1,008	496	352	256	1,760	864	496	256
VId	143	131	132	126	912	496	304	208	1,648	864	432	208
VIe	143	130	132	126	976	448	352	160	1,696	672	464	160
VIf	138	127	130	123	800	192	192	0	1,200	224	272	0

Notes on Additional Control Scenario Modeling

The modeling of many of the onroad mobile source reductions was very approximate, since there are no generally available models capable of handling the new Tier II, heavy duty diesel, and federal low sulfur standards. The Mobile6 model should address these and other issues, but unfortunately has not yet been released. In several cases, reductions were applied multiplicatively, which ignores any interactions among the reduction factors. If Mobile6 is released on schedule (by the end of 1999), the commission modeling staff plans to use it to re-calculate the reductions for modeling in the 2000 SIP. A couple of inconsistencies in the calculation of the reduction factors were also noted during the peer review process, but are relatively minor and will be corrected in future modeling. First, the initial estimates for the new Tier II/federal low sulfur NO_x reductions were 17% in HGA, while later calculations showed the correct amount to be 13%. Secondly, the new low sulfur reduction factor was applied on top of the California RFG reduction, while it should have replaced it. Both these factors serve to overestimate the reduction to onroad mobile source NO_x, combining to produce about 26 tons/day more NO_x reduction in the HGA area than would be expected in Scenarios VIa and VIb, and about 13 tons/day extra NO_x reduction in Scenarios VIc through VIf. If the additional control scenarios were re-modeled with these corrections, we would expect slightly higher modeled ozone concentrations to result.

Supplementary Modeling

As a result of comments by EPA Region VI on the original SIP proposal, the commission conducted two additional modeling runs, which are described here. Region VI expressed concern about two elements included in the additional strategy modeling runs discussed above: the arbitrary 50% reduction in nonroad mobile source emissions (Scenarios VIb-VIf), and the assumption of a 2015 vehicle fleet (Scenarios VIc-VIf), since the commission was not able to specifically identify means of achieving these emission reductions. The additional modeling runs, identified as Strategies H1 and H2 (to distinguish them from the many Scenarios run earlier), included some minor corrections to assumptions made in Scenarios VIa-VIf, as well as addressing the concerns of Region VI. The Strategies are:

Strategy H1

Updates **Scenario VI** as follows:

Regional reductions, applied to pollutants transported into the modeling domain:

Account for widespread NO_X reductions resulting from EPA's NO_X SIP call.

Onroad Mobile Sources, entire modeling domain:

Update Tier II, low sulfur assumptions based on new information from Radian Corp.

Onroad Mobile Sources, eight-county nonattainment area:

Increase I/M compliance rate due to registration denial

Update I/M 240 reductions due to new information from Radian Corp.

Nonroad Mobile Sources, eight-county nonattainment area:

Reduce construction emissions by 33% based on California data

Update reductions from California RFG, Diesel standards based on Radian report

Adds the following Local Measures to **Scenario VI**:

Off-road Mobile Sources, eight-county nonattainment area:

Reduce NO_X emissions from all categories by 24 tons/day for 3% VMEP credit

Adds the following State Measures to **Scenario VI**:

Area Sources, Selected counties in Central and East Texas:

Stage I refueling

Strategy H2

Adds the following State Measures to **Strategy H1**:

Off-road Mobile Sources, HGA nonattainment counties:

Shift construction activity from 7AM-7PM to Noon-Midnight

Strategy H1 is similar to Scenario VIb, except that improved reductions for onroad mobile source programs were used, and the 50% reduction in nonroad mobile source emissions was replaced with a more conservative estimate based on an analysis of construction-related emissions in the Los Angeles area (emissions from construction equipment was reduced by one-third). Additionally, the nonroad category NO_X emissions were reduced by 24 tons/day based on the new Voluntary Mobile Emissions Program (VMEP), which allows up to three percent of the reduction needed to reach attainment to be taken from voluntary programs.

Strategy H2 is identical to Strategy H1, except that construction activity is shifted by five hours, as in Scenario VIf. The peak modeled ozone concentrations obtained for these two Strategies are listed below in Table 22. For comparison, the table also includes modeled peak ozone concentrations for the 1993 base case, 2007 future base, and Scenario 6f. Emissions by category for these runs are tabulated below in Table 23.

Table 22: Maximum daily modeled ozone for supplementary Houston/Galveston modeling runs				
Scenario	September 8	September 9	September 10	September 11
1993 Base case	182	180	178	186
2007 Future base	171	166	165	171
Scenario VIf	138	127	130	123
Strategy H1	155	143	148	142
Strategy H2	152	141	146	140

Table 23. Emissions by category for additional HGA control scenarios (8-county area), September 8								
	NO_x emissions (tons/day)				**VOC emissions (tons/day)**			
Scenario	**point sources**	**area/non road sources**	**onroad mobile sources**	**Total**	**point sources**	**area/non road sources**	**onroad mobile sources**	**Total**
1993 Base case	695	226	416	1337	411	318	199	928
2007 Future base	564	222	266	1052	243	263	103	609
Scenario VIf	64	105	80	249	243	263	30	536
Strategy H1	64	148	195	407	243	257	79	579
Strategy H2	64	148	195	407	243	257	79	579

7.0 WEIGHT OF EVIDENCE ANALYSES

Observation-Based WOE Determination

In the previous HGA SIP adopted on May 6, 1998, there was an extensive discussion of observation-based weight of evidence results that are relevant to the HGA area. These analyses have not been modified, so are not repeated here, but may be found on pages 193 through 221 of the above referenced document. The conclusions from those analyses, which are equally relevant to the current SIP, are discussed below.

Experts on the FACA Science and Technical Support Work Group have indicated that a minimum of six years of data is necessary to establish trends based on monitoring data. A minimum of six years of data collected in the HGA area has been analyzed for ozone and the ozone precursors of NO_x and VOC. This analysis indicates that NO_x and VOC levels have decreased over the HGA area. This finding is consistent with estimates of the emissions reductions based on emissions inventory information. Since this SIP models large reductions of precursors that greatly exceed past reductions, it is reasonable to assume that the historical trends established for ozone concentrations will continue in a similar fashion.

Three metrics have been applied to the ozone monitoring data collected since 1987. These metrics are similar to the metrics used for the modeling described earlier. Historical trend lines have been projected to the future for each of these metrics. For the design value and total exposure metrics, the projected metric indicates that the one-hour ozone standard can be expected to be attained by 2007. The data from the areal exposure is not consistent from day to day, so projections to the future may not be useful. Projections of this metric to the future do not predict attainment of the standard by 2007. In summary, two of the three observation-based metrics predict attainment by 2007.

These analyses of historical monitoring data, coupled with the modeling, indicate that if the large reductions of ozone precursors defined in this SIP are achieved, the HGA area will attain the one-hour ozone standard by 2007.

Meteorological Analysis

All of the modeled episode days do not show attainment of the standard for the control scenarios modeled. The area that appears to be the most resistant to controls is the region immediately south of the Houston metropolitan area. Based on a review of the meteorological fields for this episode and animations of ozone and its precursors for the 1993 base case, it appears that these peaks are associated with an area of convergence and stagnation in the surface winds.

The stagnation areas are associated with areas where wind monitors are clustered and this leads us to believe that the assimilation of wind observations is inducing the stagnation area in the SAIMM used to prepare the meteorological inputs. It is probable that these assimilation ("nudging") processes are resulting in the improper placement and extent of the convergence zone.

September 8, 1993 provides a good example of the problem. On this day the modeled area of stagnation is centered at the intersection of Harris, Brazoria and Fort Bend counties. This area is close enough to the central Houston area to have a high NO_x level. Normally, we would expect an area with high levels of NO_x to be titrating ozone, but in this case the model predicted the domain-wide peak at the intersection of Harris, Brazoria and Fort Bend counties. The high NO_x concentrations are verified by the fact that in the directional guidance model runs, there is a disbenefit when NO_x reductions are simulated. Logic would dictate that the high ozone in the region is due to a convergence of NO_x from Houston to the east and biogenic VOC from Brazoria and Fort Bend counties.

When we refer back to the model performance evaluation for this episode, we note that the Croquet site in southern Harris County is located in this area, and the ozone peak at this site is overpredicted by 50 ppb on this day. We believe that this ozone peak is artificially enhanced because of the simulated meteorology and may in fact, be easier to control, than the model is currently showing. The commission's future work may include the use of non-hydrostatic meteorological models which are anticipated to more accurately simulate the complex meteorology of the Gulf Coast area.

Supplementary Weight-of-Evidence: Alternative Emissions Inventory Analysis

As described in the March, 1998 SIP for the HGA nonattainment area, comparisons of both the emissions inventory and modeled pollutant concentrations with ambient measurements indicate that the VOC/NO_X ratio in the inventory may be too small; that is, either the inventory underrepresents anthropogenic VOC, overrepresents anthropogenic NO_X, or both (the reduction to construction equipment NO_X emissions applied in Strategies H1 and H2 is consistent with this hypothesis). At the same time, comparisons of inventory and modeled values of isoprene with measurements indicate a strong possibility that biogenic VOC emissions may be overrepresented in the inventory. The previous SIP described modeling conducted by the Commission in which the modeling inventory was modified to resemble more closely the ambient monitoring data. This modeling verified that a NO_X-based control strategy was still appropriate for the region, even if the inventory differs substantually from reality. This modeling also indicated, that under inventory assumptions more closely aligned with the ambient data, attainment may be possible with significantly less NO_X reduction than would be necessary using the "normal" inventory.

At the recommendation of EPA Region VI staff, the Commission conducted additional modeling runs to test the efficacy of Strategy H2 under an alternative emissions inventory assumption. For this analysis, the on-road mobile source VOC emissions were doubled (from Strategy H2), while the biogenic VOC emissions were halved. The modeling conducted under these assumptions showed significantly lower peak ozone concentrations than were seen using the normal inventory, as shown in Table 24 below:

Table 24: Maximum daily modeled ozone with different inventory assumptions				
Scenario	September 8	September 9	September 10	September 11
Strategy H2, normal inventory	152	141	146	140
Strategy H2, alt. inventory	141	133	132	131

While the modeling with alternative inventory assumptions did not quite bring the area into attainment, it shows that a strategy like H2 could be very effective in improving the region's air quality, if the alternative assumptions prove to be true. Further, given the inherent uncertainties in any emissions inventory, this exercise suggests that under other plausible alternative inventory assumptions, Strategy H2 could well be sufficient to reach attainment. The Commission is currently engaged in, and will continue to engage in, sincere efforts to reduce the uncertainty in all aspects of the emissions inventory in Texas. As these efforts mature, the commission will re-evaluate the modeling conducted for this SIP, and will revise the area's control plan as necessary.

One check to ensure that the alternative inventory is reasonable is to apply the alternative assumptions to the base case, and conduct model performance analysis with these assumptions. Similar to the results reported in the 1998 HGA SIP, model performance under the alternative inventory assumptions degraded somewhat from the original base case, but still fell within EPA recommended ranges (with one exception - September 8 Unpaired Peak Accuracy) for each primary episode day. Table 25 below shows model performance for the original base case and for the base case run with the alternative emissions inventory.

Table 25. CAMx Performance Statistics for HGA 8-County Area, Sept. 6-11, 1993						
Episode Date	Modeling Inventory	Normalized Bias (+/- 5-15%)	Gross Error (30-35 %)	Unpaired Peak Accuracy (+/-15-20%)	Simulated Peak Ozone (ppb)	Measured Peak Ozone (ppb)
9/6/93	Normal	**7.9**	**17.8**	**20.7**	164	136
	Alternative	**3.9**	**17.8**	**16.2**	158	
9/7/93	Normal	**10.6**	**21.5**	50.8	167	111
	Alternative	**4.7**	**20.1**	39.8	155	
9/8/93	Normal	**9.2**	**24.8**	**-15**	182	214
	Alternative	**-0.1**	**23.8**	-21.6	168	
9/9/93	Normal	**11.4**	**28.2**	**-7.9**	180	195
	Alternative	**3.6**	**26.2**	**-18.1**	160	
9/10/93	Normal	**-4.2**	**24.4**	**9.7**	178	162
	Alternative	**-12.6**	**24.5**	**0.9**	164	
9/11/93	Normal	**8.4**	**23.6**	**-1.8**	186	189
	Alternative	**0.0**	**22.3**	**-9.6**	171	

8.0 FUTURE MODELING ANALYSES

The commission modeling and air policy staffs plan to work closely with stakeholder groups in the area to identify additional control strategies which may be effective in reducing ozone in the HGA area. In the coming months, the modeling staff expect to perform numerous analyses to help evaluate these candidate control strategies. Modeling will also be conducted to assess the controls which will be part of the SIP to be submitted by the end of 2000.

The commission modeling staff also plan to work closely with emissions inventory staff and interested stakeholder groups to improve the modeling inventory prior to the 2000 SIP submittal. Of particular interest is the nonroad sector of the inventory, since it appears large relative to the onroad component (for example, projected 2007 NO_x emissions from construction equipment in the eight-county area are larger than the corresponding emissions from heavy-duty trucks), and because ozone concentrations are highly sensitive to this sector of the inventory, as evidenced by the response shown in Scenario VIb, where a 50% reduction in emissions from this category resulted in an average reduction in daily peak ozone of 10 ppb. Commission staff plan to increase efforts to develop bottom-up activity data for construction equipment and shipping, and to develop more accurate surrogates for both spatial and temporal allocation of nonroad emissions.

If MOBILE6 is released by December 1999 as expected, commission staff plan use it to re-evaluate the onroad mobile source emissions used in this modeling analysis. MOBILE6 is expected to greatly enhance states' abilities to evaluate mobile source controls, including Tier II standards and I/M programs, and to allow several items to be modeled simultaneously. These capabilities can be used to refine the simple methods used in constructing the control scenarios described above. Even if MOBILE6 is released on schedule, however, it may not be possible to completely rebuild the future onroad mobile source emissions in time for inclusion in the year 2000 SIP submittal.

The commission staff, in cooperation with the Photochemical Modeling Technical Oversight Committee, have endeavored for the past several months to develop improved growth methodologies. Specifically, a workgroup has been studying the issue of forecasting emissions as opposed to just forecasting economic growth. The uniform approach employed in this modeling analysis for point sources represents a step in this direction, but more refined growth forecasting tools are needed. If the workgroup is successful in its efforts to develop an improved growth forecasting methodology, the modeling staff hopes to employ it for the 2000 SIP submittal.

In the longer term, the commission is participating in a major field study planned for the summer of 2000. This study will address many questions left open as the COAST modeling draws to a conclusion, including better characterizing the coastal meteorological patterns that frequently lead to ozone events, enhancing the emissions database, and analyzing the performance of the model's chemical reaction mechanism under the unique conditions found along the Texas Gulf coast. It is hoped that the field study will yield high-quality monitoring for several ozone episodes which can be used in future modeling analyses for the region.

Bibliography

Chameides et al. (1988). The role of biogenic hydrocarbons in urban photochemical smog: Atlanta as a case study. *Science* 241: 1473-1475.

Emissions Inventory Improvement Program (1996). *Biogenic Source Preferred Methods, Volume V, Emissions Inventory Improvement Program*. Prepared for the Area Sources Committee of EIIP by L. Adams, Radian Corporation, May 1996.

ENVIRON (1996) *Future-Year Boundary Conditions for Urban Airshed Modeling for the State of Texas*, prepared for TNRCC by ENVIRON International Corporation, 1996.

ENVIRON (1998). *Draft: A Biogenic Emission Inventory for the Tyler/Longview/Marshall Area Based on Local Data*, prepared for The East Texas Council of Governments by ENVIRON International Corporation, December 1998.

EPA (1998). *June 1998 Draft NONROAD Model*, Unites States Environmental Protection Agency, Office of Mobile Sources. See http://www.epa.gov/oms/nonrdmdl.htm.

Estes et al. (1996). Biogenic emissions modeling for southeastern Texas. *AWMA EI Conference: Key to Planning, Permits, Compliance and Reporting*, Sept 4-6, 1996, New Orleans, La., pp. 349.

Geron et al. (1994). An improved model for estimating emissions of VOCs from forests in the eastern US. *JGR* 99(D6): 12,773-12,791.

Geron et al. (1995). Reassessment of biogenic VOC emissions in the Atlanta area. *Atmos. Environ*. 29(13): 1569-1578.

MCNC, 1999. *Incorporation of emissions improvements for the HGA CAMx modeling*, prepared for TNRCC by N. Wheeler, J. Vukovich, and P. Dolwick of MCNC–North Carolina Supercomputing Center, Environmental Programs, March 1999–Draft.

Radian and Valley Research Corporation (1994). *Biogenics Emissions Factors Project*, prepared for TNRCC by Radian Corporation and Valley Research Corporation, March 1994.

Sillman S. (1999) The relation between ozone, NO_x and hydrocarbons in urban and polluted rural environments. *Atmos. Environ*. 33: 1821-1845.

TNRCC (1998a). *Revisions to the State Implementation Plan for the Control of Ozone Air Pollution: Attainment Demonstration for the Houston/Galveston Ozone Nonattainment Area*. Rule Log No. 97184-SIP-AI, February 5, 1998.

TNRCC (1998b). *Revisions to the State Implementation Plan for the Control of Ozone Air*

Pollution: Attainment Demonstration for the Dallas/Fort Worth Ozone Nonattainment Area. Rule Log No. 98046-SIP-AI, October 21, 1998.

TNRCC, (1998c). *Protocol for ozone modeling of the Houston-Galveston areas with the Comprehensive Air Quality Model with Extensions (CAMx) and COAST data*. Prepared by SIP Planning Section, Air Quality Planning and Assessment Division, TNRCC, December 14, 1998.

Wilkinson et al., (1996). An intercomparison of biogenic emissions estimates from BEIS2 and BIOME: Reconciling the differences. *AWMA EI Conference: Key to Planning, Permits, Compliance and Reporting*, Sept 4-6, 1996, New Orleans, La. pp.985

Yarwood G., D. Allen, A. Guenther, C. Quigley, C. Wiedinmyer, W. Strange, B. Baugh, and K. Lee (1997) *Leaf Biomass Density Data for North-Central Texas*, prepared for TNRCC by ENVIRON International Corporation, University of Texas Department of Chemical Engineering, and the National Center for Atmospheric Research, October 1997.

Yarwood G., D. Allen, A. Guenther, C. Quigley, C. Wiedinmyer, W. Strange, B. Baugh, and G. Wilson (1999). *Leaf Biomass Density Data for South East Texas*, prepared for TNRCC by ENVIRON International Corporation, University of Texas Department of Chemical Engineering, and the National Center for Atmospheric Research, February 1999.

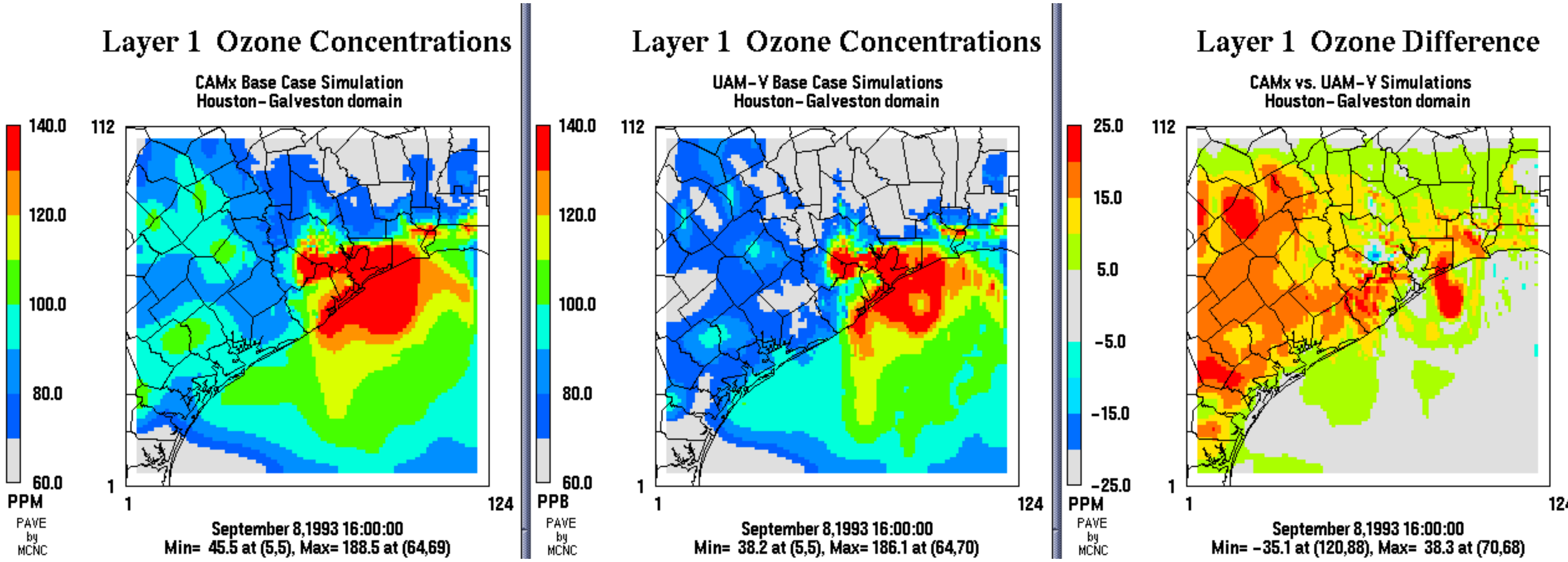

Figure 1: Comparison of modeled ozone concentrations using CAMx and UAM-V

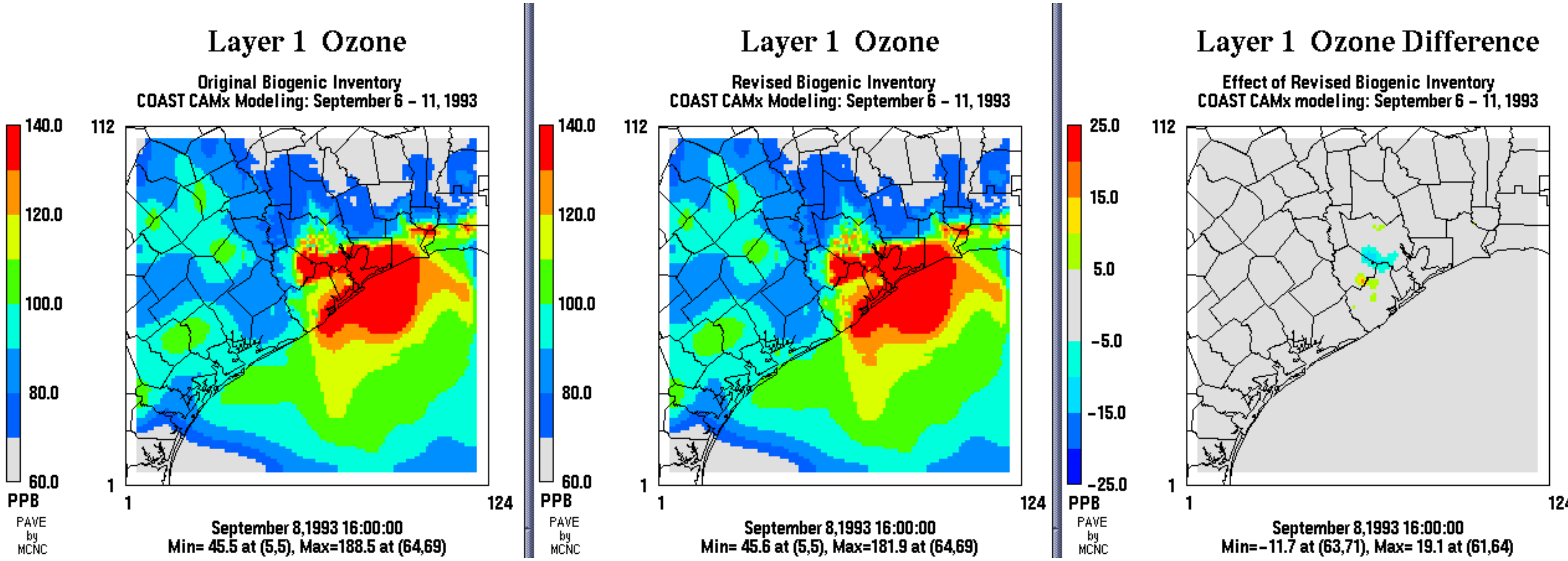

Figure 2: Comparison of modeled ozone concentrations using original and revised biogenic emissions.

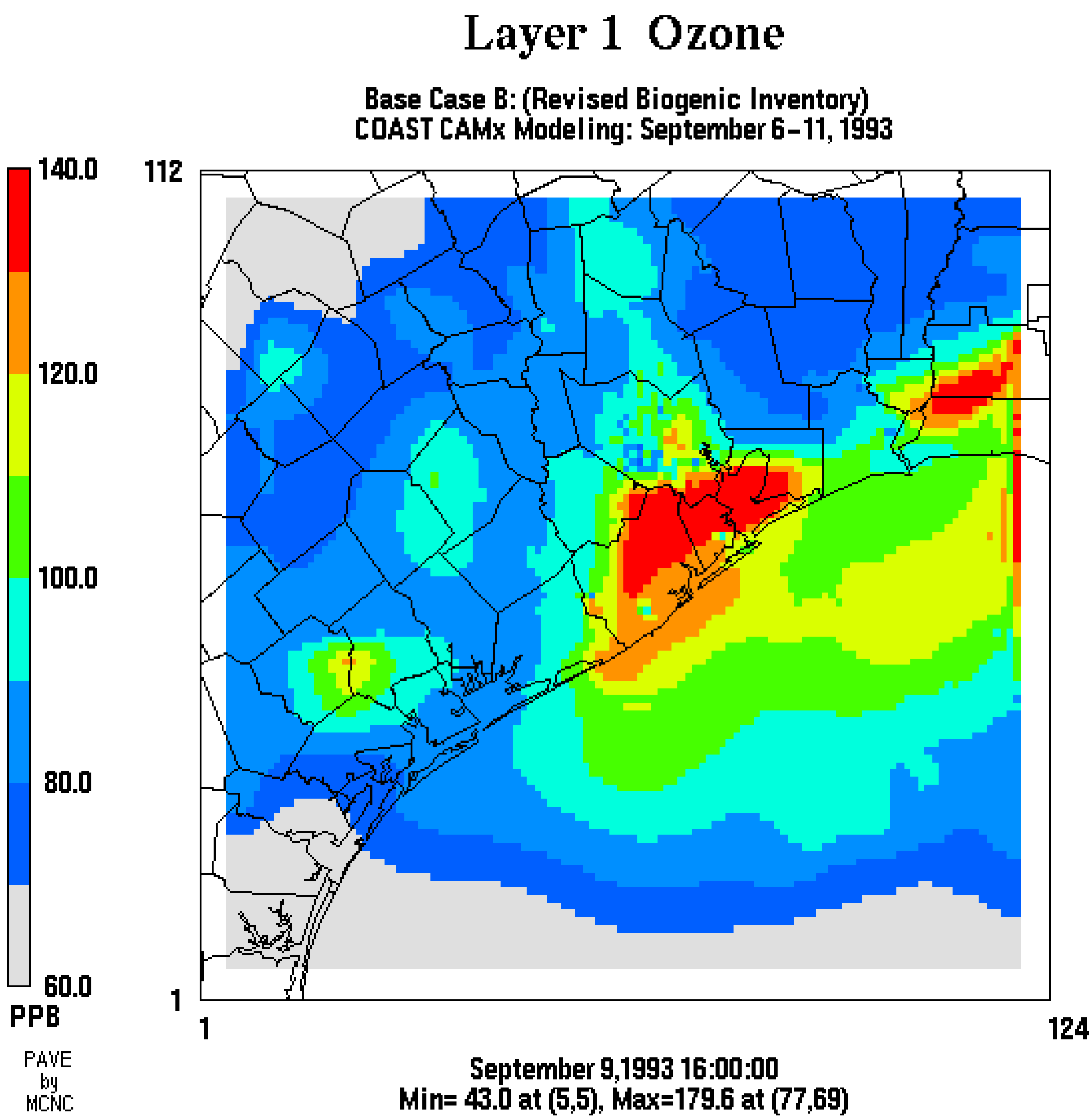

Figure 3: Base case modeled ozone at 16:00 on September 9, 1993.

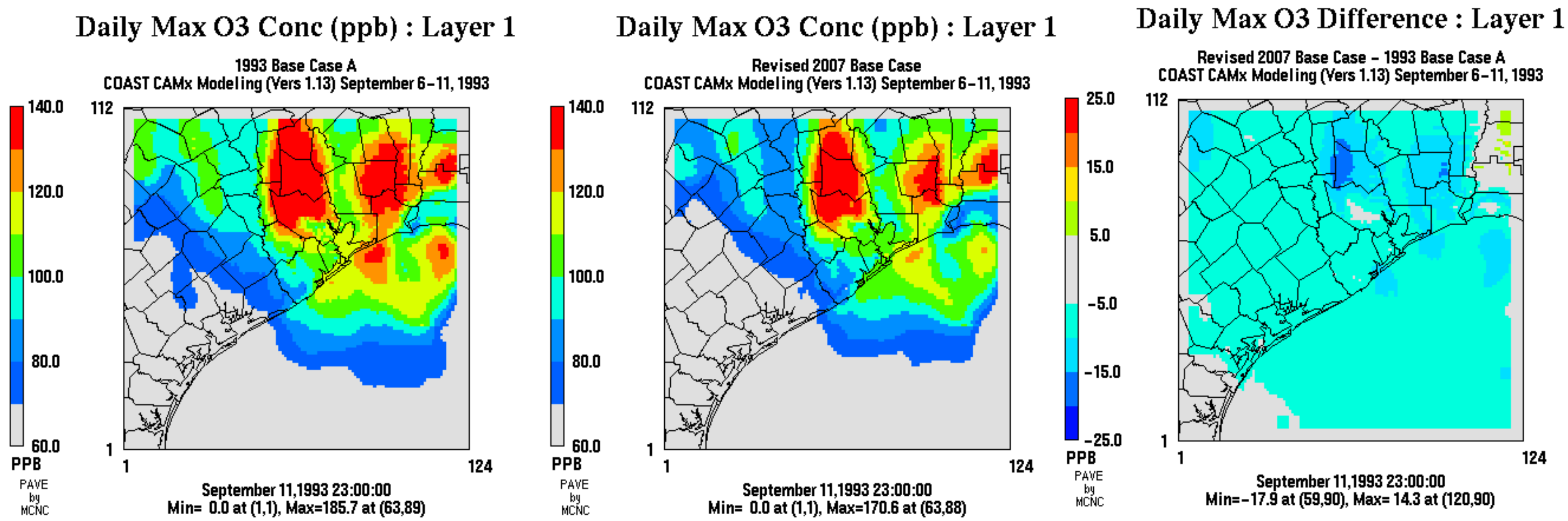

Figure 4 Comparison of 2007 future base ozone concentrations with 1993 base case

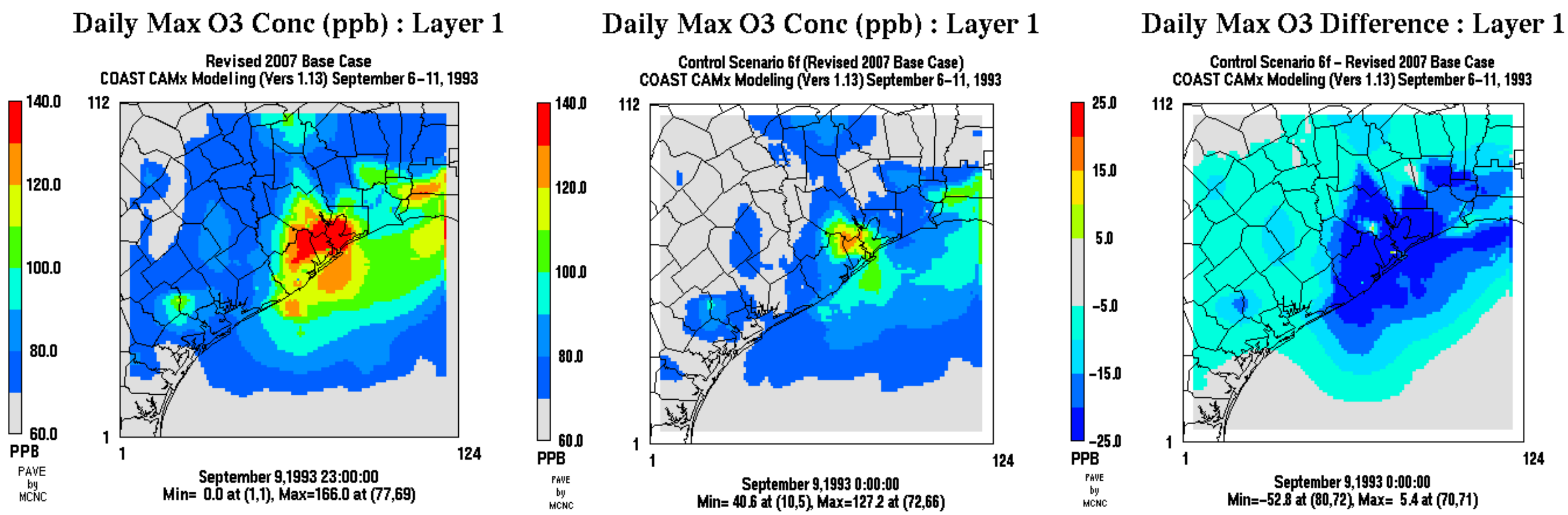

Figure 5 Comparison of Scenario VIf predicted ozone concentrations with 2007 future base