Clean Air Act Implementation in Houston: An Historical Perspective 1970-2005

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Preface

The following report is a background paper written for the February 24th, 2005 Shell Center for Sustainability forum "Lessons Learned: Meeting the Houston Ozone Standards, 1970-2004." This forum will attempt to answer four key questions:

- What was the intent of the Clean Air Act and its subsequent regulations related to ozone control?
- What were the key economic, scientific, social, political and regulatory challenges to the implementation of the Clean Air Act ozone requirements?
- What were the lessons learned which either impeded or supported the implementation of the ozone requirements?
- What improvements can be made to improve the SIP process?

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The report was developed from May 2004 to February 2005 as a research project under the supervision of the Shell Center for Sustainability. The report was co-authored by Rice University graduates Clayton Forswall ('04) and Kathryn Higgins ('03), with assistance from Abigail Watrous (Rice '04), Will Conrad (Rice '05), and Sarah Mason (Rice '06), a current Professional Master's student at the Wiess School of Natural Sciences.

This report does not represent new academic research, but serves to provide a summary of existing information on the history of ozone control in the Houston-Galveston Area. Our charge was not to offer conclusions or recommendations, but to supply a thorough historical background to panel members and forum attendees so that they may offer their own conclusions and recommendations.

The report was compiled from an array of sources, including over 40 interviews with key stakeholders and experts from the industry, government, non-profit, health and academic sectors. A list of the interviewees and reviewers, as well as their title and affiliation, can be found in Appendix A. The report has also developed a Houston-Galveston Area Ozone Control timeline. We feel this timeline is important to understanding the chronology and interactions of different aspects of Houston ozone control. The timeline can be found in Appendix D.

Previous drafts of this report were shared with all listed interviewees.

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Glossary

APCA	Air Pollution Control Act
AQCR	Air Quality Control Regions
AQM	Air Quality Management
ASE	Accelerated Science Evaluation
BCCA	Business Coalition for Clean Air
BCCA-AG	Business Coalition for Clean Air – Appeals Group
CAA	Clean Air Act
CAMx	Comprehensive Air Model with Extensions
CAPCA	California Air Pollution Control Act
CARB	California Air Review Board
COAST	Coastal Oxidant Assessment for Southeast Texas
DOH	Department of Health
EI	Emissions Inventory
EKMA	Empirical Kinetic Modeling Approach
EPA	U.S. Environmental Protection Agency
EQC	Environmental Quality Council
FCAA	Federal Clean Air Act
HAOS	Houston Area Oxidant Study
HEW	Department of Health, Education and Welfare
HGA	Houston-Galveston Area
H-GAC	Houston-Galveston Area Council
HRVOCs	Highly Reactive Volatile Organic Compounds
I/M	Inspection and Maintenance
LDAR	Leak Detection and Repair
MCR	Mid-Course Correction
NAAQS	National Ambient Air Quality Standards
NAPCA	National Air Pollution Control Administration
NEPA	National Environmental Policy Act
NO_x	Nitrous Oxides
O_3	Ozone
OTAG	Ozone Transport Assessment Group
ppb	Parts per Billion
ppm	Parts per Million
PM	Particulate Matter
RACT	Reasonably Available Control Technology
RAQPC	Regional Air Quality Planning Committee
ROP	Rate of Progress
SIP	State Implementation Plan
SOS	Southern Oxidant Study
TAC	Texas Administrative Code
TACB	Texas Air Control Board
TCAA	Texas Clean Air Act
TCEQ	Texas Commission Environmental Quality
TERP	Texas Emissions Reduction Plan

TexAQS	Texas Air Quality Study
THOES	Transient High Ozone Events
TMC	Texas Motorist's Choice
TNRCC	Texas National Resource Conservation Commission
UAM	Urban Airshed Model
VOC	Volatile Organic Compounds
WOE	Weight of Evidence

Introduction

Many aspects of Houston contribute to its struggle with air pollution. The city's close proximity to a bay and subsequently a port with a channel that reaches into the heart of the city has allowed for unrestricted growth and expansion. The discovery and procurement of nearby natural oil and gas reserves contributed heavily to this growth and with the world scale port allowed a dense concentration of oil refineries and petrochemical facilities to develop in conjunction with the city. The emissions from a metropolis of this size are combined with those of world-scale industrial facilities to create a unique combination of air chemistry. This combination is overlaid with the environmental factors of a warm sunny climate compared to the rest of the US and a meteorological system that incorporates circular wind patterns to create a situation conducive to ozone formation and one of the worst and most complex air pollution problems in the United States.

Ground level ozone is formed during atmospheric reactions of volatile organic compounds (VOCs) and nitrogen oxides (NO_x) in the presence of sunlight. Though power plants and on-road vehicles typical of large cities have high concentrations of NO_x emissions, and biogenic sources and petrochemical plants have high concentrations of VOC emissions, both chemicals are often co-emitted from the same sources. These chemicals are related to other air pollutants in addition to ozone. NO_x includes nitrogen dioxide, itself associated with respiratory problems and included as one of the six criteria pollutants regulated under the Federal Clean Air Act. NO_x is also a precursor of fine particulate matter, another criteria pollutant that has been associated with increasing health concerns. Many VOCs are classified as toxic substances, including benzene and

1,3-butadiene, and pose significant health risks to neighborhoods surrounding facilities emitting these compounds. Therefore, a key aspect of ozone regulation is that it benefits the reduction of other harmful pollutants.

Ozone regulation in Houston has been a multi-faceted process, marked with controversy and complexity. The following paper discusses the history of this process and attempts to provide a solid background for where Houston stands today.

1955-1990 – The Advent of Air Pollution Control in the United States

Recognition of the need for pollution control measures began approximately fifty years ago in the United States. News reports of health effects pushed air pollution into the spotlight both nationally and locally, bringing about social and political change through policy and legislation.

Although many regard the Federal Clean Air Act of 1970 (FCAA) as the beginning of air pollution control in the United States, the national quest for clean air began long before. This section will review many of the events – from environmental crises to legislation to public opinion changes – that had an effect on air pollution in the United States. It will also relate the changes that took place specifically in Texas and Houston during that time.

Early Legislation: 1947-1968

The Air Pollution Problem is Recognized

California was the first state to implement a statewide pollution control act. Governor Earl Warren signed the California Air Pollution Control Act (CAPCA) into law on June 10, 1947. This law authorized the creation of Air Pollution Control districts out of every county, with Los Angeles county, one of the most polluted areas in the nation, being the largest. Also key to this event was the fact that Eisenhower would later appoint Warren Chief Justice of the Supreme Court in 1953, thus changing the judicial view of air pollution.[1]

In the eight years following the California APCA, several air pollution disasters brought world attention to the problem. In the fall of 1948 the industrial valley community of Donora, Pennsylvania was hit by a temperature inversion that trapped a heavy acrid smog of smoke and particulate matter from local zinc works and steel mills.

When the smog passed five days later, over 20 people were dead and over 6,000 were ill.[2,3,4]

Four years later, a similar air inversion settled over London. In the cold December weather, the city stayed inside and warmed itself with coal-fed fires while industry continued to emit pollution into the air. Unable to rise through the inversion, the coal smoke and pollution settled at ground level, reducing visibility to almost zero. This was the "Great Killer Fog of 1952," and after four days of blackness, almost 3,000 people were dead and thousands more were sick. Epidemiological studies would later show that the mortality and morbidity rates would not return to normal until six months later. All in all, about 13,000 more deaths took place in that six-month period than would have under normal circumstances.[5] This and other British smog problems brought about Great Britain's first Clean Air Act in 1956.[6]

As public concern and outcry increased, many state and local governments began to pass their own air pollution control laws. Citing the increased need for federal intervention, the first federal law dealing with air pollution in the united States was passed on July 14, 1955. The Air Pollution Control Act of 1955 (APCA) was the grandfather to all future clean air legislation, as all other acts, including the most famous, FCAA of 1970, would all be but amendments to the 1955 Act. However, the law was far from solving the air pollution problem. The goal of the original act was "to provide research and technical assistance relating to air pollution control."[7] It provided the Public Health Service and the Department of Health, Education, and Welfare (HEW) $5 million annually for five years to perform research on air pollution. Although the APCA had no legal enforcement authority (thus little progress was made to actually clean the air), it did recognize air pollution as a national problem and gave Congress the power to make future laws dealing with the control of air pollution.

Just a few months later, Los Angeles's struggle for clean air would come to a head. Although it was written off at the time as just a series of smoggy days, epidemiological studies in 1959 would show an extra 1,200 deaths in Los Angeles over a ten-day period in August of 1955. Meteorological records show an air inversion during this period that would have trapped pollution in the valley.[8,9]

The APCA was amended in 1960, extending research funding for four more years, and again in 1962 to enforce the principal stipulations of the 1955 Act and to call on the U.S. Surgeon General to research the health effects of vehicle exhaust. That same year, marine biologist and environmentalist Rachel Carson published Silent Spring. The book examined the effects of DDT and other synthetic substances on man and nature. The best-selling book heightened public awareness of toxic chemicals and, it is argued by some, set off the environmental movement of the 1960s and 1970s.[10]

The First National Efforts

In 1963 the Senate Subcommittee on Air and Water Pollution was established. After examining comments from numerous public hearings and research programs, the committee became inundated with public concern over the health risks of polluted air. "Our legislative initiatives evolved slowly but picked up momentum as the Subcommittee developed confidence in its understanding of what was required," said Senator Edmond Muskie (D-Maine), a member of the Subcommittee.[11] (Muskie would later champion the FCAA of 1970. In 1990, Senate Majority Leader George Mitchell (D-Maine) described Muskie as "the greatest environmental legislator in congressional history."[12])

The Clean Air Act of 1963 was passed as "an Act to improve, strengthen, and accelerate programs for the prevention and abatement of air pollution."[13] The law contributed $95 million over a three-year period to state and local governments and air pollution control agencies and programs. It also ordered the development of "air quality criteria" that would set safe pollutant levels and encouraged states to work together with HEW to address interstate air pollution problems, especially in relation to high-sulfur coal and oil-use pollution. In addition, the Act recognized the problem of motor vehicle exhaust and encouraged development of emissions standards, as well as standards for stationary sources.[14] In amendments to the Act in 1965, the Secretary of HEW was directed to develop emissions standards for new automobiles and their engines. The 1965 amendments also recognized the problem of transborder air pollution and encouraged research on the movement and effects of pollution to and from Mexico and Canada.

During this time, the environmental movement began to catch the attention of the national media. The number of articles on environmental topics in the New York Times doubled from 1964 to 1965.[15] Public opinion polls conducted by the Opinion Research Corporation showed the percentage of Americans who thought air pollution was a serious problem also almost doubled from 28% in 1965 to 55% in 1968.[16]

Texas Takes on Air Pollution

On a local level, air pollution control began in Texas at the end of 1953 when the Harris County Commissioners Court established a "Stream and Air Pollution Control Section" as part of the Health Department. This would later become Harris County Pollution Control in 1971.[17]

The Houston Chamber of Commerce (which later became the Greater Houston Partnership) commissioned a scientific study of air pollution in the Houston area from the Southwest Research Institute titled "Air Pollution Survey of the Houston Area." The study was conducted over a two-year period between 1956 and 1958. Dr. Herbert McKee, then Manager of Air Pollution Research at SRI, commented, "During this two year study, no atmospheric ozone levels above natural background were measured, with no readings exceeding 50-60 ppb. Within the limits of measurement capability at that time, this indicated that no Los Angeles-type oxidant or ozone occurrences existed in the Houston area."[18] The report, however, was concerned with sulfur compounds, "the most common pollutants of industrial origin," especially sulfur dioxide and hydrogen sulfide.[19] A follow-up study was conducted in 1964-66, to identify changes that might have occurred with the intervening rapid growth of the city and industrial activity. Dr. McKee recalls, "During this period, a few elevated ozone levels, as high as 120-140 ppb, were measured indicating that photochemical smog was becoming a reality."[20]

At a state level, Texas signed its first clean air legislation– the Texas Clean Air Act (TCAA) – in 1965. The TCAA established the Texas Air Control Board (TACB) under the Texas Department of Health (DOH). The TACB "was charged with safeguarding air resources of the state by controlling or abating air pollution, taking into consideration health and welfare and the effect on existing industries and economic development of the state. It was also to establish and control the quality of air resources and provide enforcement by civil action through injunction and/or fines."[21] It was composed of nine members, five from specialized fields and four from the general public, who were appointed by the governor with the concurrence of the state Senate for six-year terms.[22] Dr. Herbert McKee was elected chairman by the other board members, while the State Health Commissioner selected the Executive Director with the concurrence of the TACB Chairman. The first Executive Director was Charles Barden, a longtime staff member of the State Health Department with extensive public health experience, especially in environment-related activities.[23] After its members were appointed in 1966, the Board began to place staff, which was supplied by the Department of Health. By 1967, the TACB adopted its first air regulations. Although general laws against public nuisances such as open-air burning had been on record in Texas for many years, these guidelines were a first step at regulating emissions in the interest of public health. One regulation set a standard for particulate matter (PM) and another regulation limited emissions of sulfur, particularly sulfur dioxide and hydrogen sulfide.[24] Pam Giblin, the chief counsel for the TACB from 1970-1976, affirmed Texas's foresight in its regulations. "Many states didn't put in any air laws until after the 1970 Federal Clean Air Act," she said. "Even the federal government did not put in a regulation on hydrogen sulfide until the 1990 FCAA Amendments." In fact, until 1971, the Texas ambient air standards for particulate matter and sulfur oxides were more rigorous than the federal standards.[25]

On a local level, environmental issues in the Houston-Galveston Area (HGA) were to be addressed by a new organization formed in September 1966 by the local elected officials from the eight county region. This group, the Houston-Galveston Area Council (H-GAC), began a long history of "devoting itself almost entirely to solving problems in physical development and the environment."[26]

Federal Clean Air Act Amended

In 1966, the FCAA was again amended, this time expanding local air pollution control programs. Following New York City's "Great Smog Disaster of 1966," which killed 120 people over five days, the public demand for air quality laws grew stronger.[27] Amendments were made again the next year with the Air Quality Act of the 1967. "By 1967, there was broad agreement that current local and state efforts were inadequate," said Senator Muskie, "federal action was required."[28] Muskie oversaw the drafting of the Act and it quickly passed in the Senate 88 to 0. These changes and additions were seen as revolutionary as they created the National Air Pollution Control Administration (NAPCA) under HEW and designated Air Quality Control Regions (AQCR) across the United States as a means of monitoring ambient air. Although controversial, national emissions standards for stationary sources were also established, as well as air quality criteria. The Act also instituted federal preemption to establish automobile emission standards (with the exception of the state of California, which already had its own strict emission standards in place). [29] This was the "first comprehensive federal air pollution control," said Muskie.[30] "The states were given primary responsibility for adopting and enforcing pollution control standards," said Representative Paul Rogers (D-Florida).[31] NAPCA was directed to provide technical information to the states, which each state used to adapt ambient air quality standards to serve as goals for regulatory programs. NAPCA then had veto power over the standards set by the states.[32]

"The approach was a notable failure," said Rogers.[33] By 1970 fewer than 36 air quality regions had been designated, although the predicted number was well over 100. Also, no state had developed a full pollution control program. Dr. McKee explained the difficulties in implementing such a broad statutory mandate. "With no precedents to guide the Board, and almost no staff until they could be hired and trained, it seemed at times that the combination of scientific, engineering, legal, and political considerations was overwhelming. It took six months to a year of patience and hard work before everyone involved could see a reasonably clear pattern of what was needed and how it might be achieved."

In 1969, the Act was amended yet again, this time authorizing and expanding research on low emissions fuels and automobiles. Although it was a minor victory for the environmental cause, the amendment was just the beginning of a whirlwind of green legislation that would blow through the federal government over the next two years.

<u>The Green Years: 1969 – 1978</u>

1969 and 1970: The Benchmark Years

A few months after his inauguration in January of 1969, President Nixon established the Environmental Quality Council (EQC) and the Citizens Advisory Committee on Environmental Quality in his cabinet. (This Council would later be recognized as the forerunner of the EPA.)[34] Over the next 8 months, Congress wrestled with the National Environmental Policy Act (NEPA) before passing it. President Nixon signed the Act into law on January 1, 1970. In addition to requiring the federal government to analyze and report on the environmental implications of its activities through environmental impact statements, NEPA also directed the President to establish a Council on Environmental Quality (not to be confused with the EQC mentioned above). President Nixon named Undersecretary of the Interior Russell Train its first chairman. (Train would later serve as the second EPA administrator under President Ford).[35] The

Council, comprised of three members and a full staff, was to assist President Nixon by preparing an annual Environmental Quality report for Congress, gathering data, and advising on policy.[36] Also in January of 1970, President Nixon made very clear to the nation his environmental commitments by saying "[the 1970s] absolutely must be the years when America pays its debt to the past by reclaiming the purity of its air, its waters, and our living environment. It is literally now or never."[37] President Nixon followed this stirring call with an unparalleled 37-point speech to Congress in February on the environment in which he requested $4 billion for multiple pollution control and clean-up programs.[38] Later that summer President Nixon announced his reorganization plan to form the EPA out of three federal departments, three bureaus, three administrations, two councils, one commission, one service, and multiple offices. Throughout the summer, hearings were held in Congress to analyze the reorganization plan. At the end of September 1970, both the House and Senate subcommittees approved the plan and the EPA opened its doors on December 2, 1970 with William D. Ruckelshaus as the first head administrator, 5,600 employees, and a $1.4 billion budget.

Following the signing of NEPA and the establishment of the EPA, 1970 became "the benchmark year" for air pollution control.[39] The Senate Subcommittee on Air and Water Pollution sprang back into action. Leon Billings, Senator Muskie's Chief of Staff and a staff member of the Senate Environment and Public Works Committee, drafted a concise 32-page document, which became known as the Muskie Bill. The law was robust and stringent and Congress soon found itself caught in the middle of a raging public debate. During the hearings on April 22, 1970, 20 million Americans and millions of others in Europe took part in the first Earth Day celebration.[40] Later that summer, Washington, D.C. "suffered one of the worst and longest air pollution episodes in its history."[41] The states' "unsatisfactory record" of action, especially in the air quality control regions, "coupled with the public pressures created by the Earth Day movement, provided the necessary impetus to convince Congress that national air quality standards were the only practical way to rectify the United States' air pollution problems," said Rogers. The 1970 law would "impose statutory deadlines for compliance…in the hope that those deadlines would spur action. Thus, the two key provisions in the 1970 FCAA were not a frenzied reaction to public pressure, but instead were a deliberate response aimed at correcting the demonstrated failures of previous regulatory efforts."[42]

"Three fundamental principles shaped the 1970 law," Senator Muskie recalled in 1990. "I was convinced that strict federal regulation would require a legally defensible premise. Protection of public health seemed the strongest and most appropriate such premise." Other Senators added to the key principles. "Senator Howard Baker (R-Tennessee) believed that the American technological genius should be brought to bear on the air pollution problem, and that industry should be required to apply the best technology available. Senator Thomas Eagleton (D-Missouri) asserted that the American people deserved to know when they could expect their health to be protected, and that deadlines were the only means of providing minimal assurance. Those three concepts evolved into a proposed Clean Air Act that set deadlines, required the use of best available technology, and established health-related air quality levels."[43]

Also included in the FCAA was the provision for citizen enforcement through legal action. "The Clean Air Act was the first federal environmental statute to include provisions for citizen enforcement," said Senator Muskie.[44] If deadlines and standards were not met, the law gave the public the right to sue and removed legal hurdles that had once made it all but impossible to seek compensation for environmental injury, especially in federal courts. In his book, A Fierce Green Fire, Philip Shabecoff points out that this was "inspired in part by the Supreme Court under Chief Justice Earl Warren, which demonstrated that the judicial system could be a powerful instrument for social change."[45] "This was the most far-reaching piece of social legislation in American history," said Senator Muskie in 1990.

The FCCA passed through both houses of Congress in late 1970 and was signed into law by President Nixon on December 31st. It is argued that public pressure on Congress, as well as the approaching election year helped push the bill into law. President Nixon, facing reelection in 1972, was almost positive he would face Senator Muskie in the next presidential race and some say a series of "political one-up-man-ship" helped create some of the most monumental and controversially stringent laws in environmental history.[46, 47]

Strategies of Air Pollution Control Put to Practice: NAAQS and Emissions Standards

At the time the FCAA was written, several air pollution strategies were available as "master plans" to clean the air. In Air Pollution, Nevers, et. al. list air quality management, emissions standards, emission taxes, and cost-benefit approaches as the four main strategies that could be used independently or together to control pollution. The strategies and their descriptions are listed in the table below.

Table 1: Comparison of Air Pollution Strategies[48]

Air Pollution Strategy	Description
Air Quality Management	Specifies a set of ambient air quality standards; the quality of air is managed to meet these standards; management takes place through

	regulation of the amount, location, and time of pollutant emissions.
Emissions Standards	Establishes permitted emission levels for specific groups of emitters and requires that all members of these groups emit no more than these permitted emission levels; can be based on some air quality standards (above) or be entirely independent (called "best practicable means approach").
Emission Taxes	Taxes each emitter of major pollutants according to some published scale related to its emission rate; tax rate set so most major polluters find it economical to install pollution control equipment rather than pay taxes; no sanctions for those who pay taxes and don't control emissions.
Cost-Benefit	Attempts to quantify damages from various pollutants and cost of controlling those pollutants; then selects those pollution-control alternatives which lead to minimum sum of pollution damage and pollution control costs; leads to more stringent air quality requirements for urban air than for rural air because of population differences.

The FCAA of 1970 was based mainly on the Air Quality Management (AQM) approach, but also incorporated the Emissions Standards approach. The AQM approach is clearly illustrated in the National Ambient Air Quality Standards (NAAQS). Under section 109 of the FCAA, the EPA was required to publish NAAQS for specific pollutants within 120 days of the signing of the law. The "criteria pollutants" to be regulated included carbon monoxide, nitrogen oxides, sulfur oxides, photochemical oxidants, hydrocarbons, and particulate matter – almost identical to the same six criteria pollutants still regulated today; lead was added in 1978 and hydrocarbons, also known as Volatile Organic Compounds (VOCs), were deleted from the list 1983.[49] Ozone, a photochemical oxidant, was regulated under that superset until 1979 when instruments became available to measure ozone independently and the category was changed to simply "ozone." Toxic pollutants were also addressed in limits established by the EPA through section 112 of the FCAA.[50]

Standards were set for each of the criteria pollutants based upon a collection of the most current research and information, known as "criteria documents." An adequate margin of safety was added to protect against unknown hazards that had not yet been identified by the current science.[51] Initially, these standards were not based upon the cost it would take to realize them, but rather focused only on protecting public health.

The NAAQS were then to be handed down to the states, as were specific deadlines for states to develop plans that met these standards. These plans, state implementation plans (SIPs), contained emission control strategies designed by the state to bring existing non-attaining areas into compliance with the NAAQS. The SIPs were due to the EPA by 1972; in turn, the EPA would then approve or disapprove the SIP. If the EPA found the SIP inadequate, the EPA was required by the FCAA to replace it with a federal plan.[52] The FCAA set an initial deadline of 1975 for all areas in the United States to be in attainment of the NAAQS.

The Emissions Standards approach was also initially used by the FCAA to get more immediate results. The use of this strategy was one of the most controversial parts of the Act, as it called for a 90% reduction in auto emissions by 1975 (although there was a one-year extension provision included). "The business community was outraged," said Senator Muskie. This part of the FCAA was placed to "force" better technologies. "There was no assurance that appropriate control devices could be designed and placed in cars within five years," Senator Muskie recalled in 1990. "Strict standards and deadlines were expected to force the development of an appropriate control technology."[53] In recounting how the percentage for the reduction was chosen, EPA staff recalled Billings called the agency in 1970 and asked them to evaluate the risk of emissions on public health. "Look," said Billings, "we can pass a bill requiring a 90% reduction in air pollution from cars over 1970 levels if you can tell us it's bad for public health." Taking the lead from a paper published earlier that year by a researcher with the NAPCA that found a reduction of 90% in air pollution would be of great benefit to public health, the EPA backed the percentage and it was written into the law.[54] "Our knowledge as to its [the Clean Air Act] health effects was incomplete. It was impossible to identify a threshold below which health effects could be regarded as inconsequential," said Senator Muskie. "But we were convinced that progress toward a maximum reduction of adverse health effects must be the critical test of the Act's effectiveness. It was an 'experimental law'."[55]

"It was a carrot for technical development," said Giblin, who is currently an environmental attorney with Baker Botts LLP and has represented many industry clients. "The genius of it is that we will always be striving for it and getting better. The pursuit of the standard was the point."[56] The use of a combination of AQM and Emissions Standards approaches in the FCAA led to one of the most disputed topics in air pollution control. "The idea that this system was manageable by man is incredible," said Dr. Harvey Jeffries, a professor of environmental science at the University of North Carolina at Chapel Hill, specializing in atmospheric chemistry and atmospheric computer models.

Texas Reacts to the Federal Clean Air Act

Dr. Herb McKee recalls, "Many people involved in the process were glad to see the 1970 Clean Air Act which eliminated the overlapping responsibilities of the national agency and the various states by requiring EPA to set NAAQS to apply nationwide and then requiring states to prepare SIPs to achieve those standards."[57] New amendments to the TCAA established the state's first air permit program, which authorized the TACB to issue air quality permits. Included in these laws was a grandfather clause that excluded sources constructed before 1971; only new or modified sources were required to obtain a permit.[58, 59]

The following year, the TACB submitted its first SIP, which included provisions for bringing Houston into compliance with ozone standards. Giblin remembers the Texas Air Control Board's exceptional operation and performance compared to other states in the nation. "Texas had a fairly sophisticated SIP with its own rules and regulations." Giblin also found other states looked to Texas for help with their clean air initiatives. "During the 70's I traveled to around 40 different states," she recalled.[60]

By 1972, Texas had set up its first air monitoring station. The following year, the Texas legislature removed the TACB from the Department of Health and made it an independent state agency. The agency was authorized 366 staff positions. On November 6, 1973, the EPA rejected the Texas SIP on the grounds that it would not meet the ozone standard in Harris County.[61, 62] The EPA then promulgated its own plan to get Houston into attainment, integrating additional hydrocarbon control measures, such as gasoline rationing, federal restrictions on construction of parking facilities, and other transportation control measures, along with the proposed Texas plan.[63, 64] The following year, in 1974, the State of Texas and 24 other governmental and industrial parties, including Harris County, filed suit against the EPA to challenge its rejection of the Texas SIP and the plan it had put in its place.[65] On August 7, 1974 the Court of Appeals for the Fifth Circuit decided that the EPA's rejection of the Texas SIP was right; however, the court also found the EPA's new plan and harsher regulations were unfounded and/or had to be delayed for further consideration by the EPA.[66] After the lawsuit, the TACB submitted the second Houston SIP to the EPA in 1974 (which became irrelevant after the

1977 amendments were passed). That same year, the TACB completed its first continuous air-monitoring network.[67]

In 1975 catalytic converters were developed and began to be installed on auto emission sources. The converters could cut hydrocarbons and carbon monoxide emissions by up to 96% and nitrogen oxides by 75%. Because the lead in gasoline at this time would foul the catalysts in the converters, unleaded gasoline was also introduced that year and slowly replaced leaded gasoline as pre-1975 vehicles were phased out.[68]

In October 1976 the Houston Chamber of Commerce established the Houston Area Oxidant Study (HAOS) in response to federal standards they felt were unattainable. They also felt the proposed federal strategies they felt were too stringent (for example, earlier that year the EPA had proposed that Houston reduce vehicle miles traveled by 75%[69]). By investing $6 million dollars in the HAOS, the city's major industries and financial establishments hoped to "fully investigate the sources of ozone in Houston."[70] Discussing the goals of the HAOS, Larry Feldcamp, a member of the Houston Chamber of Commerce's Environment Committee and chair of the study, said, "At the time the linear rollback method was used to determine the amount of reduction needed. The science supporting this simplistic method was inadequate and our goal was to investigate the extent, causes, effects and abatement of ozone in the Houston area."[71] The bulk of the data for the study were collected during the summer of 1977 and was therefore not available during the hearings for the 1977 FCAA amendments; however, the major conclusions of the HAOS were released in 1978 and 1979. The main conclusions were:

- "During the HAOS intensive monitoring period (June through October 1977) ozone levels were below the NAAQS over 98% of the time. Ozone levels were below 0.06 ppm 90% of the time."

- "Reducing emissions of hydrocarbons alone may not significantly reduce ambient ozone concentrations in the Houston area. Ozone concentrations were more strongly associated with nitrogen oxide than hydrocarbon concentrations."
- "Ozone formed outside of the Houston area (from the Gulf of Mexico, forested areas, and the stratosphere) contributes heavily to ozone levels in metropolitan Houston."
- "Proposed air quality control strategies would seriously reduce projected growth and employment in Houston's chemical, machinery manufacturing, and primary metals industries. By 1995 under worst case conditions total regional employment would be 81,000 jobs less than projected and total regional economic output would be $5-7 billion dollars less, a 5-7% reduction."[72]

According to the 1981 Houston Case Study by the National Commission on Air Quality, the City of Houston, as well as the TACB, agreed with these conclusions.[73] In 1980, the EPA responded with "A Critical Review of the Houston Area Oxidant Study Reports," which cited several problems with some of the HAOS conclusions and methodology. Specifically, EPA concluded that the assumptions made in regard to achieved emissions reductions were unfounded, outside contributions to Houston's ozone were not large, and the health effects conclusions were unjustified.[74] Many interviewees, including Jim Blackburn, an environmental attorney who has represented many citizens' groups, believed the HAOS's research was politically motivated. "The HAOS demonstrated the ability to use scientific information for a political agenda. It was a missed opportunity to investigate the science; instead, a lot of money and effort was directed at showing that ozone was not a problem."[75]

Amendments to the Federal Clean Air Act: 1977

In the 1981 Houston Case Study, the National Commission on Air Quality cites the main objections of the TACB, the City of Houston, and industry to the Federal ozone standard and control strategy to be the following during this period:

- "There is no proven link between the current standards and any health effects upon individuals."
- "Even if a connection exists, the hydrocarbon reductions policy of the EPA is the wrong approach to lowering ozone levels."
- "The current standard is unattainable in Houston under any circumstances, short of actions which would completely disrupt the economic activity of the region (and there is some doubt as to whether even under those circumstances the standard is attainable.)"[76]

Also according to the National Commission on Air Quality, the "independent, questioning stance [of the TACB] toward Federal air quality programs," as well as the friction over the first and second Texas SIPs, led the state to pursue changes in the FCAA. The first key endeavor in this regard was a document called "The Texas Five Point Plan," a proposal prepared by the TACB in May 1975. The plan consisted of five major revisions to the FCAA, allowing more flexibility for the states' requirements for transportation control measures and land-use planning. There are different views on the TACB's intentions with this plan. "Texas was very interested in working on the changes that would later become the FCAA amendments of 1977. We were taking a very active role in trying to share what we had learned and trying to get the FCAA to focus on certain things like monitoring," said Pam Giblin. Brandt Mannchen, current Chair of the Houston Air Quality Committee of the Houston Sierra Club and longtime environmentalist, believes the plan was reflective of the conflict-oriented relationship between the TACB and the EPA. "The five points in the plan were general recommendations playing down the EPA's concept of transportation management without offering viable alternatives."[77]

In the seven years after the FCAA of 1970, special interests groups also had time to mobilize and prepare arguments against the new amendments. "The entire focus was on weakening and limiting the application of policies previously adopted," said Senator Muskie in 1990. Although groundbreaking technology in auto emissions had been developed in the previous years, "the automotive industry waged an all-out battle against the statutory standards," said Senator Muskie. After a session ending filibuster in the Senate pushed the matter into the next year, the automotive industry gained yet another foothold with the four year delay to comply with statutory auto emission standards. "Fortunately, most of the special interests' political capital was exhausted in the fight for the auto industry amendment, and we were able to avoid a number of other special industry efforts," said Senator Muskie.[78]

Since many of the deadlines set by the 1970 FCAA had passed without success, the 1977 amendments included "non-attainment" laws. All areas not in compliance with the NAAQS in 1977 were given an extension of five years to meet the standards; this included parts of Texas. In addition, stronger guidelines for construction of new emission sources in non-attainment areas were also passed in the amendments, as well as a "clean growth" policy to protect areas that were already in attainment and prevent the creation of new non-attainment areas.

Focusing on Houston's Ozone: 1979-1989

Up to this point, this paper has given a broad and overarching view of air pollution legislation and policy; however, the purpose of this paper is to focus on the history of Houston's struggle with ozone. Although there were many other SIP revisions and attainment/control programs going on all over Texas during this time period, this paper will now concentrate solely on the revisions that affected Harris County and the HGA in relation to ozone. It is important to remember the TACB was heading up multiple projects in other cities throughout Texas while concurrently managing the Houston ozone issue.

In 1979 the TACB submitted revisions to the Texas SIP as required by the 1977 FCAA Amendments. The SIP outlined control strategies for areas in Texas that exceeded the NAAQS in ozone, particulate matter, and carbon monoxide between 1975 and 1977 (there were no areas that exceeded nitrogen oxides or sulfur oxides limits). Although the EPA had relaxed the permissible one-hour standard for ozone from 0.08 to 0.12 PPM in 1979, Harris County was still not in compliance, as it exceeded NAAQS in ozone; thus it was also included in the SIP.[79] The 1979 SIP revision also asks for a deadline extension from 1982 to 1987 for Harris County to meet EPA ozone standards (as provided in the FCAA Amendments of 1977). All other areas in Texas were to be in attainment by December 31, 1982. The proposals to revise the Texas SIP were submitted to EPA on April 13, November 2, and November 21, 1979. The EPA approved the proposed revisions in the Texas SIP related to vehicle inspection and maintenance (I/M) on December 18,1979. It also extended the attainment deadline for Harris County until December 31, 1987. Over the next four years, Texas gradually submitted most of the necessary SIP revisions and they were approved. "The FCAA Amendments of 1977 required SIPs to be revised by December 31, 1982 to provide additional emission reductions for those areas for which EPA approved extensions of the deadline for attainment of the NAAQS for ozone or carbon monoxide. The only area in Texas receiving an extension of the attainment deadline to December 31, 1987 was Harris County for ozone. Proposals to revise the Texas SIP for Harris County were submitted to EPA on December 9, 1982. On February 3, 1983, EPA proposed to approve all portions of the plan except for the Vehicle Parameter (I/M) Program. On April 30, 1983, the EPA Administrator proposed sanctions for failure to submit or implement an approvable I/M program in Harris County. Senate Bill 1205 was passed on May 25, 1983 by the Texas Legislature to provide the Texas Department of Public Safety (DPS) with the authority to implement enhanced vehicle inspection requirements and enforcement procedures. On August 3, 1984, EPA proposed approval of the Texas SIP pending receipt of revisions incorporating these enhanced inspection procedures and measures ensuring enforceability of the program. These additional proposed SIP revisions were adopted by the state on November 9, 1984. Final approval by the EPA was published on June 26, 1985."[80]

In 1982, the TACB restructured its air monitoring network and relocated continuous air monitoring stations. In 1985, the TCAA was heavily amended, authorizing the TACB to charge administrative penalties for violations of state and national air quality regulations. The amendments also require the TACB to review operating permits every 15 years.[81]

1990-2000 – Extensive SIP revisions

After major changes to the Clean Air Act in 1990, the HGA SIP underwent multiple revisions and experimented with several control strategies. These major regulatory changes are discussed in this section.

The Clean Air Act Amendments of 1990 reorganized the air regulation across the country. The last deadline had passed in 1987 and George H. Bush had made promises during his 1988 presidential campaign to revamp the program. In 1990 the amendments he signed reset the SIP process with new ozone attainment deadlines based on severity and a rate-of-progress plan that assured immediate and continuous improvements. Specifically the amendments authorized the EPA to designate areas failing to meet the NAAQS for ozone as non-attainment and to classify them according to severity. These classifications were marginal, moderate, serious, severe and extreme. The 1990 amendments also required:

1) A SIP revision by November 15th, 1993 that showed how any area with a moderate or worse rating intended to reduce VOC emissions by 15% net of growth by November 15th, 1996;
2) A SIP revision by November 15th, 1994 that described how each area would achieve further reduction of VOC and/or NO_x in the amount of 3% per year (averaged over three years) that included UAM modeling demonstrating attainment.[82]

In addition to those requirements, the states also had to develop contingency rules that would result in an additional 3% reduction of either NO_x or VOC emissions. The amendments allowed for the substitution of NO_x controls in recognition that "NO_x controls may effectively reduce ozone in many areas and that the design of strategies is more efficient when the characteristic properties responsible for ozone formation and control are evaluated for each area."[83] Texas would adhere to a VOC-only policy until the late 1990s due to evidence in the early '90s that NO_x reductions were not beneficial to attainment, though the national policy accepted both. According to the new classification, the HGA, with a one-hour design value of .22 ppm, was designated as a Severe-17 nonattainment area for ozone and was given 17 years to reach attainment in 2007.[84]

Advent of the TNRCC and Regional Air Quality Planning Committee: 1991-1993

In November 1990, Ann Richards was elected the 45th governor of Texas. During a special session in the summer of 1991, the 72nd Texas legislature passed Senate Bill 2 that authorized the consolidation of multiple state agencies and boards dealing with the environment and health. Over the next two years, the TACB, the Texas Water Commission, and parts of the Texas Department of Health were to become the Texas Natural Resource Conservation Commission (TNRCC), "one of the most comprehensive state environmental programs in the nation."[85] The TNRCC was to be responsible for air, waste, and water management in Texas and would be overseen by three commissioners appointed by the Governor, as opposed to the previous set-up of an appointed nine-member board. The bill was signed into law on August 12, 1991 and preparations began for transfer of functions two years later on September 1, 1993 when the TACB would become the Office of Air Quality in the TNRCC.[86]

On a local level, the HGA also became more organized. In 1991, the Regional Air Quality Planning Committee (RAQPC) was created by the H-GAC to advise the H-GAC board of directors and Transportation Policy Council on issues relating to air quality. The RAQPC is composed of 26 representatives of local government, environmental, public health, citizen groups, business, and industry stakeholders from all eight counties of the nonattainment area, making it one of the first local multi-stakeholder groups.[87]

Rate-of-Progress SIPs: 1993-1995

Texas submitted the required ROP reductions in two phases. Phase I accounted for most of the 15% reductions needed by 1996 in a SIP proposed on November 10th, 1993. Phase II accounted for the remaining percentage and the 3% contingency measures proposed on May 13th, 1994. Following these two SIPs outlining the strategies to achieve 15% reductions, the Post-1996 Rate-of-Progress SIP revision on November 9, 1994 outlined the increased controls to achieve the 9% reductions required over the three years of 1997, 1998 and 1999.[88] A revision on January 11th, 1995 revised the 9% ROP strategies and included urban airshed model (UAM) modeling for 1988 and 1990 base case episodes which demonstrated progress toward attainment using a 1999 future year emissions inventory.

On January 26th, 1996 EPA proposed a limited approval/limited disapproval for the 15% ROP SIP. The designation provided limited approval for improving air quality through significant reductions in emissions, but limited disapproval because the EPA believed the reductions were insufficient to meet the 15% ROP requirements.[89]

COAST Study: 1993

In the summer of 1993 the TNRCC conducted the Coastal Oxidant Assessment of Southeast Texas (COAST) study. "The goals of the study were to improve the understanding of the causes of high concentrations of ozone in Southeast Texas and to provide decision makers with the necessary tools to create effective control strategies."[90] Up until this point, regulation and control strategies were based on episodes monitored in 1988 and 1990. The study was planned and fielded to run concurrently with the Gulf of Mexico Air Quality Study[91]. The GMAQS was a larger study carried out by the Minerals Management Service (MMS) and executed in response to a FCAA mandate to assess the potential impacts of emissions from offshore oil and gas operations on onshore ozone concentrations.[92] Both studies took place in July and August 1993. The COAST study focused on Beaumont and Houston, while the GMAQS examined a larger area including parts of Louisiana. Throughout this period the number of surface monitoring sites continuously measuring ozone and meteorological parameters was increased and airborne sampling was conducted on days when conditions were favorable for ozone exceedances.[93] In addition to two highly instrumented twin-engine aircraft flown for the GMAQS, the TNRCC flew an extra instrumented aircraft. The COAST study also included extra surface-level air quality sites, extra surface VOC grab samples, and additional onshore upper-level meteorological measurements. The GMAQS and COAST study were both successful in recording several high-ozone episodes, including those with peak ozone concentrations historically high for the study area. [94]

Enhanced datasets provided by the COAST study resulted in several improvements to the modeling capabilities of the TNRCC. The emissions inventory (EI) was improved by collecting activity data for specific area and non-road source categories that contribute most to emissions. A survey of local vegetative species and biomass densities improved the biogenic emission inventory. The on-road emissions and point source emission inventories were also enhanced with the use of day-specific travel demand modeling and actual hourly speciated emissions respectively.[95] These improvements created a more robust dataset (to be used in future modeling) than what had previously been available.

General Modeling Overview and History

In order to forecast the effects of a control strategy, photochemical models have been important to the process from the beginning. Two particular characteristics of ozone make modeling its production difficult: while nonattainment areas have specific boundaries, the air within them is in constant flux with the surrounding air; and ozone is the only criteria pollutant that is not emitted, but is formed through a complex array of photochemical reactions. As a result, the model must accurately estimate the movement of air into and out of the modeled area, and recreate the complex photochemistry within the area based upon the starting concentrations and emission values. "Photochemical air quality models take data on meteorology and emissions, couple the data with descriptions of the physical and chemical processes that occur in the atmosphere, and mathematically and numerically process the information to yield predictions of air pollutant concentrations as a function of time and location."[96] This process is shown in Figure 1.

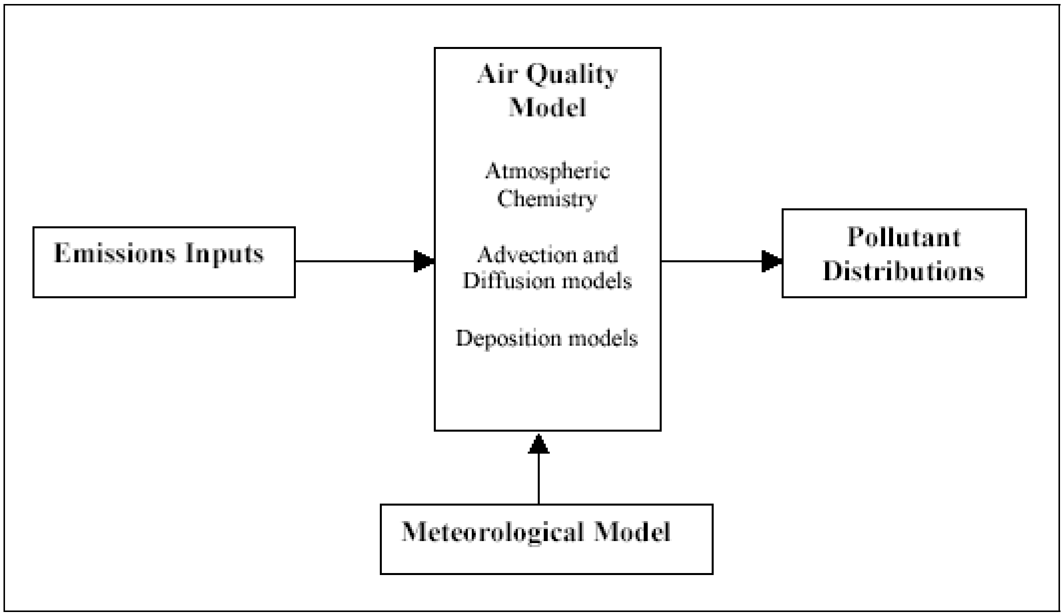


Figure 1: Conceptual Map of Photochemical Model[97]

Two types of models are used in regulation. A "box" model uses a three dimensional box over the modeled area and calculates the concentrations over time assuming the area is well mixed. This type is comparatively simple and is often used for smog chamber experiments. The first model used by Texas was a modification of this type, the Empirical Kinetic Modeling Approach (EKMA) that was used until the 1988 SIP. EKMA modeling differed from a typical box model by varying the dimensions and placement of the 3 dimensional box based on specific conditions. The more complex model type is a grid model. "In this approach a three-dimensional grid network is defined over the region to be modeled and all of the emissions, chemical processes and physical processes are accounted for in each grid cell."[98] Figure 2 depicts this setup.

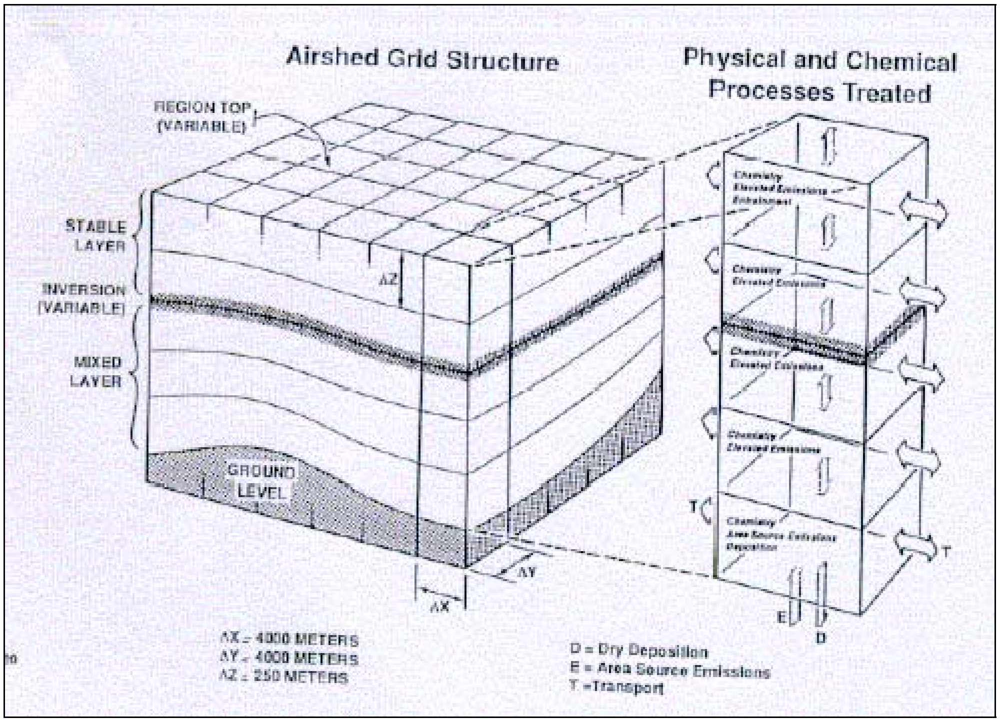


Figure 2: Eulerian (fixed grid) modeling approach

In 1988 TACB purchased UAM-IV, a variable grid model, and used it until 1993 when they switched to UAM-V with the COAST study data. UAM-V updated the grid model creating a grid structure that is fixed in space and time rather than varying with the atmospheric mixing height during the day, and a fine grid of 2 km x 2km rather than the 5 km grid in UAM-IV. UAM-V also updated the chemical mechanism with the latest chemistry involving isoprene.[99]

Houston Smog Alerts: 1994-1995

In 1993, the TNRCC developed the Ozone Advisory Program (OAP), in which state meteorologists would forecast the likelihood of high ozone levels and pass this information on to local authorities for public dissemination.[100] The advisories were to be delivered the night before days when state officials predicted weather conditions would make ozone formation probable. In turn, the public was urged to take voluntary steps to reduce ozone the next day, like carpooling or using public transportation.[101] However, the TNRCC would only provide forecasts "where there is broad-based, widespread support across the community," and would not "bypass the city and county."[102] Therefore, the RAQPC, worked with the TNRCC during 1994 to set up the necessary framework to deliver the "smog alerts" (as they were popularly known in Houston).[103] The GHP opposed the use of the alerts, citing the science behind the forecasting as inexact and worried that issuing numerous warnings could be "deceptive" and "a scare tactic" to the public and could also hurt attempts to draw new business to Houston.[104] In March 1994, at the urging of the GHP, the RAQPC voted to postpone the smog alerts for at least a year.[105] Later that year in August, the H-GAC and the GHP came to an agreement to postpone the alerts until after a public education program could be launched.[106] However, in May 1995 the program was abandoned as the multi-interest group set up to work on the issue dispersed.[107] The reluctance of local business leaders to participate in the program was cited as a major factor in the disbanding.[108] At this time, alerts were being issued publicly in Dallas, Austin, San Antonio, Corpus Christi, and Tyler-Longview-Marshall areas.[109]

Within a month, however, "one of the largest environmental coalitions in recent Houston history" began to appeal to Houston officials to start issuing the smog alerts. The Smog Action Task Force, made up on 42 health, legal and medical groups, focused on the program more as a measure to protect public health and less as a means of voluntary ozone prevention.[110] At the beginning of August 1995, Houston Mayor Bob Lanier approved city participation in OAP and delegated the dissemination of the alerts to the Houston Health Department.[111] The Houston smog alerts began shortly in mid-August 1995 and focused mainly on the health implications of high ozone days.[112]

Contrary to local fears of inaccuracy, TCEQ data show that the ozone alerts were issued correctly in the Houston area 77% of the time over the last ten years.[113]

I/M 240 and The Texas Motorist's Choice Program: 1994-1995

In May 1994, Texas submitted the SIP charting the initial 15% emissions reduction, which was to be completed by November 1996. A significant component of the 1994 SIP was a vehicle emissions testing program that met the SIP reduction requirements and was to be approved by the EPA. The Texas program, called "I/M 240" (Inspection/Maintenance, 240 for the time in seconds the specific emission test took to complete), was to play a key role in the SIP and would be implemented in the Dallas/ Fort Worth Metroplex and the Houston/Galveston/Beaumont/Port Arthur areas. The tests would focus on emissions of NO_x, VOCs and CO.[114]

In May 1993, Tejas Testing Technology was chosen as the highest bidder for the major government contract to provide the I/M testing to every car and truck in the two large aforementioned areas.[115] Tejas spent much of 1994 preparing the infrastructure for the program and began free trial testing in November 1994. Although Tejas reportedly tried to disseminate information about the new testing program to the public, which was slated to begin January 1, 1995, it was reported that the TNRCC did not issue the bulk of these public announcements until after the November 1994 elections so as not to interfere with then Governor Ann Richard's bid for re-election.[116, 117] However, the free trial testing soon attracted public interest when long lines formed and new equipment malfunctioned. When local Houston talk radio personality Jon Matthews took on a personal crusade against the program, frustration with I/M 240 seemed to grow within certain populations. "It was an example of the media echo-chamber magnifying something into something it wasn't," said Bill Dawson, the former environment writer for the *Houston Chronicle*. This aversion quickly spread to the Texas legislature, where Senator John Whitmire championed Senate Bill 19 to suspend the state's I/M program for 90 days; it passed on January 31, 1995.[118] The bill, signed into law that same day, was the first piece of legislation George W. Bush signed as governor of Texas.[119] On May 1, 1995, Senate Bill 178 cancelled the I/M 240 testing program completely, reinstated a previous testing program, and authorized the renegotiation of a new vehicle emissions testing program that would be "more convenient and less costly."[120] Liz Hendler, a former SIP coordinator with the TNRCC, noted that the state agency realized that the EPA was not enforcing penalties on other states that did not implement I/M programs. Thus when the I/M 240 program was canceled in 1995, Texas was not especially at risk for EPA sanctions.[121]

In September of that year, the EPA amended its I/M rule to allow ozone nonattainment areas with an urbanized population of less than 200,000 the flexibility of demonstrating attainment without I/M.[122] Most of the HGA was therefore excluded from the new plan, "The Texas Motorist's Choice Program," (TMCP) because of population size. In Houston, only residents of Harris County would be required to participate in TMCP – the other seven surrounding counties in the HGA were excluded because of population size.[123] Also, because of the NO_x waiver (see below), the newly implemented I/M program did not account for NO_x emissions as the I/M 240 program would have, an issue that would later resurface in 2000 when Houston switched to a NO_x-based strategy.[124] Tejas later sued the state for breach of contract and won $160 million in damages and legal fees – the largest single settlement ever imposed on the State of

Texas.[125,126] Texas used money from the TNRCC budget to pay the settlement, leaving other environmental programs underfunded the following years.[127] A minor SIP revision adopted the TMCP on May 29th, 1996 and was submitted to the EPA on June 25th, 1996. The EPA proposed conditional interim approval of the TMCP based on Texas's "good faith estimate of emissions reductions and the program's compliance with the FCAA."[128]

NO_x Waiver: 1995-1997

The modeling in the January 1995 SIP represented first phase of satisfying the requirement in the 1990 FCAA Amendments. The second phase of the attainment demonstration modeling would be conducted using data obtained primarily from the COAST study. The COAST study created a more robust database, "providing a higher degree of confidence that the strategies will result in attainment of the ozone NAAQS or target ozone value."[129] The UAM modeling in the January 1995 SIP showed that a decrease in NO_x emissions would actually result in an increase in ozone levels. The modeling showing this disbenefit from NO_x reductions was submitted to the EPA on August 14th, 1994. Section 182(f) of the Clean Air Act allows the EPA to waive the following NO_x measures if a disbenefit is shown:

1) Reasonably Available Control Technology (RACT) for large stationary sources
2) Nonattainment New Source Review (NNSR)
3) Vehicle Inspection/Maintance
4) General Transportation Conformity

The EPA approved a temporary NO_x waiver for the HGA on April 19, 1995 based on the modeling, despite the opposition of local environmental groups. "The Sierra Club criticized the NO_x modeling that predicted potential increases in ozone as having several technical flaws," said Neil Carmen, Clean Air Director for the Sierra Club's Lone Star Chapter.[130]

The NO_x waiver was set to expire on December 31, 1996, but was extended for one year to December 31, 1997. The exemption allowed more time to conduct UAM modeling using data from the COAST study. These UAM results were important in determining whether, and to what extent, NO_x reductions were needed to attain the ozone standard. When the NO_x exemption was allowed to expire at the end of 1997, the state had finished the UAM modeling and showed that NO_x reductions were in fact needed to reduce ozone in the Houston area.[131] The expiration of the waiver required the state to implement the NO_x control programs including the Reasonably Available Control Technology (RACT) program that had been delayed for several years.

Two-Phased Attainment Demonstration: 1995-2000

The 1990 FCAA Amendments required a rate of progress plan for the 15% reductions by 1996 and a minimum of 3% per year reduction thereafter. In addition to these set reductions, it also required modeling to demonstrate attainment of the NAAQS by the assigned deadline. Initially, this modeling was required to be submitted to the EPA by November 15th, 1994; however, this proved to be considerably more difficult than at first anticipated. By the 1994 deadline, most states did not have the models running correctly and were unable to meet the deadline. The Post-1996 SIP revisions submitted on November 9th, 1994, which contained Houston's plan for the 9% reduction through 1999, did not contain the modeled attainment, but promised it by January 11th, 1995.[132] Although area health and environmental groups had sometimes argued that Texas was doing more to undermine the FCAA than to enforce it, Liz Hendler, now a consultant for the GHP, but who coordinated the Houston SIP for the TNRCC from 1995 into 1998, recently noted, "It wasn't a matter of will, but rather a matter of the technology and modeling that wasn't available or fully understood." In addition to the state's inability to model attainment, the issue of photochemical transport, particularly in the Northeast, was garnering attention. Transport issues arise from the fact that there is no boundary between the air in a non-attainment area and surrounding atmosphere. The photochemicals necessary to produce ozone can travel very long distances across the nation with the jet stream. These chemicals can then cause ozone problems in an area that previously had no problem. The quantity of chemicals transported from area to area was not well understood at this time and created major problems for the photochemical models.

In the face of these problems and in order to prevent the need for federal enforcement in every area unable to model attainment, the EPA made an effort to realign the science with the regulation. On March 2nd, 1995 Mary Nichols, EPA Assistant Administrator for Air and Radiation, issued a memo that gave states more flexibility in designing an attainment demonstration provided they continue the 3% per year baseline progress.[133] The memo set up a two phase process for states in which the initial phase intended to continue progress in reducing levels of VOC and/or $NO_{x,}$ while scientific issues such as modeling and transport were addressed. The second phase would design a plan to achieve attainment including the results of the scientific investigation. The memo allowed for a delay in modeled attainment, provided the states in the Eastern half of the country would participate in an Ozone Transport Assessment Group (OTAG).

Essentially the memo created two sets of SIP revisions: Phase I Rate-of-Progress plans, which required set reductions of 3% a year until attainment, and Phase II Attainment Demonstration plans, which would model attainment based on new control strategies by the compliance deadline. Table 2 shows elements specifically required by Phase I.

Table 2

Elements Required by Phase I Rate-of-Attainment Demonstration Plans[134]
1) Control strategies to achieve reductions of ozone precursors in the amount of 3% per year from the 1990 emissions inventory (EI) for 1997, 1998, and 1999.
2) UAM modeling out through the year 1999, showing the effect of previously adopted control strategies that were designed to achieve 15% reductions in VOCs from 1990-1996.
3) A demonstration that the state has met the VOC RACT requirements of the 1990 FCAA amendments.
4) A detailed schedule and plan for the "Phase II" portion of the attainment demonstration which will show how the nonattainment areas can attain the ozone standard by the required dates.
5) An enforceable commitment to: a. Participate in a consultative process to address regional transport, b. Adopt additional control measures as necessary to attain the ozone NAAQS, meet ROP requirements, and eliminate significant contribution to nonattainment downwind, and c. Identify any reductions that are needed from upwind areas to meet the NAAQS.

In Texas, elements one and two had been provided for in the SIP revisions submitted in November 1994 and January 1995. Requirements three, four, and five were submitted to the EPA on January 10, 1996.[135]

Weight-of-Evidence

In addition to the 1995 memo from Mary Nichols, the EPA offered states struggling with models an alternative test with which to demonstrate attainment. In June 1996, EPA issued a guidance document entitled, "Guidance on Use of Modeled Results to Demonstrate Attainment of the Ozone NAAQS."[136] This document introduced the concept of "Weight of Evidence" (WOE) as a tool to help demonstrate modeled attainment. "[The] Weight of Evidence argument was first admitted as a result of states trying to model attainment and not making ends meet," said Chuck Mueller, former TCEQ Texas SIP Coordinator.[137] The guidance document states,

> "If the attainment test is not passed and exceedances cannot be explained as model artifacts, the Deterministic Approach allows use of a weight of evidence determination to assess whether attainment is, nevertheless, likely. A weight of evidence determination includes a subjective assessment of the confidence one has in the modeled results. This is supplemented with a review of available corroborative information, such as air quality data. The more extensive and creditable the corroborative information, the greater influence it could have in permitting deviations from the deterministic test's benchmark."[138]

The guidance document suggests the following types of analyses may be included in the WOE argument: Photochemical Grid Model, trend data, observational models, selected episodes, and incremental costs/benefits.[139] Texas used the WOE argument in the 1998 and Attainment Demonstration SIP Revision to introduce alternative inventories used in testing different control strategies.[140] In 1999 EPA issued a draft document titled *Guidance for Improving Weight of Evidence Through Identification of Additional Emission Reductions, Not Modeled*, which contained two methods for calculating emission control shortfalls, i.e. gaps. Neither one could be applied to Texas however, so EPA Region 6 used the guidance to create a new method including a quadratic equation to calculate the NO_x gap for use in the 2000 Attainment Demonstration.[141]

The 2004 National Research Council publication *Air Quality Management in the United States* suggests that, "for [the deterministic test] approach to work, the weight-of-evidence analysis must be applied in an unbiased manner and not simply to justify lower emission reductions than those indicated by air quality model simulations." However, the NRC report goes on to say, "the introduction of the weight-of-evidence approach…appeared to have invited such a biased application, and bias in using the weight-of-evidence approach has been alleged in legal challenges to SIPs for a number of states."[142] Texas was not excluded from such legal challenges.

Sonoma Study: 1999

In order to assess the importance of health benefits related to the air quality in the HGA, the City of Houston commissioned researchers at Sonoma Technology, Inc., California Stae University, and the University of California, Irvine, to perform a study of health and economic benefits of reducing area air pollution. The overall purpose of the study was "to provide information that will assist decision-makers in setting priorities for emissions reductions based on the relative health benefits of different emission control strategies."[143] *The Air Quality Reference Guide for the Houston Galveston Area* notes that major findings included:

- Total annual economic benefits associated with improved health if the area were in compliance with one-hour ozone and Particle $Matter_{2.5}$ ($PM_{2.5}$) NAAQS in 2007 would be $2.9 billion to $3.1 billion.
- The health benefits of lower exposure to fine particles outweighed the benefits of reduced ozone exposure significantly.[144]

While this report represents an important effort to estimate the benefit of air quality control, much controversy exists over the methods utilized in the study.

Attainment Demonstration

Prior to submittal of a Houston SIP revision accomplishing Phase II of the Attainment Demonstration, the EPA policy regarding SIP elements and timelines went through three changes. First in order to assess the role of transport on ozone formation in the eastern two thirds of the nation, the Ozone Transport Assessment Group (OTAG) was created and allowed states to postpone their attainment demonstrations until the transport issue was better understood. Second, the EPA established the WOE guidance to facilitate states in modeling attainment. The third change was EPA's promulgation of the new 8-hr ozone standard on July 18, 1997. This stricter standard required a lower concentration averaged over a longer, eight-hour period. As a result of these changes the EPA issued another guidance document on December 29th, 1997.[145] It required that:

1) Revisions be submitted by April 1998 that had a list of measures and regulations and/or a strategy including technology forcing controls needed to meet ROP requirements and attain the 1-hour NAAQS;
2) States must commit to submit a plan on or before the end of 2000 that contained target calculations for Post-1999 ROP milestones up to the attainment date and adopted regulations needed to achieve the Post-1999 ROP requirements up to the attainment date and to attain the 1-hour NAAQS.

The Texas 1998 SIP required by the EPA guidance was submitted May 6, 1998. "The EPA stated that it could not approve the SIP until specific control strategies were modeled in the attainment demonstration."[146] EPA stipulated the modeling would be required by November 15, 1999.

Table 3

May 6th, 1998 SIP Revision Elements[147]
1) UAM modeling based on emissions projected from a 1993 baseline out to the 2007 attainment date.
2) An estimate of the level of VOC and NO_x reductions necessary to achieve the one-hour ozone standard by 2007.
3) A list of control strategies that the state could implement to attain the one-hour ozone standard.
4) A schedule for completing the other required elements of the attainment demonstration.
5) A revision to the Post-1996 9% ROP SIP that remedied a deficiency that the EPA believed made the previous version of that SIP unable to be approved.
6) And evidence that all measures and regulations required by Subpart 2 of title I of the FCAA to control ozone and its precursors have been adopted and implemented, or are on an expeditious schedule to be adopted and implemented.

The modeling was subsequently submitted in a SIP revision on October 27th 1999. This revision contained seven basic modeling scenarios, and is described in the 1999 SIP itself as "the next step in an iterative process of evaluating potential control strategies, an effort which will continue through the summer of 2000"[148]

Table 4

October 27th, 1999 SIP Revision Elements[149]
1) Photochemical modeling of potential specific control strategies for attainment of the 1-hour ozone standard in the HGA by the attainment date of November 15, 2007.
2) An analysis of seven specific modeling scenarios reflecting various combinations of federal, state, and local controls in HGA.
3) Identification of the level of reductions of VOC and NO_x necessary to attain the 1-hour standard by 2007.
4) A 2007 mobile source budget for transportation conformity.
5) Identification of specific source categories which, if controlled, could result in sufficient VOC and/or NO_x reductions to attain the standard.
6) A schedule committing to submit by April 2000 an enforceable commitment to conduct a mid-course evaluation.
7) A schedule committing to submit modeling and adopted rules in support of the attainment demonstration by December 2000

The October 1999 SIP Revision was Texas' first proposal to include a NO_x-based strategy. "In order for HGA to reach attainment, reductions of NO_x emissions by 65-85% will be necessary."[150] The April 2000 SIP further explored the NO_x based strategy and determined additional reductions needed for attainment. It contained a list of "preliminary" control measures to be developed and refined for the 2000 Attainment Demonstration.

Table 5

April 19th, 2000 SIP Revision Elements[151]
1) A quantified shortfall of the NO_x reductions needed for attainment of 118 tpd in addition to the reductions already modeled for the November 1999 SIP.
2) A list of potential control measures to meet the shortfall.
3) An enforceable commitment to submit a SIP revision by the end of 2000 with the first phase of adopted rules for attainment.
4) An enforceable commitment to submit the Post-99 ROP plan by the end of 2000.
5) An enforceable commitment to perform a mid-course review by May 1, 2004.

The April 2000 SIP also committed to perform a mid-course review (MCR) and to submit these results to EPA by May 1, 2004. "This effort will involve a thorough evaluation of all modeling, inventory data, and other tools and assumptions used to develop the attainment demonstration."[152] The MCR process was initially set to incorporate the findings of an intensive field study that was set for the summer of 2000.

Texas 2000 Air Quality Study and the 2000 SIP Revision

In August and September 2000, the most comprehensive air quality study in Texas was conducted. This study led to major advances in understanding the photochemical, meteorological, and atmospheric processes of ozone production in the Houston-Galveston Area.

Into 2000, modeling was still based on episodes monitored in the 1993 COAST study, and there were many questions about the atmospheric processes, emissions (both biogenic and anthropogenic, as well as meteorology). The need for improved data was recognized and new technology was available to record data with higher efficiency and precision. EPA had just finished funding a decade long study of five cities in the Southern Oxidants Study (SOS) and Texas was able to bring many members of that team to Houston to conduct a similar study. This study, the Texas 2000 Air Quality Study (TexAQS 2000), addressed three key areas of uncertainty: the emission inventories, chemical and physical processes in the atmosphere, and the gridded photochemical air quality models themselves.[153] The major objectives of TexAQS 2000 are shown in the following table:

Table 6

Major Objectives of TexAQS 2000 [154]
1.) Characterization of ozone and particulate matter formation in extended metropolitan areas.
2.) Understanding of diurnal cycles in chemistry and meteorology (especially night-time chemistry).
3.) Characterization of meteorological effects on ozone and particulate matter formation (especially boundary layer and marine interactions).
4.) Characterization of the composition of particulate matter.
5.) Improve emission inventories (especially biogenics, particulate matter, and selected reactive compounds).

TexAQS 2000 took place between August 15th and September 15th, 2000 in the HGA and in the central and east Texas regions. Approximately 300 investigators were involved, along with 40 research organizations, including the TNRCC, the Department of Energy, the National Oceanic and Atmospheric Administration, the EPA, the National Center for Atmospheric Research, the National Aeronautic and Space Administration, the Texas Air Resource Center, the Cooperative Institute for Research in Environmental Science, and several universities. The TexAQS 2000 budget was approximately $20 million from several sources, including the state and federal governments, and utilized six research aircraft and a network of ground-based monitoring stations to record the most extensive data ever recorded during multiple high ozone episodes (Figures 3 and 4 below show peak ozone concentrations during the study).[155]

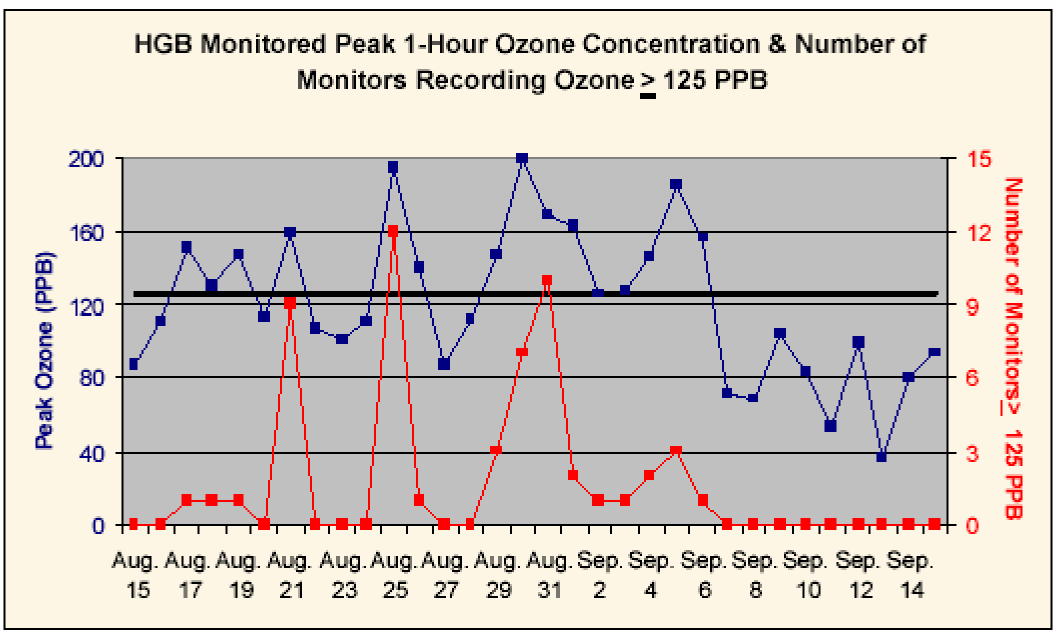


Figure 3: One-hour peak ozone concentrations and number of monitors recording one-hour ozone concentrations ≥ 125 ppb during TexAQS 2000.

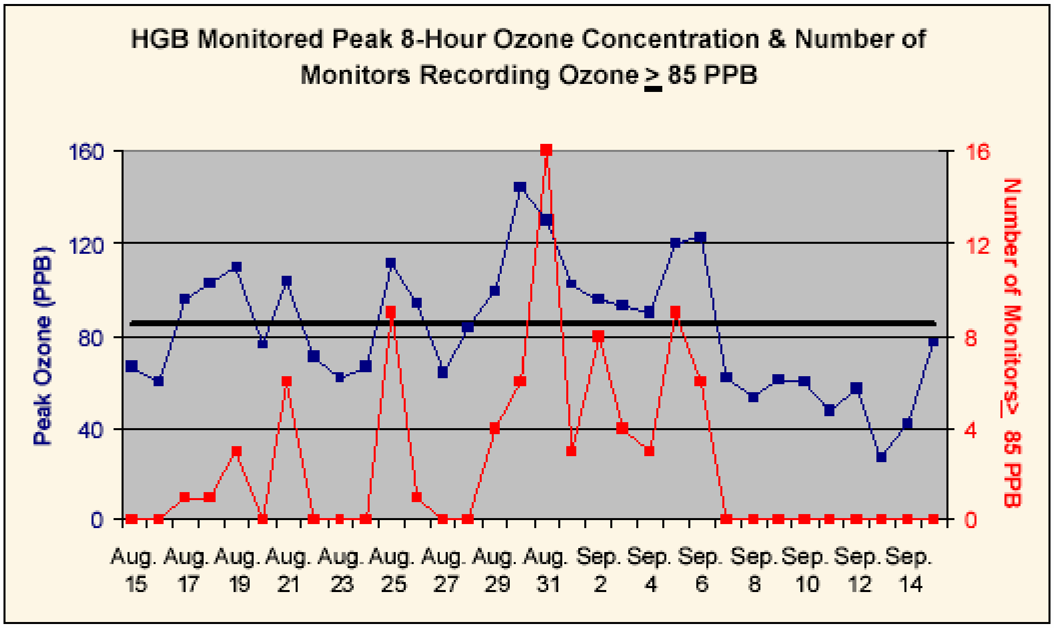


Figure 4: Eight-hour peak ozone concentrations and number of monitors recording eight-hour ozone concentrations ≥ 85 ppb during TexAQS 2000.

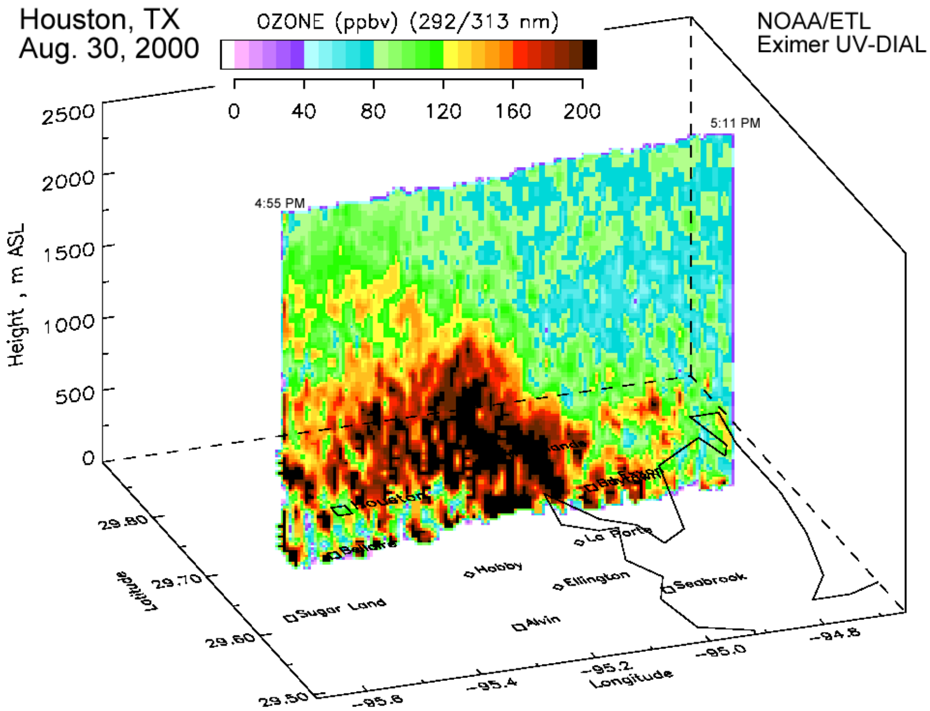


Figure 5: East-west vertical cross section of ozone concentration across Houston obtained by National Oceanic and Atmospheric Administration Environmental Technology Laboratory's airborne ozone LIDAR on August 30, 2000.[156]

One aircraft was equipped with a downward-looking LIDAR system, capable of mapping concentrations of pollution plumes. The figure above shows an example of data of a plume rising off the industrial region surrounding the Houston Ship Channel. The plane flew the over the area from 4:55 PM to 6:11 PM and the LIDAR system created the 2-D "curtain" image that shows the ozone concentration by altitude directly below the plane during flight.

The December 2000 SIP Revision

In December 2000, after TexAQS 2000 had been completed, a controversial attainment demonstration SIP revision was adopted as the second part of the 2-Phase Plan initiated by the Federal government in 1995. The revisions included a shift from VOC-only controls to a NO_x based strategy that relied most heavily on point source NO_x

reductions. Since the inception of the State program, ground level ozone strategies had focused primarily on VOC components. The switch to a NO_x based strategy was controversial and had been discussed heavily in the few years leading up to the revision.

The shift to a NO_x based strategy began at the end of 1997 when the NO_x waiver was not renewed. In November 1999, after the decision to let the NO_x waiver die, TNRCC Chairman Barry McBee reported, "As of today we're probably no longer focused on an exclusive VOC strategy in Texas."[157] From a modeling standpoint, Dr. Harvey Jeffries explains, "The model was more sensitive to NO_x controls than VOC controls."[158] Though NO_x reductions were realized as necessary for attainment in the 1998 and 1999 SIP revisions, the December 2000 revisions represented the culmination of the effort to incorporate NO_x controls and outlined the specific control strategies necessary.

The 1993 COAST study database was used for modeling episodes that led to a proposal to reduce point source NO_x emissions 90% beyond the RACT program implemented in 1999. [159] It was understood that a 90% reduction was close to the maximum capability and that the last 10% from 80% to 90% was comparatively expensive. In turn, industry leaders argued that the benefits achieved by this strategy were not sufficiently supported by the science.[160]

After the 1998 SIP revision, TNRCC began using the CAMx photochemical model, replacing the UAM-V model. This model has been used for all subsequent SIP revisions, and has had several small improvements since its first use. COAST study episodes were still used in modeling in the 2000 SIPs because TexAQS 2000 data were not yet available. When modeling the episodes from the COAST study in 1999 and

2000, Harvey Jeffries noted, "even with extreme increments of reactive VOCs, the photochemical grid models would not produce the peak ozone observed."[161] The monitored and modeled high ozone episodes recorded in September of 1993 are shown in Figure 6. The COAST stations from September 6 – 11th monitored 15 different events characterized by an increase greater than 40 ppb in one hour resulting in a concentration of 120 ppb or more. Though the model predicted the typical increases of 20 – 30 ppb, it fails to predict any increases of more than 40 ppb.

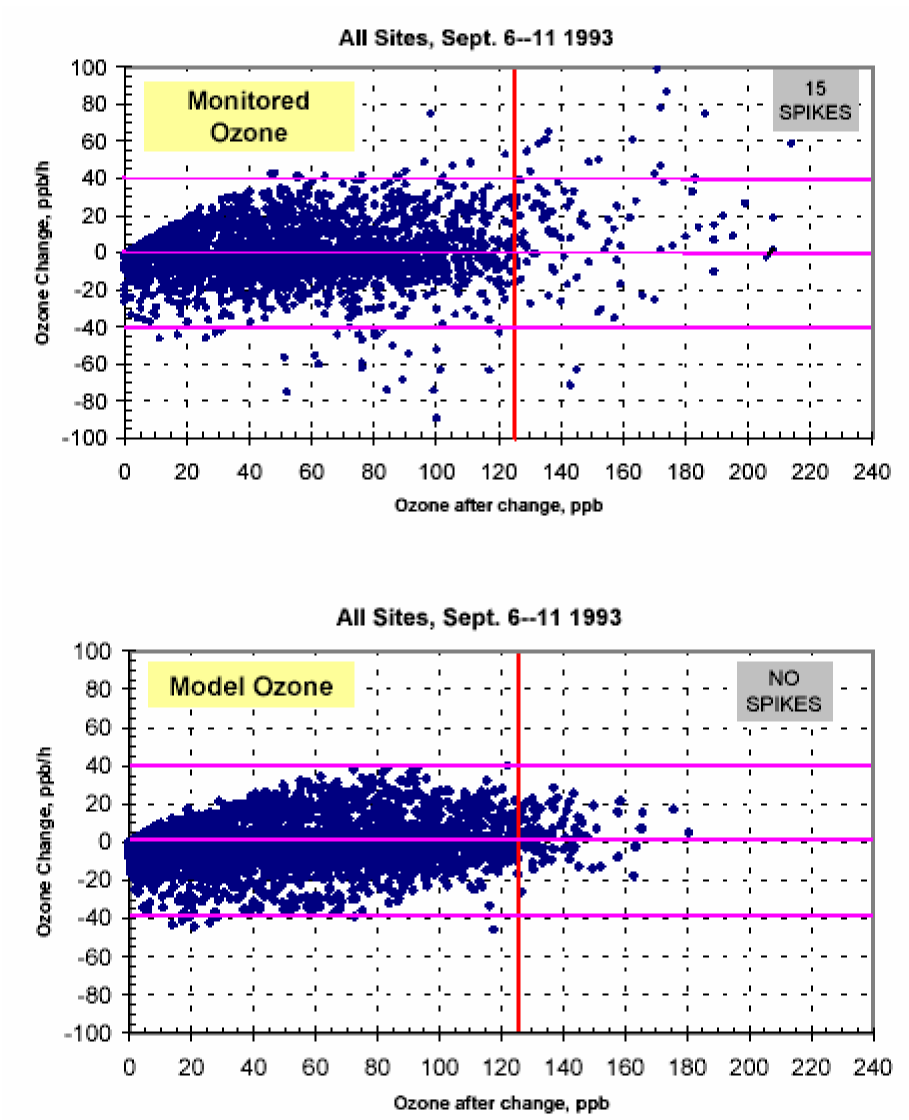


Figure 6: COAST monitored ozone levels and modeled ozone levels.[162]

The controls strategies included in the adopted December 2000 SIP are outlined in Appendix B along with their NO_x tpd reductions. The modeling in the 2000 SIP suggested that ultimately more than 750 tpd of NO_x reductions, in addition to about a 25% reduction in VOC emissions, would be needed to reach attainment.[163] The measures in the 2000 SIP fall short of this though by an estimated 56 tpd of NO_x. This shortfall was to be addressed during the MCR process that was set in place by the 1999 SIP revisions. In the 1999 proposed conditional approval and disapproval of the HGA attainment demonstration SIP, the EPA approved the usage of a MCR process and enforceable commitments to make further reductions, though many, including Ramon Alvarez, a scientist with Environmental Defense, saw this as a further delay in the clean air process.

Influences on the 2000 SIP Revision

While the decision to propose a NO_x based strategy was controversial, the agency faced a federal deadline "to submit modeling and adopted rules in support of the attainment demonstration by December 2000."[164] In addition to the schedule set in place by the 1998 SIP revisions, several events brought the Houston ozone problem to national attention. In 1997 an article in the *Houston Chronicle* compared the ozone issues in Houston to Los Angeles.[165] This article by Bill Dawson, "Smoggy Air Apparent? Houston Gaining on L.A. as Ozone Capital," inadvertently started a media-conducive "race" that was picked up by national media. The article examined annual days exceeding federal one-hour ozone standards. As the article predicted, by the end of 1999

Houston surpassed Los Angeles as the "smog champion" for the first time in history with 52 days exceeding the one-hour ozone standard versus Los Angeles' 42 days. [166]

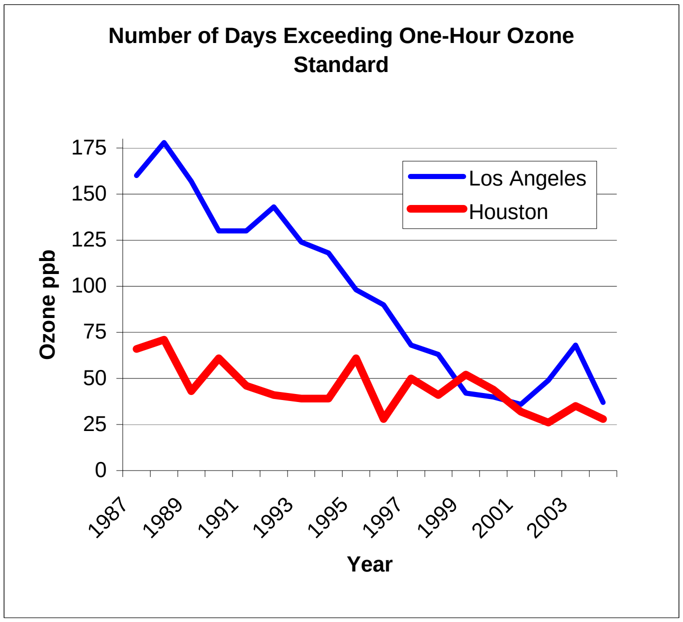


Figure 7: Annual Days Exceeding Federal One-Hour Ozone Standard[167]

The Houston ozone problem was now put in the national context of being worst in the nation, while Governor Bush was beginning his presidential campaign. "When Houston did replace Los Angeles as the city with the most violation days in 1999, it attracted national attention mainly because Governor Bush was running for president. Major parts of his Texas record – which, fairly or unfairly, could be portrayed as including Houston's recent air pollution trends – were automatically going to be in the national spotlight," said former *Houston Chronicle* writer Bill Dawson. "At the same time all that was happening, Bush's appointees at the TNRCC were working hard to come up with the huge ozone-reduction plan to meet a federal deadline at the end of 2000, which had been set as a result of legislation his own father, a Houston resident, had signed into law," said Dawson.[168] In response to attacks on his environmental record, Bush touted the 90% plan as "unprecedented in the nation" more than a year before its adoption.[169]

As Houston gained on Los Angeles at the end of 1999, another event brought even more attention to Houston's ozone problem. On October 7, 1999, a cloud of ozone formed over the Deer Park area of Houston.[170] While ozone levels exceeded the federal health standard of 125 ppb at 10 of 20 Houston monitors, levels exceeded 180 ppb at 5 monitors.[171] The highest reading, however, was in Deer Park, which recorded an hourly average of 251 ppb, the highest local ozone measurement in a decade and a level deemed "very unhealthy" by federal standards.[172] This exceedance also placed Houston over L.A. in ozone violations for the first time.

Three weeks later, after initially reporting the incident in an article on October 9th, the *Houston Chronicle* featured articles reporting that middle and high school athletes participating in sports the afternoon of October 7th had suffered respiratory difficulties, such as uncontrollable coughing, aching chests, and sore throats. State officials asserted that computer problems had prevented them from quickly posting the high readings on their website and the TNRCC stated that they did not issue a health warning because it was considered to be "a very short event."[173] Eleven days later, Harris county implemented the "Ozone Alert Notification System" that would send warning emails to anyone who wanted them, including schools, anytime the Houston ozone levels exceeded the national health standard. "I think our article in the Chronicle conveyed a sense of the harm that high levels of ozone and other air pollution could do to people – in this case, healthy middle-school and high-school athletes. It's one thing to talk about pollution's health risks in an abstract or statistical way, and it's another thing altogether to have real-life evidence of what those risks mean," said Dawson.[174] "All in all, I think the interplay of these related events in the late 90's – the Houston-L.A. story, Bush's run for the presidency, the SIP deadline, the Deer Park incident – created a combined momentum that drove the process forward. The number one spot on the ozone-violation list was a significant factor in persuading corporate leaders here that this was a problem that needed to be dealt with."[175] Dawson noted this recognition his July 30th, 2000 *Houston Chronicle* article. " 'It's our desire to get out of the line of fire,' said James Royer, Chairman of the [Greater Houston] Partnership, in reference to the bad publicity that followed the No. 1 ozone ranking."[176]

Industry's acceptance of ozone as a problem was marked by the GHP's creation of the Business Coalition for Clean Air.[177] The group's objectives as listed in the BCCA Clean Air Call to Action Notebook 2000 are:

- Endorse the Principles for Cleaner Air developed by regional stakeholders.
- Coordinate advocacy efforts on behalf of the business community.
- Help maintain the focus on development of the region's ozone SIP.
- Educate the business community on efforts to achieve clean air goals.
- Raise funds for technical, educational, and advocacy needs.[178]

Kelly Frells stated the group's first initiatives included a public information campaign, a regional economic impact study (Smith Tolley Report), and ongoing technical analysis.[179]

The Smith Tolley Report: 2000-2001

From April to December 2000, the GHP funded $325,000 for a report on the economic impact a stringent NO_x based strategy would have on Houston. This report, "Clearing Houston's Air: An Economic Evaluation of Clean Air Act Compliance Strategy Alternatives," by Dr. Barton Smith and Dr. George Tolley, was published in February 2001.[180] It found that "because of diminishing returns the measures armed at reducing NO_x emissions, the last 10-15% reduction is by far the most costly." [181] It continues, "The mandated 90% NO_x reduction is especially damaging to the Houston economy because, independent of costs, it leaves little room for growth in such industries as refining and petrochemicals. As a result, the proposed TNRCC SIP actually entails a no-growth mandate for about one fourth of Houston's economic base."[182] Industry felt that other strategies could be much more cost effective without affecting Houston's economy as severely. As Walt Crow, a contact manager with URS Corporation, recalled, "Industry believed there was more than one way to skin a cat."[183]

2001 BCCA-AG Lawsuit

Discussion between the BCCA and TNRCC over the control techniques occurred in the years leading up to the proposal. Pam Giblin spoke of the process, "The agency was listening to our arguments for more HRVOC control and agreeing with us, but then the clock ran out and they didn't have enough time to review the HRVOC research."[184] When the "clock ran out" and the 90% plan was adopted despite industry's support of an alternative 80% plan, 13 companies of the BCCA formed the BCCA Appeal Group (BCCA-AG) to continue the fight for a different control strategy in court.

On January 19th, 2001 the BCCA-AG filed a judicial appeal seeking a temporary injunction on all NO_x rules in the December 2000 SIP, followed by a complete withdrawal of the SIP. The proceedings began on May 14th, 2001 in the Travis County District Court before Judge Margaret Cooper. In particular, the testimonies of Cyril

Durrenberger, a Senior Engineer in the Technical Analysis Division at the TNRCC, and Dr. Harvey Jeffries outlined the inability of the model to accurately reproduce Houston ozone episodes, as well as the arbitrary methods used to determine the 90% reduction scheme. After five days of testimony, the TNRCC entered into a consent order, "because of the uncertainty and cost of litigation."[185] Judge Cooper signed the Consent Order on June 8th, 2001 that gave TNRCC eighteen months to perform an "objective evaluation of the causes of rapid ozone formation events and the identification of potential measures not yet identified in the HGA attainment demonstration."[186] The order led to the Accelerated Science Evaluations (ASE) of the TexAQS 2000 data that had been collected almost a year before.

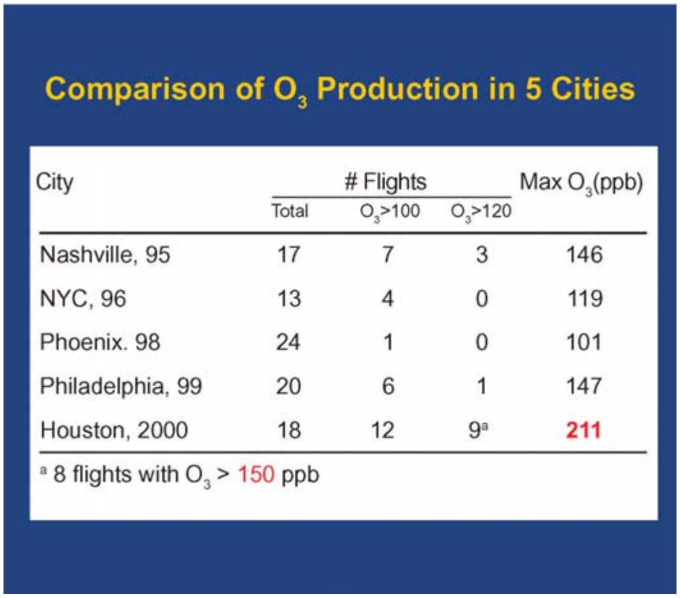
While slowing the implementation of a plan to clean the air, the decision to table the 2000 SIP did allow for the scientific understanding to catch up with the regulation. Dr. David Allen, a professor of chemical engineering at the University of Texas and the main author of the ASE, observed, "The decision to seek out the necessary science to make a reasonable decision has had a great benefit. The 2000 SIP would not have performed well or given us the expected results."[187]

The ASE of the TexAQS data became available in 2002. This timeframe was extremely accelerated compared to the typical scientific process. By comparison, a similar air study performed at the same time as TexAQS 2000 released its findings in the summer of 2004.[188]

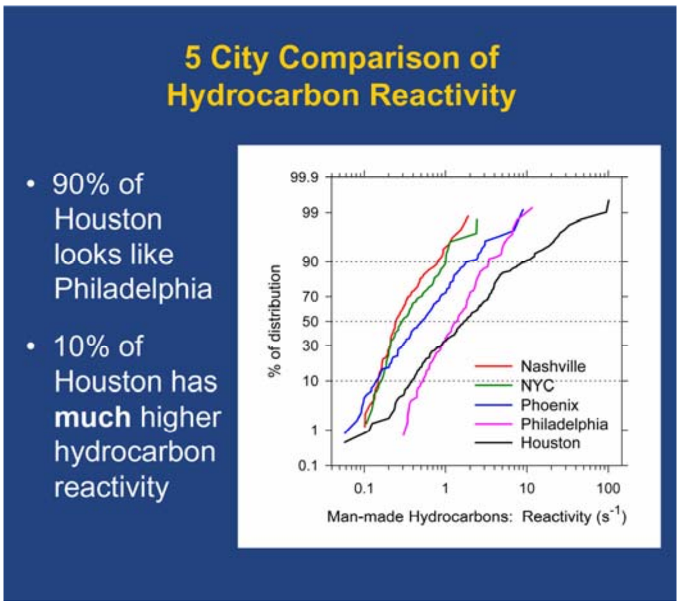
<u>TexAQS 2000 Findings</u>

The TexAQS 2000 results significantly changed the direction of Houston air quality regulation. The major findings of TexAQS 2000 as listed in the ASE Summary are in Appendix C. The key findings centered on the understanding of the high ozone formation rates in Houston as compared with other cities. TexAQS was designed to allow consistent comparison of the results to the SOS. Such a comparison reveals that the mechanism for ozone formation in Houston is different that for other cities. Cities in the SOS included Nashville, Phoenix, Philadelphia and New York. Each of these urban areas consisted of a different mix of conditions as described in Dr. Peter Daum's presentation at the Shell Center for Sustainability Fall 2003 Air Quality Seminars :

- Nashville – Isolated city in region of high biogenic emissions surrounded by major NO_x emitters (power plants).
- Phoenix – Major urban area, low biogenics, no power plants or major industrial facilities, very dry atmosphere, isolated from other urban centers
- Philadelphia and New York – Major urban areas imbedded in the Washington-Boston urban corridor. Inter-urban transport a major issue.
- Houston – Major urban area, extensive industrial facilities, coastal location.



City	# Flights Total	O_3>100	O_3>120	Max O_3(ppb)
Nashville, 95	17	7	3	146
NYC, 96	13	4	0	119
Phoenix. 98	24	1	0	101
Philadelphia, 99	20	6	1	147
Houston, 2000	18	12	9[a]	211



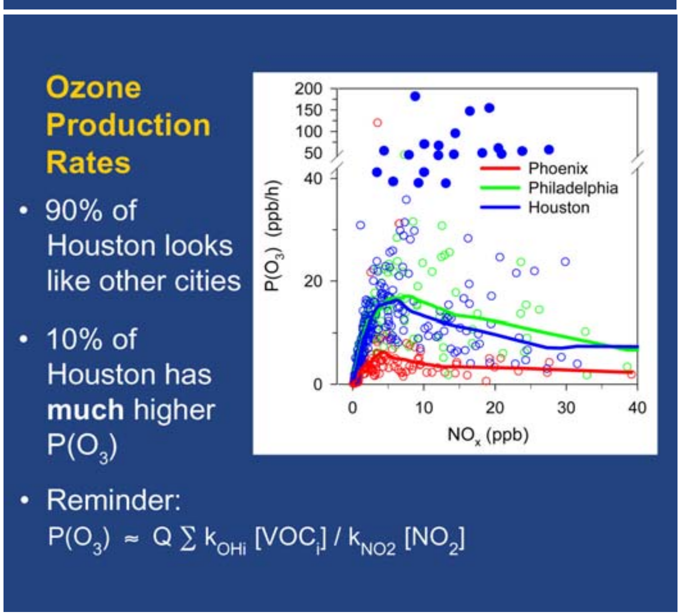


Figure 8: TexAQS 2000 and SOS City Comparison of Ozone Production

The difference between Houston and the other areas is exemplified in Figures 8, 9, and 10 from Dr. Daum's presentation. The data comparison, shown in Figure 8, indicates that ozone concentrations were consistently higher in Houston during the overflights than in the other cities. Figure 9 shows how Houston's VOC reactivity in 10% of the distribution is considerably higher than any other city. The proportion of more highly-reactive VOC, coupled with the fact that the NO_x concentration is relatively similar to the other cities, identifies the photochemical characteristic responsible for the higher ozone production rates in Houston as shown Figure 10.

TexAQS 2000 helped better explain this photochemistry. Before TexAQS 2000 all hydrocarbons, regardless of their reactivity, had been lumped into the one category of VOCs and these had been underestimated in emission inventories. In actuality, the VOCs each have very different reactivities and thus potential to form ozone and were present in much higher quantities than estimated. A list of hydrocarbons and their reactivities is shown in Table 7.

Table 7: Hydrocarbons and Reactivities

VOC Group Name	Compounds in the Group	Average MIR Values for Species in Group
Propylene	Propylene	11.58
Ethylene	Ethylene	9.08
Butadiene	1,3-Butadiene	13.58
Butenes	1-Butene, c-2-Butene, t-2-Butene	12.48
Pentenes	1-Pentene, c-2-Pentene, t-2-Pentene	9.42
Isoprene	Isoprene	10.69
C2C3	Ethane, Propane, Acetylene	0.71
Butanes	n-Butane, Isobutane	1.34
Pentanes	n-Pentane, Isopentane	1.60
Alkanes	n-Hexane, 2-Methylpentane, 3-Methylpentane, 2,2,4-Trimethylpentane, 2,3,4-Trimethylpentane, n-Heptane, –Octane, n-Nonane, n-Decane, 2-Methylheptane, 2-Methylhexane, 3-Methylheptane, 3-Methylhexane, 2,2-Dimethylbutane, 2,3-Dimethylbutane, 2,3-Dimethylpentane, 2,4-Dimethylpentane	1.39
Toluene	Toluene	3.97
Xylenes	o-Xylene, — + p-Xylene	5.87
Trimethylbenzenes	1,2,3-Trimethylbenzene, 1,2,4-Trimethylbenzene, 1,3,5-Trimethylbenzene	9.89
Aromatics	Benzene, Styrene, Isopropyl Benzene (Cumene), Ethylbenzene, m-Diethylbenzene, p-Diethylbenzene, n-Propylbenzene	3.13
Cyclos	Cyclopentane, Cyclohexane, Methylcyclopentane, Methylcyclohexane	2.14
Ethyltoluenes	o-Ethyltoluene, m-Ethyltoluene, p-Ethyltoluene	6.61

This table provides a complete listing of the individual VOCs and their designated VOC compound groups.

At the top of the list are four hydrocarbons: ethylene, propylene, butene, and butadiene. These four VOCs have a much higher ozone production potential and became known as Highly Reactive Volatile Organic Compounds (HRVOCs).

HRVOCs are particular important in Houston because of their ubiquitous use in the petrochemical industry that dominates the Houston Ship Channel. In 2000, 17% of the world's ethylene and 22% of the world's propylene were produced on the Texas coast.[189] This characteristic sets Houston apart from Los Angeles and any of the other ozone problems in the United States. The TexAQS 2000 flights conclusively linked the high ozone plumes that reach all over Houston to the ship channel emissions through back trajectory analysis. Dr. Peter Daum noted, "Without exception, back trajectories from the locations where these high O_3 plumes were observed passed over, or in close proximity to, sources of NO_x and hydrocarbons surrounding the Houston Ship Channel."[190]

The new observations of HRVOC emissions and their resulting high ozone formation rates aided in the understanding of the Transient High Ozone Events (THOEs) that had yet to be modeled. Dr. Harvey Jeffries acknowledged, "Combining the TexAQS 2000 results emerging in August 2001 with TCEQ's existing data, led most to agree that 'rapid ozone formation' due to highly reactive VOC compounds were responsible for THOEs." [191] While this understanding has improved the model, there are new problems that arise in such a complicated system. These are discussed later in the paper.

One of the major findings of the TexAQS 2000 was the extent of the underestimation of VOC concentrations. Though the COAST study in 1993 did find that emission inventories were not congruent with the atmospheric concentrations, TexAQS 2000 specified that industrial hydrocarbon emissions, particularly the HRVOCs, were significantly underestimated. The ASE reported the monitored hydrocarbon to NO_x ratio was consistently 2-15 times, and in some cases 50 or more times higher than the ratios reported in the inventories.[192] This underestimation is a result of the inventory calculation process.

Emissions inventories are calculated using "emission factors" that are compiled by the EPA for a variety of sources and activity levels. These factors are then used to calculate the output (emissions) from a variety of inputs (production rate, fuel nitrogen content, etc.). EPA has reported the factors in "AP-42 Compilation of Air Pollutant Emission Factors" since 1972. Though EPA updates the report periodically, the factors are developed from the average of a limited emission source population and might not be statistically representative of the population.[193] This calculation method has shown to be acceptable for NO_x calculations that are emitted from combustion processes, but this does not work for VOC inventories. Hydrocarbons, extensively used in most petrochemical processes, are often present in process fluids in the liquid state and can volatilize anywhere in a process. This results in many more potential emission points than NO_x and creates a much more complicated inventory.

It is interesting to note that in the 1991 National Resource Council publication "Rethinking the Ozone Problem in Urban and Regional Air Pollution" one of the major findings was that "current emissions inventories significantly underestimate anthropogenic emissions of VOCs."[194] This document goes on to state that in the findings on VOC versus NO_x controls, "If the anthropogenic VOC inventory is as badly underestimated as recent studies indicate, areas that were previously believed to be adversely affected by NO_x controls might actually benefit from them."[195] This predated the NO_x waiver introduction, and expiration, as well as the discussion of emission inventory problems arising from both the COAST and TexAQS 2000 field studies.

<u>2001 SIP Revision</u>

Table 8

2001 SIP Revision Elements
1) Corrections to the ROP table/budget for the years 2002, 2005, and 2007 due to a mathematical inconsistency.
2) Incorporation of a change to the idling restriction control strategy clarifying that the operator of a rented or leased vehicle is responsible for compliance with the requirements of Chapter 114 in situation where the operator of a leased or rented vehicle is not employed by the owner of the vehicle.
3) Incorporation of revisions to the clean diesel fuel rules to provide greater flexibility in complying with the requirements of the rule while preserving the emission reductions necessary to demonstrate attainment in the HGA.
4) Incorporation of a stationary diesel engine rule that was developed as a result of the state's analysis of EPA's reasonably available control measures.
5) Incorporation of revisions to the point source NO_x rules.
6) Incorporation of revisions to the emissions cap and trade rules.
7) The removal of the construction equipment operating restriction and the accelerated purchase requirement for Tier 2/3 heavy duty equipment.
8) The replacement of these rules with the Texas Emission Reduction Plan program.
9) The layout of the mid-course review process which details how the state will fulfill the commitment to obtain the additional emission reductions necessary to demonstrate attainment of the 1-hour ozone standard in the HGA.
10) The replacement of 2007 Rate of Progress Motor Vehicle Emissions Budget (MVEB) to be consistent with the attainment MVEBs.

The SIP revision adopted in September 2001 clarified several aspects of the 2000 SIP (but not the 90% rule, as the consent decree had just been reached in May). The 2000 SIP revisions contained other smaller measures that were immediately brought under scrutiny as soon as they were adopted. Aside from the NO_x point source reductions, the measures that were eventually repealed were:

- **Construction Equipment Operating Restrictions –** Rrestricted the use of heavy-duty diesel construction equipment from 6:00 AM to Noon from April to October in five of the eight HGA counties.
- **Accelerated Purchase of Tier 2/Tier 3 Diesel Equipment** – Required the early retirement of older equipment and purchase of newer, cleaner non-road diesel equipment.
- **Speed Limit Reduction** – Reduced the speed limit of all roadways with a speed limit above 55 mph to 55 mph.

The construction restrictions and the accelerated purchase were repealed in the 2001 SIP revisions that were adopted on September 26th, 2001. The speed limits were revised to 5 mph below their original limits in a small revision adopted in September 2002.

The accelerated purchase of Tier 2/Tier 3 Diesel Equipment control strategy was intended to control NO_x emissions from non-road vehicles. These vehicles characteristically use diesel engines that inherently emit more NO_x, but less VOCs, than gasoline engines. According to the 2000 HGA approximation used in the 2004 MCR, non-road vehicles, in addition to area sources, release 11% of the VOC emissions by volume and 17% of the NO_x emissions.[196] This significant portion, of which diesel equipment makes up the majority, was controlled solely by federal standards. The standards, termed Tier 1/2/3, were set to increase the strictness of engine standards in a stepwise progression. The timescale for the implementation of each increase had been decided by the federal government to allow the engine manufacturing industry to develop and produce the necessary technology.

The state sought to speed up the implementation of these standards because the federal timescale would not take full effect until after Houston's 2007 attainment deadline. Section 209 of the FCAA protects the federal governments right to set these standards: "No State of political subdivision thereof shall adopt or attempt to enforce any standard relating to the control of emissions from new motor vehicles or new motor vehicle engines."[197] This restriction applies to both on and off-road vehicles with the exception of California (which is allowed to set their own standards because of legislation put in place before federal standards). Several legal challenges were filed after the 2000 SIP revisions, including several against the accelerated purchase rule. As previously stated, the rule was repealed in the 2001 SIP Revision.

While Texas' inability to reduce non-road emissions frustrated the search for emission reductions, many believe federal preemption of engine standards has several benefits outside of Houston's ozone problem. Jed Anderson, an attorney for the Port of Houston Authority, argues that not only are many of these engines that are subject to the standards nationally mobile (if not internationally considering the Port), but the implementation of state standards would create separate markets across the country. Using the separate California standards as an example, it becomes clear what 50 separate state standards might occur.[198] Another issue arises from the slow turnover associated with diesel vehicles. Dr. Herb McKee notes, "EPA vehicle emission standards apply to new vehicles at the time of manufacture. Because of turnover, passenger vehicles have a delay of 8 to 10 years before full benefits are achieved; however, normal replacement schedules for diesel vehicles often range from 20 to over 30 years."[199] In order to reduce the non-road sector of emissions, a substitute program was implemented in the 2001 SIP revision. Entitled "Texas Emissions Reduction Plan" (TERP) and modeled after the Carl Moyer Memorial Air Quality Standards Attainment Program in California, the program provides "grants and other financial incentives for emission reductions and alternatives to certain components of the SIP."[200] The major portion of this program was dedicated to replacing the emission reductions lost by the repeal of the construction ban and the accelerated purchase rules. The program was jeopardized in 2002 when the primary source of funding, a tax on out-of-state vehicle registrations, was found to be unconstitutional. After the EPA proposed a failure to implement, the 78th Texas

Legislature passed House Bill 1365 which restored funding to the program through an increase in vehicle title fees.[201] Following this action, the funding was less than the initial amount, but increased each year and has resulted in cost effective reductions per ton of NO_x.[202]

2002-2004 – HRVOC Controls

The findings from TexAQS 2000 prompted a shift in the ozone strategy from a NO_x based strategy to a mixed strategy controlling both precursors with higher precision and more emphasis on monitored data.

HRVOC controls were added to the SIP in two phases. The first implementation came in the 2002 SIP revisions and the second phase in the 2004 MCR. In December 2002 the first SIP revision that incorporated the TexAQS 2000 findings was adopted. New HRVOC reductions substituted lowering the NO_x reductions from 90% to 80%. The HRVOC reductions focused on 4 different sources: fugitives, flares, process vents, and cooling towers and accounted for approximately a 36% reduction in industrial HRVOC emissions.[203] Technical documentation that accompanied the SIP supported that the "air quality specified in the approved December 2000 HGA SIP" would still be met after the HRVOC substitution. As of the last revision of this document, the EPA has yet to take action on this SIP and the HRVOC substitution.

The new HRVOC rules were designed to be "performance-based, emphasizing monitoring, recordkeeping, reporting, and enforcement rather than establishing individual unit emission rates."[204] The 2002 SIP defined HRVOC as ethylene, propylene, 1-3,butadiene, and butenes in Harris County and ethylene and propylene in the other seven counties in the HGA nonattainment area. The new controls were applied to essentially any process involving an HRVOC. Because VOCs are not solely products of combustion as in the case of NO_x and are often used as initial inputs, they can be present throughout a process stream. This results in many more opportunities to be leaked into the atmosphere. The 2002 SIP addressed the HRVOC emissions from 4 different sources: cooling towers, vent gas, flares, and fugitives. VOC emissions often end up in industrial process cooling tower emissions because of a leak in the process stream. Water is used to cool off processes and if there is a small leak with positive pressure on the process side relative to the water, the process fluid will leak into the water. When this water is cycled through a cooling tower, the process fluid can volatilize into the atmosphere. Flares and vent gas streams emit VOCs into the atmosphere similarly to NO_x but are not necessarily products of combustion; rather they are often the products of incomplete combustion. Because of VOCs presence throughout the process stream and their tendency to volatilize, anywhere there is a leak in the process an emission can exist. This means that all connections throughout a process can be a potential emission source. These emissions are collected into the fugitives category and are particularly hard to quantify and reduce.

To control emissions from process vents, flares, and cooling towers the 2002 SIP set a site-wide cap calculated on a 24-hour rolling average. These site-wide caps were required to be in compliance by April 1, 2006. The regulations set up more stringent monitoring and testing requirements than in the past, but relied on continuous flow monitors to calculate the emissions from the flow rate.[205]

Fugitive emissions are controlled through monitoring and equipment standards. The fugitive emissions monitoring requirements are listed in the Leak Detection and Repair (LDAR) program. Significant changes to the LDAR program in 2002 require testing that varies from weekly to monthly to quarterly depending on the type of equipment and whether it has previously leaked, repairs to be made within specific time limits, and added equipment standards and efficiencies. Compliance with the new rules was required before the end of 2003. In addition, an audit was required every two years by an independent third party (not the site company or the current LDAR contractor).[206]

While the new HRVOC rules signified an important shift in the strategy, they represented only the initial phase of HRVOC rule implementation. The TexAQS 2000 findings showed the VOC emissions inventories were significantly off, but created debate about whether the underestimation was continuous or variable. In previous modeling, hourly emission rates were continuous throughout the day, calculated from a yearly average; in reality VOC emissions were found to be highly variable throughout the day.[207] The fluctuations in emission rates are a result of the variability in industrial emissions arising in part from sudden accidental releases or "upsets." In order to assess this problem, a regulation was passed on January 31, 2003 that lowered the emission event required reporting level from 5,000 to 100 lbs over the permitted amount.[208] This regulation created an Emission Event Database to better characterize emissions over time and improve the model performance. In their report "State of the Science of Air Quality in Eastern Texas: Major Scientific Findings and Recommendations," Dr. David Allen of University of Texas and Dr. Eduardo Olaguer of the Houston Advanced Research Center find that, "roughly 3 times per month in 2003, reported emission events caused single facilities to have emissions of ethene, propene, butenes or butadiene that were greater than 10,000 lb/hr (the total annual average emissions of these highly reactive volatile organic compounds, from all industrial point sources in the Houston-Galveston region is approximately 5,000 – 10,000 lb/hr)."[209] The improved understanding of emission variability helped to create more effective regulations in the 2004 MCR using a two-pronged approach to controlling HRVOC emissions rather than the single rolling 24-hr cap introduced in the 2002 SIP.

The MCR that was required by May 2004 was proposed late on June 23rd, 2004 and adopted on December 6th, 2004. It represents the final phase of implementing the HRVOC strategy, refining the controls of the 2002 revisions, while retaining most of the NO_x controls from the 2002 SIP, including the 80% NO_x emission reduction. Incorporating the emissions event database to improve the model, the MCR notes, "[r]esults from the TexAQS 2000 and recent photochemical modeling suggest that ozone formation in the HGA stems from a combination of two different events: (1) the daily variable routine emissions of a large industrial base located in an urban core, and (2) short-term releases of extremely highly reactive VOCs in the immediate presence of NO_x. A two part approach is required in order to address this problem effectively."[210] This two-part approach limits both the long term and short-term emissions using a site cap on yearly emissions along with a not-to-exceed limit on HRVOCs of 1200lbs/hr.[211]

The MCR also contained provisions for a HRVOC Emissions Cap and Trade (HECT) program to create incentive-based reductions. The program will establish a baseline for each account as the average annual HRVOC emissions from 2000-2004. The first control period will be from April 1, 2006 to December 31, 2006 with only 75% of the annual emissions in the initial allocation. Allowances may be traded as current year, future year or stream trades and unused allowances can be banked for one year. Because of the separate definitions of HRVOC, no trades will be permitted between Harris County and the surrounding seven counties. This stipulation also stands to prevent an influx of emissions into Harris County.[212]

Elements of the MCR notably include the repeal of the Heavy Duty Idling Restriction and the Commercial Lawn and Garden Restriction. This comes as a result of modeling that shows these rules are no longer needed to reach attainment of the 1-hr standard.[213]

The 2004 MCR stands to be the last SIP revision for the 1-hr standard if approved by the EPA. The next step in Houston's attainment will be producing a SIP for the 8-hr standard, due by 2007. Many believe that this will be a tougher standard to achieve with design values averaged over eight hours instead of one. The focus then shifts from the rapid ozone formation events to background ozone levels and transport from other areas that affect the sustained rise throughout the day rather than the short spikes that the recent science has focused on explaining. Many of these issues specific to the 8-hr standard will be assessed another landmark study in TexAQS II set to begin in the summer of 2005.

While there have been many controversies throughout the history of the regulation and progress has been slow, Guy Donaldson of EPA Region 6, feels it necessary to understand, "many of the latest control strategies based off of the large scientific advances achieved in TexAQS 2000 have yet to be implemented and will result in significant improvements."[214]

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[210] TNRCC. "Revisions to the State Implementation Plan for the Control of Ozone Pollution. Houston Galveston /Brazoria Ozone Nonattainment Area. 23 June 2004. Page 5-7.
[211] TNRCC. "Revisions to the State Implementation Plan for the Control of Ozone Pollution. Houston Galveston /Brazoria Ozone Nonattainment Area. 23 June 2004. Page 5-2.
[212] TNRCC. "Revisions to the State Implementation Plan for the Control of Ozone Pollution. Houston Galveston /Brazoria Ozone Nonattainment Area. 23 June 2004. Page 5-2.
[213] TNRCC. "Revisions to the State Implementation Plan for the Control of Ozone Pollution. Houston Galveston /Brazoria Ozone Nonattainment Area. 23 June 2004. Page 5-1.
[214] Interview. Guy Donaldson. 25 January 2005.

Appendix A

Interviewee and Reviewer List

Name	Title	Affiliation
Allen, Dave	Gertz Regents Chair in Chemical Engineering, Ph.D	University of Texas
Alvarez, Ramon	Scientist, Ph.D.	Environmental Defense
Anderson, Jed	Attorney	Port Authority Atty
Ayers, Victor	Senior Staff Analyst	Mayor's Office, City of Houston
Barbre, Bruce	Regional SH&E Advisor Americas	ExxonMobil
Berger, Pam	Director of Environmental Policy	Mayor's Office, City of Houston
Beskid, Craig	President	Mickey Leland National Urban Air Toxics Research Center
Blackburn, Jim	Attorney	Blackburn Carter LLP
Cappiello, Dina	Environment Writer	Houston Chronicle
Carmen, Neil	Clean Air Program Director	Sierra Club Texas
Cook, Steven	Sr. Corporate Counsel	Lyondell
Crossley, David	President	Gulf Coast Inst.
Crow, Walt	Contact Manager	URS Corporation
Dawson, Bill	Former Environmental Writer	Houston Chronicle
Deason, Doug	Senior Staff Engineer	ExxonMobil
Donaldson, Guy	Texas SIP	EPA, Region 6
Durrenberger, Cyril	Senior Lecturer in Chemical Engineering	University of Texas; former TCEQ
Feldcamp, Lawrence	Attorney (Retired)	Baker Botts LLP
Flannery, Richard	Technical Specialist, Waste Section	TCEQ
Flatt, Victor	Law Professor	University of Houston
Frels, Kelly	Senior Partner	Bracewell Patterson LLP
Gaudet, Monica	Manager, Environment	GHP
Giblin, Pam	Attorney	Baker Botts LLP
Hall, John	Consultant	TERC
Hamilton, Winnie	Assistant Professor, Ph.D.	Baylor College of Medicine
Healy, Meg	Research Director	GHASP
Hendler, Liz	Consultant	GHP/BCCA; former TCEQ
Holmes, Christian	Executive Director	Shell Center for Sustainability
Hushka, Leslie	Chemical Issue Advisor	ExxonMobil
Jeffries, Harvey	Professor Environmental Sciences and Engineering	UNC
Keel, Kelly	HGA SIP Coordinator	TCEQ
Klineberg, Steven	Professor, PhD	Rice University
Kuryla, Matt	Attorney	Baker Botts LLP
Lester, Jim	Director, Environmental Group	HARC
Mannchen, Brandt	Chair, Houston Air Quality Committee	Sierra Club; founding member of GHASP
Marquez, Ralph	Commissioner	TCEQ
McKee, Herb	Consultant/Lecturer	former TACB; University of Houston
Mueller, Chuck	Program Specialist	TCEQ
O'Donnell, Frank	Executive Director	Clean Air Trust, Washington, D.C.
Olaguer, Jay	Sr. Research Scientist	HARC
Pepple, Karl	Senior Air Quality Planner	H-GAC
Sigman, Dave	Chief Environmental Counsel (Retired)	ExxonMobil
Stock, Tom	Professor	UT SPH
White, Bill	Mayor	City of Houston
Wilson, John	Director	GHASP
York, Larry	GIS Specialist	Health Department, City of Houston

<u>**Appendix B**</u>

Summary of NO_x/VOC tpd reductions of December 2000 SIP control measures

Type of Measure	Description	NO_x	VOC
EXISING FEDERAL MEASURES			
Federal on – road	These reduction estimates reflect the difference of 1993 vs. 2007 on-road emissions, which consider the effect of federal controls and growth	201	98
Federal area/non-road	These reduction estimates reflect the difference of 1993 vs. 2007 area and non-road emissions, which consider the effect of federal controls and growth	8	35
ADDITONAL FEDERAL MEASURES			
Heavy-Duty Engine Consent Decree	Additional fleet turnover of cleaner heavy-diesel trucks subject to federal standards embodied in the consent decree	5	0
Federal Measures Total		**214**	**133**
STATE			
A. Base Measures (November 1999 SIP) **1. State Rules**			
Point Source NO_x	- Requires a wide variety of minor and major stationary sources to meet new emission specifications and other requirements in order to reduce NO_x emissions - Requires overall NO_x reductions of 89% from these sources from the 1997 baseline (85% reduction with new, post-1997 facilities) - Requires sources with a design capacity to emit 10 tpy or more to participate in the proposed mass emission cap and trade program	595 tpd	--
Emissions Banking and Trading Program	Creates an overall NO_x Mass Emission Cap and Trade Program for the HGA. - Creates a partial bridge between the existing Emissions Banking and Trading Programs and the Mass Emission Cap and Trade Program to provide maximum flexibility in meeting the SIP	--	--

	requirements - Revises current open market rules currently located in 101.29 to: 1) Consolidate banking and trading rules into one location (101, Subchapter H) 2) Require registration of emission reduction credits within 180 days of the actual reduction 3) Provide an improved mechanism for mobile sources to generate credits 4) Guarantee that actual emission reduction are not double counted, ie, shown as a reduction in the SIP and banked for future use.		
Inspection/ Maintenance	- Requires ASM or equivalent testing as well as OBD testing - Begins May 1, 2002 for Harris County - Begins May 1, 2003 for Brazoria, Fort Bend, Galveston, and Montgomery Counties - Begins May 1, 2004 for Chambers, Liberty, and Waller Counties - Provides Chambers, Liberty and Waller Counties flexibility to submit a resolution by May 1, 2002 that is approved by the commission and EPA and provides an alternative air pollution control strategy which assures equivalent emission reductions	36.20 tpd	18.05
Construction Equipment Operating Restrictions	Establishes a restriction on the use of HDD construction equipment from 6:00 a.m. – noon starting in April 2005 - Only applies from April 1 - October 31 each year - Applies in Harris, Fort Bend, Brazoria, Galveston, and Montgomery Counties - Exempts wet concrete operations and emergency operations - Provides an exemption from the rule if an alternative plan is submitted assuring equivalent emission reductions	7.8 tpd NO_x shifted 6.7 tpd equivalent	--

Cleaner Diesel Fuel	- By May 1, 2002, the fuel will have improved aromatics and cetane for all on-road sales statewide and for all on- and non-road sales in East/Central Texas - By June 1, 2006, sulfur will be reduced to 15 ppm in East/Central Texas for on- and non-road fuel	3.98 tpd on-road 2.69 non-road	
Small, Spark-Ignition Engine Operating Restrictions	- Restricts the use of handheld and non-handheld spark-ignition equipment, for commercial use only, rated at 25 hp and below between the hours of 6:00 a.m. - noon starting in 2005 - Only applies April 1 through October 31 each year - Applies in Harris, Fort Bend, Brazoria, Galveston, and Montgomery Counties - Commercial operators are exempted from the rule in the case of certain emergencies, or if they can develop a plan to lower emissions which receives the approval of the commission and the EPA	.23 tpd NO_x shifted 12.4 tpd VOC shifted 4.6 tpd NO_x equivalent	--
VOC RACT	Implements RACT requirements for batch processes, bakeries, and offset lithographic printers	--	--
2. Local Measures			
VMEP	- SIP control strategy (no rule required) - Numerous projects have been identified by the HGAC for inclusion in the SIP such as telecommuting, bus fare promotions, alternative fuel programs, and ozone action days	23	--
Base Measures Total		**672.17**	**18.05**
B. Gap Measures **1. Federal Measures**			
Energy Efficiencies	These reductions estimates reflect the minimum standards of energy efficiency for many major appliances as established by the U.S. Congress in the National Appliance Energy Conservation Act of 1987.	3.57	--
2. State Rules			

Accelerated Purchase of Tier 2/Tier 3 Diesel Equipment	- Requires the early retirement of older equipment and purchase of newer, cleaner non-road diesel equipment - Phased-in implementation beginning in December 2004 - Provides an exemption from the rule if an alternative plan is submitted assuring equivalent emission reductions	12.20 tpd	1.86
Speed Limit Reduction	- The speed limit on all roadways with a current maximum speed limit above 55 mph would be reduced to 55 mph in the 8-county area - Starts May 1, 2002	12.33 tpd	1.76
Airport GSE	The rule was withdrawn, however, agreements were reached with Continental Airlines, Southwest Airlines, and the City of Houston to make certain local reductions of NO_x from sources at Houston area airports. These federally enforceable agreements are equivalent to the NO_x reductions proposed in the rulemaking package being withdrawn	5.09 tpd	--
California Spark-Ignition Engines	- Requires manufacturers to ensure that all affected large spark ignition engines are certified to California LSI standards - Exempts agriculture and construction equipment less than 175 hp, recreational equipment, stationary engines, marine vessels, and equipment on tracks - Statewide rule	2.80 tpd	7.58
Vehicle Idling Restrictions	- Limits idling for all vehicles over 14,000 pounds to five consecutive minutes - Begins April 1, 2001 - Only applies from April 1 through October 31 each year	0.48 tpd	0.19
Gas-fired Water Heaters, Small Boilers, And Process Heaters	Rule already adopted for statewide sales of water heaters, small boilers, and process heaters	0.50 tpd	--
2. Local Measures			

TCMs	- SIP control strategy (no rules required). - Numerous projects have been identified by H-GAC for inclusion in the SIP, such as traffic signalization and bicycle/pedestrian projects.	1.06 tpd	2.13
Gap Measures Total		**38.03**	**13.52**
Equivalent NO_x reduced as a result of VOC reductions		**1.14**	
Gap		**90.9**	
Remaining gap to fill		**51.73**	

Appendix C

TexAQS 2000 Findings Accelerated Science Evaluation of Ozone Formation in the Houston-Galveston Area Executive Summary (11/13/2004)
Issue 1: What are the likely causes of rapid ozone formation events?
Finding 1: Almost without exception, air parcels with very high ozone concentrations, observed by aircraft during the Texas Air Quality Study, had back trajectories that indicated a substantial contribution of emissions from industrial source regions. These air parcels also had chemical compositions that were representative of industrial sources, rather than typical urban sources.
Finding 2: The rate of ozone production in and around the industrial source dominated areas in Houston can be very high; ozone formation rates ranging between 50 ppb/hr and 150 ppb/hr were measured on multiple days during the month long Texas Air Quality Study.
Finding 3: The efficiency of ozone production in and downwind of the industrial source dominated areas in Houston can be very high, ranging from 10-20 molecules of ozone per molecule of reacted NOx.
Finding 4: Ozone production in the Houston urban plume was found to be slower and less efficient than in the composite industrial plume from the Ship Channel region and in plumes from isolated petrochemical facilities.
Finding 5: The high rates and high efficiencies of ozone production in the industrial plumes are driven by high concentrations of reactive hydrocarbons in the presence of NOx.
Finding 6: Industrial hydrocarbon emissions are significantly underestimated.
Finding 7: Observations of wind fields aloft, and other meteorological phenomena during Texas Air Quality Study, support and refine the evolving conceptual model of meteorological conditions that lead to ozone formation in the Houston-Galveston area.
Issue 2: How will the rapid and efficient ozone formation observed in industrial plumes respond to VOC controls and NOx controls?
Finding 8: The chemical mechanisms for ozone formation currently employed in models of air quality in the Houston-Galveston area are adequate to explain the main features of rapid and efficient ozone formation observed in industrial plumes.
Finding 9: Ground observations of hydrocarbon concentrations, taken over a period of several years, and aircraft data collected during the Texas Air Quality Study, identify numerous episodes with very high hydrocarbon concentrations. While the species detected at high concentrations vary from episode to episode, most hydrocarbon species emitted from industrial sources have been detected at high concentration in at least some episodes.

Finding 10: Measurements, made by the Baylor aircraft downwind of industrial sources in the fall of 2001, suggest that while some industrial plumes are well mixed, other plumes are spatially heterogeneous. The spatially heterogeneous plumes can contain regions with high concentrations of VOC, regions with high concentrations of NOx and regions with high concentrations of both VOC and NOx. Whether a plume is well mixed or heterogeneous is likely to depend on the distance from the source and atmospheric stability conditions.
Finding 11: Results from box model simulations run under conditions based on Houston's industrial regions suggest that emissions of as little as 100 pounds of light alkenes (ethylene, propylene, butenes, pentenes, butadiene) and aromatics can lead to >50 ppb enhancements of ozone concentrations over a 1 km2 area. Ozone productivities of alkane emissions are generally significantly lower than for alkenes and aromatics. The box model simulations also indicate much higher ozone productivities under conditions that involve high concentrations of both VOC and NOx, as opposed to conditions that involve high concentrations of VOC alone.