TEXAS ENVIRONMENTAL RESEARCH CONSORTIUM

environmental improvement through research and science

Strategic Research Plan 2004-2007

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NOTE
This document will be revised from time to time to reflect research findings, stakeholder input, and on-going plan evaluation.

For updated information see
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Strategic Research Plan
Texas Environmental Research Consortium

Overview

Over nine million Texans live in the Houston-Galveston-Brazoria and Dallas-Ft. Worth metropolitan areas. These regions account for more than half of the State's economy and employment levels. Reducing air pollution, to comply with Federal air quality mandates, is one of the most pressing public policy challenges facing these regions today. Economic analyses[1] suggest that failure to meet federal mandates will result in more than $25 billion in lost economic development for the State. In response to this air quality challenge, government, business and community leaders in the Houston-Galveston-Brazoria and Dallas-Ft. Worth regions established a non-profit organization, the Texas Environmental Research Consortium (TERC), to improve the scientific basis for air quality decision-making.

The initial focus of TERC was on ozone formation in the East Texas Gulf Coast region, specifically, the Houston-Galveston area. This initial focus was consistent with regulatory timelines and with the Coastal Impact Assistance Program (CIAP), the primary source of initial funding for the Consortium, which was dedicated to coastal environmental improvements. As the Consortium has evolved, it has broadened its activities beyond the coastal region, to include all of the urban areas in eastern Texas that are in non-attainment of the federal clean air standard for ozone, particularly the Dallas-Fort Worth non-attainment area. This expanded geographical scope of activities facilitates the transfer of improvements in air quality modeling and scientific understanding of ozone formation among regions. A consequence of this enlarged scope is increased focus on regional transport of pollution affecting not only the non-attainment areas, but also the near non-attainment areas of East Texas. In addition, the Consortium has expanded its efforts to a broader range of air pollutants than just ozone. Specifically, the Consortium has expanded its charge to include fine particulate matter and hazardous air pollutants. This expansion in charge is necessary to ensure that air quality strategies for multiple pollutants are consistent and complementary.

The Charter of the Consortium[2] calls for the development of a Strategic Research Plan that guides decisions on research to be supported by TERC. The Plan is to be prepared and updated in consultation with the TERC Science Advisory Committee (SAC), the Texas Commission on Environmental Quality (TCEQ), and the U.S. Environmental Protection Agency (EPA). In addition, other stakeholders are afforded the opportunity to review and offer comments on the plan. The first version of the Strategic Plan was issued in August 2002, and the Plan has been updated, with the same opportunities for broad involvement, as understanding of air pollutant formation and air quality modeling in eastern Texas has evolved. The Strategic Research Plan set forth in this document identifies key issues, examines the related activities of other organizations, and recommends areas of focus and action for the Consortium.

The TCEQ has a unique role in relation to TERC's research planning. The TCEQ is responsible for developing and implementing the State Implementation Plan (SIP) to comply with federal air quality standards. TERC seeks to complement the TCEQ's role in formulating the SIP by providing the best science available as raw material for modeling, technical, and policy decisions, and by working collaboratively with the TCEQ to ensure that TERC's research does not duplicate the TCEQ's internal efforts. As such, TERC recognizes the valuable input of the TCEQ's Science Coordination Committee (SCC) in the identification of fruitful research avenues to be explored by TERC. Combined with the input of TERC's other stakeholders, a collaborative partnership with the TCEQ ensures that TERC's research will yield practical air quality benefits to the citizens of Texas. It should be stressed that all research considered in this Strategic Research Plan will be evaluated and further refined to maximize benefit for SIP planning purposes.

[1] Perryman Group, Report to Texas Conference of Urban Counties, "The importance of maintaining a proper state implementation plan (SIP) to address air quality issues in Texas: An economic and fiscal impact assessment", November, 2002, available at: http://www.harc.edu/harc/Projects/AirQuality/Projects/Status/Files/H14PerrymanReport.pdf.
[2] http://www.harc.edu/harc/Projects/AirQuality/Information/Background/Charter.aspx

Key Issues

The goals of the consortium are to improve the scientific understanding of air pollutant formation and to facilitate the development of sound air quality policies. Implicit in the scientific and policy goals of the Consortium are the need to continually assess progress and the need to effectively disseminate information. Therefore, the presentation of key issues and needs will address the following areas:

- Scientific issues
- Policy issues
- Health issues
- Methods for assessing progress and
- Information dissemination.

Scientific Issues

The shift from the 1-hour ozone standard to the new 8-hour standard expands the requirements of air quality research for the future. Table 1 below outlines some of the differences that result from this shift.

Table 1. Key 1-hour and 8-hour scientific issues

Research Area	Primary Issues for 1-Hour Ozone Standard	Additional Issues for 8-hour Ozone Standard
Meteorology	Boundary Layer Horizontal Flow	Free Troposphere Vertical Motion
Modeling and Transport	Urban/Regional Scales Day-Time Transport	Regional/Continental Scales Night-Time Transport
Chemistry	Highly Reactive VOCs Rapid Ozone Formation Radical Sources and Sinks	Other VOCs Long-lived Intermediates NO_x Sources, Reservoirs, and Sinks

It should be noted that all the research issues identified and pursued relative to the 1-hour standard remain important under the 8-hour standard. Nevertheless, new issues must now be considered that were not major priorities in previous research. It is not our intent to produce a comprehensive list of such issues, but to identify those that are anticipated to have the greatest impact on the State Implementation Plan. It is these issues that are listed in the third column of Table 1. They are discussed in greater detail below, along with emissions and control strategies.

Meteorology

Under the one-hour standard, ozone and its precursors above the Planetary Boundary Layer (PBL), the lowest layer of the troposphere in which turbulence plays a dominant role, were not a major concern in model simulations of ozone exceedances. Under that standard, the two most important meteorological factors affecting ozone episodes, besides temperature and sunlight, were the height of the PBL and the strength and direction of horizontal wind flow. For example, properly modeling the effects of coastal breezes in Houston was of paramount importance.

Under the new eight hour ozone standard, it becomes much more important to examine the ozone and precursors that can come from above the PBL, that is in the free troposphere up to the tropopause, roughly 10 km in altitude. It is known that tropopause folds associated with cold fronts and cut-off lows can induce a rapid downward descent of ozone into the PBL from the free troposphere and the ozone-rich stratosphere, but these events were not typical among 1-hour ozone exceedances. Even weaker downward motions, however, may be important in contributing to exceedances of the 8-hour ozone standard.

Ozone and precursors in the free troposphere can come from very distant regions. For example, it is well known that Saharan dust can contaminate the skies over the Southeastern United States by riding wind jets in the free troposphere. Likewise, a city or power plant can contribute to a distant area's non-attainment by venting pollutants from the boundary layer to the free troposphere. This venting of pollution is associated with deep convection, which also forces the surrounding air in an entire region to slowly subside, providing a means for the vented pollution to come back into the PBL after traveling a large distance horizontally. Current SIP models have altitude levels that reach up to about 4-6 km. This is too low to account for long-range transport via the free troposphere. Suggestions for meteorological research are as follows:

- Develop a formal conceptual model for the meteorology of ozone exceedances in the entire region of East Texas, including the role of intrastate and continental-scale transport.
- Improve the ability of meteorological models to simulate the surface night-time jet.
- Improve the response of meteorological models to sea surface temperature through the assimilation of high resolution satellite data.
- Improve the process of meteorological data assimilation using novel tools such as the Ensemble Kalman Filter and the Rapid Update Cycle model.
- Develop and deploy real-time meteorological forecast models to facilitate planning and execution during the Second Texas Air Quality Study.
- Conduct evaluation and intercomparison studies of vertical mixing schemes in meteorological models, including parameterizations of deep convection.
- Conduct comprehensive evaluations of meteorological model performance, using benchmarks such as the ability to simulate the diurnal temperature profile, the evolution of PBL height, and the nocturnal jet.
- Facilitate the transition from MM5 to the WRF meteorological model.
- Improve the ability of meteorological models to operate at fine spatial resolutions.
- Develop data sets that more accurately represent physical land surface characteristics and deploy them in land surface and meteorological models.

Modeling and Transport

Gridded photochemical models play a key role in the State Implementation Plan (SIP) process. To adequately address the new 8-hour ozone standard, models must now account for the impacts of long-range transport. The fact that pollution can travel very long distances in the free troposphere before descending into the PBL means that high background ozone in Texas may originate from industrialized areas all over the North American continent. The typical horizontal extent of SIP models used in Texas may not be sufficient to account for this phenomenon.

In addition to considering long-range transport, we must also consider more localized transport that occurs at night as wind speed increases. Night-time jets near the surface transports pollutants downwind, but our current inability to simulate this process dependably must be overcome in order to correctly account for its impacts. Suggestions for modeling and transport research are as follows:

- Improve model descriptions of key atmospheric processes, such as the chemistry of particulate matter formation in the atmosphere, the gas-particle partitioning of semi-volatile species, and the deposition of chemical species.
- Improve the specification of surface characteristics, such as Leaf Area Index and land cover.
- Evaluate models through process analysis and intercomparison studies.
- Use data from the Texas Air Quality Study to evaluate the ability of current models to replicate ozone and particulate matter formation.
- Develop and deploy data assimilation tools for atmospheric chemistry models.
- Develop and deploy real-time air quality forecast models to facilitate planning and execution during the Second Texas Air Quality Study.
- Facilitate the transition from CB4 to an expanded chemical mechanism such as RACM or SAPRC.
- Improve the ability of photochemical grid models to operate at fine spatial resolutions.
- Expand the horizontal and vertical domains of air quality models.

- Expand the use of source apportionment tools to characterize pollutant transport.
- Explore the significance of transport mechanisms such as the nocturnal jet and processes involving deep convection and the free troposphere.
- Examine the sensitivity of pollutant transport to fundamental representations of meteorological and chemical processes.
- Evaluate the role of the Gulf of Mexico in contributing to ozone exceedances.

Chemistry

The occurrence of rapid night-time transport near the surface and over longer distances in the cold free troposphere highlights the importance of chemical reactions that do not take place in the warm sunlit PBL. Different pollutants that are the by-products of VOC/NOx chemistry (e.g., PAN) may live longer under these conditions and influence larger areas than their cities of origin. The chemistry of these compounds is only very roughly accounted for in current Texas SIP models and may need to be considerably improved, through both surface and aircraft monitoring and fundamental mechanistic studies. The environmental chamber data used to develop and evaluate mechanisms used in current models are not adequate to test mechanisms for night-time conditions or multi-day scenarios.

Additionally, under the one-hour ozone standard, rapid ozone formation due to Highly Reactive VOCs (HRVOCs) became an intense focus of research. Under the eight hour standard, however, we may need to re-examine the importance of Other VOCs (OVOCs) that are emitted in large quantities, such as n-butane, which observations have shown to be underestimated in current emissions inventories. Moreover, analyses of reactivity-weighted VOC concentrations in Houston indicate that OVOCs can surpass butenes and 1,3-butadiene in importance.

Uncertainties in the atmospheric chemistry of aromatic hydrocarbons and oxygenated VOC intermediates continue to be important sources of uncertainty in model predictions. Aromatics are reactive compounds that are important both as radical sources and NOx sinks, and current models represent aromatics using parameterized mechanisms whose predictions are not consistent with newer environmental chamber data. Radical sources and sinks affect predictions of ozone formation rates while NOx sources and sinks affect predictions of regional ozone. The chemistry of oxygenated intermediate is expected to become increasingly important in multi-day simulations, and continues to be uncertain because such compounds are difficult to identify and study.

The Second Texas Air Quality Study presents an opportunity to study a broader set of atmospheric chemistry issues than was examined in TexAQS 2000. Monitoring by surface and airborne instruments should play a key role in providing data for further elucidating the chemical mechanisms governing both ozone and particulate formation. Suggestions for atmospheric chemistry research are as follows:

- Develop and deploy advanced instrumentation for monitoring a comprehensive set of hydrocarbon and nitrogen species aloft and at the surface.
- Investigate the importance of night-time chemical reactions, especially those involving nitrogen reservoirs.
- Investigate the effects of uncertainties in aromatic chemistry on model predictions of control strategies.
- Investigate the importance of Other VOCs that may be underestimated in current inventories in model predictions of ozone formation.
- Investigate the importance of oxygenated intermediate products of VOC decomposition in regional atmospheric chemistry.
- Evaluate gas to particle chemical pathways and the partitioning of semi-volatile species between gas and particle phases.
- Evaluate the implications of reactions that may occur on particle surfaces.
- Evaluate and inter-compare the ability of chemical mechanisms to predict particulate and ozone formation.
- Collect laboratory chamber data to evaluate mechanisms and models.
- Develop chemical mechanisms specifically designed and evaluated for regional and multi-day model simulations applicable to conditions found in Texas.
- Develop gas-particle partitioning models evaluated for conditions found in Texas.

Emissions

Emissions inventories are still in need of fundamental improvement, both in terms of reconciling them with observations of ambient pollutant concentrations (top-down approach) and in terms of basic estimation building blocks (bottom-up approach). Suggestions for research in this area are as follows:

- Evaluate the relative importance of various uncertainties in the current emissions inventories in order to appropriately prioritize research.
- Improve point source inventories, accounting for the magnitude and variability of emissions.
- Improve mobile and area source inventories based on population counts, activity data, and engineering process characterization.
- Improve the spatial and temporal resolution of emission estimates.
- Continue the process of comparing predictions to observations.
- Develop and deploy inverse models using both trajectory and grid approaches.
- Deploy satellite data to improve representations of land use/land cover and corresponding biogenic emissions.
- Obtain better data on rates, compositions and size distributions of particulate matter emissions from point sources, mobile sources and cooking.
- Improve speciation information for various sources and evaluate speciation data against measurements.
- Develop or improve emission inventories for ammonia and reactive high molecular weight organics.
- Examine scientific findings in Houston regarding petrochemical emissions and their importance for ozone formation, considering how they might be extrapolated to petrochemical plants elsewhere in east Texas.

Control Strategies/Technologies

Improving air quality in Texas depends on implementing control strategies and technologies that are both scientifically justified and cost effective. Implementing ineffective strategies squanders valuable time and resources. Suggestions for control strategy/technology research are as follows:

- Evaluate the effectiveness of various transportation control measures and mobile source emission reduction strategies in reducing emissions and ambient pollutant levels.
- Develop improved methods for quantifying emission reductions associated with on-road mobile, area, and non-road control strategies.
- Evaluate the effectiveness of spatially/temporally limited control strategies, which may be more cost-effective.
- Since most regions in Texas are NO_x-limited, survey and evaluate available new technologies and process modifications for reducing NO_x emissions.
- Survey and evaluate available technologies and process modifications for reducing emissions of VOCs.

TERC seeks to support projects that complement the Texas Commission on Environmental Quality's New Technology Research and Development (NTRD) Program, which is part of the Texas Emissions Reduction Plan (TERP). The NTRD provides incentives to encourage and support research, development and commercialization of technologies that reduce pollution in Texas.

Policy Issues

Addressing the key scientific issues identified above will provide the foundation on which an evaluation of ozone and fine particulate matter formation can be built. However, improving understanding in each of the key areas, then synthesizing that information and evaluating air quality improvement strategies, is a time consuming process. While it is essential that this process proceed, there is also a compelling need to immediately address a number of questions related to policy decisions. These questions are:

- What emission reductions lead to the greatest reductions in ozone concentrations?
- Will emission reductions selected to achieve the current air quality standard for ozone (based on one-hour

averaged concentrations) also reduce concentrations of particulate matter and lead to attainment of the new ozone standard (based on 8-hour averaged concentrations)?
- How important are regional contributions to air pollution and will emission reductions designed to achieve the current air quality standards, in Texas and elsewhere, also reduce long range transport of air pollutants?
- What new emission reduction technologies or strategies can be effectively applied in Texas?
- How do current uncertainties in emissions and models affect predictions of the models that are used as a basis for control strategy decision-making?

It will eventually be possible to address these questions using comprehensive air quality models, built using better scientific understanding resulting from the types of projects recommended earlier. However, regulatory timetables may require that some decisions be made before models are fully capable of addressing these questions. Therefore, it is desirable to use analysis tools that are currently available to provide directional guidance for policy decisions. The types of analysis tools needed are summarized in Table 2.

Table 2. Key policy issues

Issue or Analyses needed	Actions needed
What emission reductions lead to the greatest reductions in ozone concentrations (1-hour averaged)?	Assess the trade-offs between controlling emissions of highly reactive hydrocarbons and nitrogen oxides using gridded photochemical models, Lagrangian (plume) models, and other tools. Evaluate the potential impacts of cap and trade programs.
What emission reductions lead to the greatest reductions in ozone concentrations (8-hour averaged)?	Assess the trade-offs involving emissions of highly and other reactive hydrocarbons and nitrogen oxides using gridded photochemical models, Lagrangian (plume) models, and other tools. Assess whether strategies used to attain the current ozone standard will be directionally consistent with achieving the new ozone standard, including transport considerations.
How significant is regional transport of air pollutants?	Assess the trade-offs between local and regional emission control strategies using gridded photochemical models. Assess the relative importance of regional transport of air pollutants in meeting current and future air quality standards.
Will fine particulate matter concentrations and regional haze be reduced as a result of actions taken to reduce ozone concentrations?	Assess the trade-offs between controlling emissions of reactive hydrocarbons and nitrogen oxides using gridded photochemical models, Lagrangian (plume) models, and other tools. Assess whether strategies used to attain the current ozone standard will be directionally consistent with achieving the fine particulate matter and regional haze standards.

The impacts of current uncertainties both in model inputs (e.g., emissions) and formulation (e.g., mechanisms) should be evaluated as parts of these assessments, especially if models are used whose inputs have to be adjusted to yield predictions that are consistent with observations.

These policy assessments should be complemented with a carefully chosen group of technology demonstrations. The Texas Commission on Environmental Quality (TCEQ) is currently preparing a strategic plan for technology demonstration and the Consortium could use that plan to select critical demonstrations to be funded.

Health Issues

All of the work done on characterizing the science of air pollution and identifying policies for improving air quality should be done recognizing that the primary goal of air pollution regulations is to protect public health. Policies should be characterized by both their contribution to improving health and their contribution to meeting air quality standards. Ideally, these two goals would be identical, but at times they are not. For example, the total health impacts of air pollutants emitted in regions with high densities of sensitive populations, such as children and the elderly, may be greater than identical emissions released in other locations.

Characterizing the health impacts of air pollutants requires estimates of exposures to air pollutants and the health impacts associated with exposures. In addition, individuals are rarely exposed to just a single air pollutant, so potential synergistic effects of multiple exposures must be considered, and considerable effort must be expended to identify the causal agents of health effects from the diverse array of air pollutants individuals are exposed to.

Much effort has been expended at the national level to characterize the health effects of air pollutants, so given its mission of developing sound air quality policies in Texas, the Consortium will focus on improving scientific understanding of exposure patterns of the specific mixtures of air pollutants found in Texas. Exposures to air pollutants in eastern Texas may be different than in other regions of the United States because of the prevalence of air conditioning, which can reduce indoor concentrations of pollutants, and because of the prevalence of mixed industrial-residential areas. The mixtures of air pollutants found in the State will also be different than in other regions because of the distinctive mix of air pollutant sources found in Texas. Table 3 summarizes the key issues associated with characterizing the health effects of air pollution in Texas

Table 3. Key issues in the Health Effects of Air Pollution

Issues or Analyses Needed	Actions needed
Are exposures to air pollution different in Texas than in other regions of the U.S.?	Assess exposures to air pollutants using estimates of activity patterns and air pollutant concentrations outdoors, in homes, in office buildings and other workplace settings, and in automobiles; coordinate with organizations in Texas currently active in these types of programs.
How can air quality research be coordinated with research on health effects to address the specific mixtures of air pollutants found in Texas?	Identify frequencies of air pollutant related health impacts through analysis of hospital records (retrospective epidemiological studies); Monitor the health effects of cohorts of sensitive populations (cohort studies); both epidemiological and cohort studies require an extensive air quality monitoring network; coordinate with organizations in Texas currently active in these types of programs.

The epidemiological and cohort studies identified in Table 3 will not be directly addressed by TERC. However, some related aspects can be addressed if air quality monitoring and exposure data are available to characterize the spatial distribution of air pollutants and the exposure of populations. This suggests that the health effects studies should be coordinated with large air quality field programs planned for eastern Texas. The coordination of this research is within TERC's organizational mandate.

Assessment and Information Dissemination

Implicit in the scientific and policy goals of the Consortium are the needs (1) to continually assess progress and (2) to effectively disseminate information. Therefore, in addition to the activities outlined above, there is the need to pursue the assessment and information dissemination activities listed in Table 4.

Table 4. Key assessment and information dissemination activities

Issues or Analyses Needed	Actions needed
How can progress in improving air quality be assessed?	Assess the ability of the current ambient air quality monitoring network to capture high quality data on air pollution events; improve the analysis methods routinely used for interpreting ambient monitoring data; contribute to comprehensive air quality field programs conducted in Texas; consider need for regional air monitoring network; develop techniques to analyze outcomes and uncertainties of expectations to better plan for, measure and attribute success
Is information about air quality being effectively disseminated?	Facilitate communication between and among scientists and policymakers (for example, by holding workshops and building well documented electronic information exchange mechanisms); synthesize and summarize scientific and policy relevant findings concerning air quality in Texas; make the information broadly available to stakeholders

The issues identified in Tables 1-4 are linked and iterative. Improved scientific understanding will lead to more informed policies, and both the policies and the scientific understanding must be continually compared with observations, and that information must be disseminated. The issues in Tables 1-4 can, however, be pursued along parallel tracks, with a regular exchange of information between the tracks. Before making recommendations for action in each of these tracks, however, it is useful to identify activities already underway through other organizations that are relevant to achieving the goals of the Consortium.

TERC Air Quality Activities and Other Organizations

Since its inception, TERC has sought to participate in air quality research and planning with the various organizations and researchers involved in ozone modeling and air quality science. TERC has relied on TCEQ's Science Synthesis Committee process and TCEQ recommendations to identify and shape many of the projects funded to date. In addition, TERC has required contractors to maintain on-going communications with TCEQ technical staff to ensure that the research process and findings were useful and timely for TCEQ's use. Rather than creating a separate process, the TERC Charter recommended participating in the Science Synthesis Committee's various activities. The TERC Science Advisory Committee was formed to provide an independent voice on research issues and to review and rank Requests for Proposals (RFPs). The TERC Board has consistently sought to ensure that there is no duplication in processes or in the projects funded.

Organizations currently funding research and data analysis activities relevant to ozone formation in East Texas are:

Texas Commission on Environmental Quality (TCEQ) The Technical Analysis Division of the TCEQ is currently conducting a wide variety of internal and external modeling and data analysis activities. Projects include:

- Developing better estimates of emissions through "bottom-up" inventory improvements.
- "Top-down" inventory evaluations, where emission inventory data from source regions near monitors are compared to observations made at the monitors.
- Aircraft based monitoring
- Evaluations of atmospheric chemical and meteorological models, and
- Modeling analyses done in support of regulatory actions.

TCEQ's photochemical modeling activities are summarized at http://www.tnrcc.state.tx.us/air/aqp/airmodeling.html. Information about the accelerated science evaluation subsequent to the Texas 2000 Air Quality Study is available at http://www.tnrcc.state.tx.us/air/aqp/airquality_science.html. Information about planning for the new Second Texas Air Quality Study (TexAQS II) is available at http://www.tceq.state.tx.us/policy/ta/am/TexAQS_II.html.

The New Technology Research and Development (NTRD) Program was originally created as the Texas Council on Environmental Technology (TCET) by Senate Bill 5 in the 77th Legislature of the State of Texas, 2001. The program was formally transferred to TCEQ in 2003 by House Bill 37. The NTRD was initiated to support the Texas Emissions Reduction Program (TERP). Specific areas of research include: retrofit/add-on technologies targeted by the TERP, advanced technologies for new engines, modeling, advanced technologies that promote building and appliance energy performance, and advanced technologies that reduce emissions from other significant sources. Funding for NTRD comes from HB 1365 and amounts to approximately $11 million for FY '05, or 9.5% of all TERP funding. Eligible applicants include individuals, companies, organizations, governments or agencies.

Texas Air Research Center (TARC) TARC is a consortium of Lamar University, the University of Texas, Texas A&M University and the University of Houston. Headquartered at Lamar, TARC receives a legislative appropriation, through the Lamar University budget, that has historically been approximately $2 million for the biennium. Most TARC projects address long-term research needs. Some TARC projects, however, will likely have an impact on the mid-course review of the Houston-Galveston air quality plan.

U.S. Environmental Protection Agency The U.S. Environmental Protection Agency has funded two cooperative agreements with Texas Universities to address air quality research needs in the region.

- In January 2000, the EPA provided $3.65 million in funding to a consortium of 7 universities, led by the University of Texas, to conduct measurements of fine particle matter composition in southeast Texas.
- In a project to run from 2002 to 2004, a consortium involving the University of Texas, Texas A&M, and led by the University of Houston will improve air quality models for the region; funding of $3.5 million has been provided by the U.S. EPA. This work has seven major aims:(1) development of a jointly operated air quality modeling facility at the University of Houston, the University of Texas and Texas A&M University, (2) the deployment of two flux measurement stations to characterize micro-turbulence, (3) the improvement of fine particulate matter modeling capabilities, (4) the development of neighborhood scale air quality modeling capabilities, (5) improving metropolitan and regional meteorological models, (6) the improvement of chemical reaction mechanisms important in air quality, and (7) the development of a data archive for air quality field measurements.
- The EPA has supported financially the TCEQ initiative to carry out contract work to develop and acquire quality assurance data on remote sensing technology to determine the combustion efficiency and emissions from operating flares, which appear to be a significant source of emissions that contribute to high ozone concentrations under some circumstances.

Coordinating the activities of all of these organizations is a major challenge, since each operates independently and each is responsible to different sponsors. Nevertheless, there is reason to be optimistic about the ability of these organizations to coordinate studies of air quality in eastern Texas. Led by the TCEQ, a Science Coordinating Committee, comprised of scientific experts in air quality, representatives of organizations funding air quality research, and representatives of organizations funding technology demonstration activities, has been established and has drafted assessments of critical scientific research needs. This has enabled most organizations to identify a common set of initial goals and key scientific and technical issues. Projects have been launched with relatively little duplication of effort and communication among the organizations has been good.

Most research and data analysis funding available through existing organizations is confined to very specific tasks. Therefore, TERC has the unique opportunity to respond to comprehensive data analysis and research needs that emerge from on-going analyses. Further, it is important for TERC to recognize that virtually all activities sponsored by other organizations focus on scientific and technical issues. Policy analyses, evaluation of progress in air quality, and information dissemination are currently conducted almost exclusively within the TCEQ.

Recommendations

The scope of issues outlined in Tables 1-4 is too large for any single research organization to address; therefore, it is important for the Consortium to prioritize its activities. The recommendations outlined below represent the recommendations for prioritization from the Consortium's Scientific Advisory Committee (SAC), and are organized into several broad categories.

The most *significant near term scientific and technical needs* are as follows, both of which are critical and should be carried out in parallel:

- **Recommendation 1:** Adapt photochemical grid models to address the new 8-hour Federal ozone standard. Models must now address larger geographical areas and a greater number of potentially important primary and intermediate species. They must also better accommodate certain processes, including long-range transport involving the free troposphere and transport by nocturnal jets. Moreover, chemical mechanisms need to be better adapted for multi-day simulations. To ensure model performance, more rigorous examination of the underlying mechanisms governing chemistry and transport must be conducted, such as evaluation and inter-comparison of chemical degradation pathways, parameterizations of convective transport and vertical diffusion, and wet and dry deposition algorithms. Lastly, better methods to assimilate observational data must be incorporated in air quality models as well as meteorological models. A central purpose of the Second Texas Air Quality Study (TexAQS II) is to collect data over an 18-month period that will be useful to evaluate the performance of meteorological and photochemical grid models for transport of ozone and its precursors. The 2006 August-September TexAQS II intensive will collect data to check the details of daytime and nighttime processes key to transport.

- **Recommendation 2:** Improve emission inventories. Improving emission inventories is critical to the understanding both ozone and fine particulate matter formation; both bottom-up and top down emission inventory improvements are needed, as well as improved emissions and factors. The sources of ozone precursors with the greatest degree of uncertainties in current emission estimates are point sources and non-road sources. The categories of fine particulate matter precursors with the greatest uncertainties are ammonia emissions, primary emissions of organic and black carbon from mobile sources, and emissions of precursors of organic fine particles formed in the atmosphere. TERC is coordinating its efforts with TCEQ to implement emissions inventory projects. It is likely that continued improvements in emission inventories will be needed for the next several years.

The most immediate *policy assessment needs* are:

- **Recommendation 3:** Identify emission reductions that lead to the greatest reductions in ozone concentrations. A central issue in the evaluation of the Houston-Galveston area air quality plan is the extent to which emission reductions for nitrogen oxides can be replaced with reductions in the emissions of reactive hydrocarbons. TERC should fund projects that use a variety of observationally based modeling tools to evaluate the trade-offs between controls on reactive hydrocarbons and controls on nitrogen oxides.

- **Recommendation 4:** Evaluate the impacts of ozone driven controls on fine particulate matter concentrations and on the ability of the region to meet the new ozone standard based on concentrations averaged over 8 hours. Many of the emission reduction strategies designed to allow the Houston-Galveston and Dallas-Fort Worth areas to meet the current ozone standard have the potential to either help or hinder the region in meeting future air quality challenges. While many of the analysis tools needed to determine the impact of current strategies on future air quality objectives are not yet available, some analyses can be done. TERC should fund analyses designed to address these issues to the extent possible using currently available tools.

- **Recommendation 5:** Assess the relative importance of regional transport and local emission reductions in meeting current and future air quality standards. Analysis of air quality monitoring data and air quality

modeling indicate that fine particulate matter concentrations and 8-hour averaged ozone concentrations in eastern Texas depend, to a significant extent, on regional air quality. TERC should fund ambient data collection, and modeling and data analyses that determine the relative importance of local, in-state regional and out-of-state regional sources of air pollutants. The creation of a regional monitoring network would be helpful in this regard.

- **Recommendation 6**: Assess the effects of uncertainties on model predictions used for policy assessments. This includes uncertainties in both emissions and model components such as the chemical mechanism or the transport scheme. Model biases are a particular concern in policy-relevant modeling, and effects of alternative assumptions or formulations may need to be examined, particularly if adjustments have to be made to the models to make their predictions consistent with observations. Adjusted models may have compensating errors that may no longer compensate when making attainment or control strategy predictions. An expected outcome of this analysis is the identification of subsequent modeling and/or measurement activities that will lead to a reduction in the uncertainty of critical policy-relevant elements.

The most immediate *assessment needs* are:

- **Recommendation 7:** Evaluate and synthesize emerging information. Projects funded by TERC and other organizations are producing a wealth of information. If this flood of information is to inform policy development, the results must be continually evaluated and integrated into concise and clear sets of scientific findings. TERC should be involved in the synthesis of air quality information, involving multiple stakeholders and coordinating with synthesis activities undertaken by other organizations, such as the TCEQ.

- **Recommendation 8:** Participate in future air quality field programs. The Texas Air Quality Study, conducted in the summer of 2000, is having a profound impact on the direction of policies designed to bring southeast Texas into attainment for the current air quality standard for ozone. The scientific insights provided by the study and the effect of those insights on the direction of policy have made clear the need for sound scientific data in guiding air quality policies. In the next 5 years, Texas will face a new set of air quality challenges, reducing regional ozone concentrations and reducing regional haze and concentrations of fine particulate matter. The policies developed to meet these objectives should be informed by the best available scientific information, so, a broad based effort is underway to plan, implement, and analyze the results from another air quality field program. This program is currently being planned for an 18 month period in 2005-2006 and is referred to as the Second Texas Air Quality Study (~~STAQS~~) TexAQS II). TERC should be a participant in the ~~STAQS~~ TexAQS II program; its precise role will depend on the roles undertaken by other participants.

The most immediate *health effects assessment needs* are:

- **Recommendation 9:** Initiate human exposure research, coordinating with major air quality field studies. Exposure studies should be initiated. The design of these programs should be coordinated with the design of large air quality field programs planned for eastern Texas, such as the field study identified in Recommendation 6. Again, the precise role for TERC will depend on the roles undertaken by other participants.

- **Recommendation 10:** Coordinate human exposure research on hazardous air pollutants with on-going analyses of benzene exposures in the Houston-Galveston area. The U.S. Environmental Protection Agency is undertaking an evaluation of the costs and benefits of hazardous air pollutant regulations, using benzene in the Houston-Galveston area as a case study. This evaluation will reveal critical areas in which more information about hazardous air pollutants is needed. TERC should be a participant in this case study; its precise role will depend on the roles undertaken by other participants.

The most immediate *information dissemination need* is:

- **Recommendation 11:** Launch a permanent data and information exchange infrastructure. Past experience has shown that substantial confusion can result if the observational measurements, emission inventories and meteorological modeling on which analyses are based are not from a single, well-documented source. Providing a description of and links to the validated data available would be a significant service to the research community.

In addition to scientific, policy, assessment, and information dissemination needs, the TERC Board of Directors has a strong interest in *mobile source emission reduction technologies* that can be broadly applied in Texas.

- **Recommendation 12:** Incorporate mobile emissions reduction technologies demonstration programs, projects and strategies in TERC activities. New mobile source emission reduction technologies could be widely applied across Texas; selection of such projects should be coordinated with the TCEQ's New Research Technology and Development Program and others engaged in this area of research, development and demonstration.

- **Recommendation 13**: Develop methods for assessing progress in attaining federal pollution standards. There is a need to develop more rigorous techniques to analyze outcomes and uncertainties of expectations to better plan for, measure and attribute success in improving air quality. This includes expansion and better use of monitoring networks and data from field programs, as well as studies to evaluate the effectiveness of specific control strategies.

Summary

Taking action on the recommendations outlined above will position TERC as a major contributor for the continuing scientific study of atmospheric processes in eastern Texas, as the focal point for scientific data exchange and information dissemination, and as a leader in future air quality planning efforts.