tive standards to address the possible health risk associated with short-term (five-minute) exposures by exercising asthmatic individuals. All three alternatives are likely to rely on increased monitoring in the vicinity of industrial sources to demonstrate compliance and could result in additional sulfur dioxide reductions.

Briefly, the three alternatives are:

- Revise National Ambient Air Quality Standard to include a 5-minute standard of 0.60 parts per million. This concentration could not be exceeded more than once per year.
- Establish a new regulatory program under section 303 (Emergency Powers) of the Clean Air Act. A five-minute standard of 0.60 parts per million would be used and action could be required after the first time concentrations are exceeded.
- Augment enforcement of existing standards through enhanced monitoring and by targeting sources that are most likely to produce high five-minute peak concentrations.

Sulfur dioxide monitoring in the vicinity of TVA coal-fired power plants is routinely collected as hourly rather than 5-minute averages. Extrapolating from this data, five-minute levels might exceed 0.60 parts per million at some TVA coal-fired plants. Implementation of a five-minute standard as described could result in additional sulfur dioxide control requirements at these plants.

NITROGEN DIOXIDE/NITROGEN OXIDES

Health and Welfare Concerns

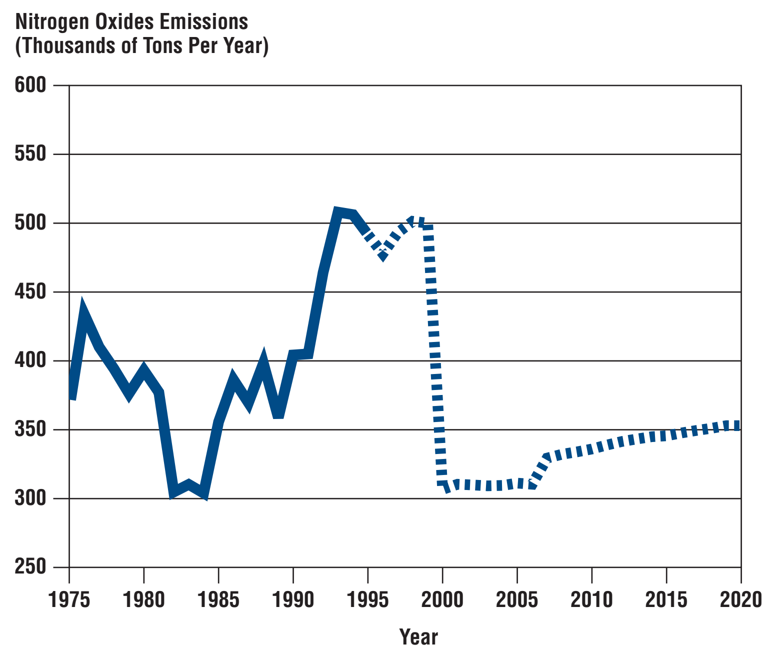
Depending on concentration, nitrogen dioxide can be a respiratory irritant. At current ambient levels in the TVA region, nitrogen dioxide health-related impacts are negligible. Nitrogen dioxide levels in the Tennessee Valley are well below the annual standard. There are no nitrogen dioxide nonattainment areas in the TVA region. Nitrogen oxides emissions do, however, contribute to regional acidic deposition and ozone formation. These are discussed in later sections. A very small amount (less than 5 percent) of the total nitrogen oxides emitted from a coal-fired power plant is nitrogen dioxide. Nitric oxide is the primary nitrogen species emitted and reacts rapidly with ozone in the atmosphere to form nitrogen dioxide.

Sources of Contribution

Natural sources of nitrogen oxides include microbial activity, lightning, and forest fires. Major human-produced sources include motor vehicles, fossil fuel power plants, industrial boilers, nitrogen fertilizers, and agricultural burning. The map in *Figure T1-24* displays total nitrogen oxides emissions from human sources, point (utility and industry), area (urban and small point source), and mobile (vehicle) sources in the greater source area likely to contribute to ozone levels in the Tennessee Valley, based on the Environmental Protection Agency's Interim 1990 emissions inventory. Within the 201 counties of TVA's service area, TVA emissions accounted for 33 percent of total human-produced nitrogen oxides, while mobile sources accounted for 31 percent. The map in *Figure T1-25* shows biogenic or natural emissions of nitrogen oxides estimated for the greater TVA source region. The Environmental Protection Agency's Biogenic Emissions Inventory, System II Model was used. Emissions of nitrogen oxides from fertilized soils on a hot, sunny summer afternoon can contribute up to 20 percent of daily nitrogen oxides emissions from all sources.

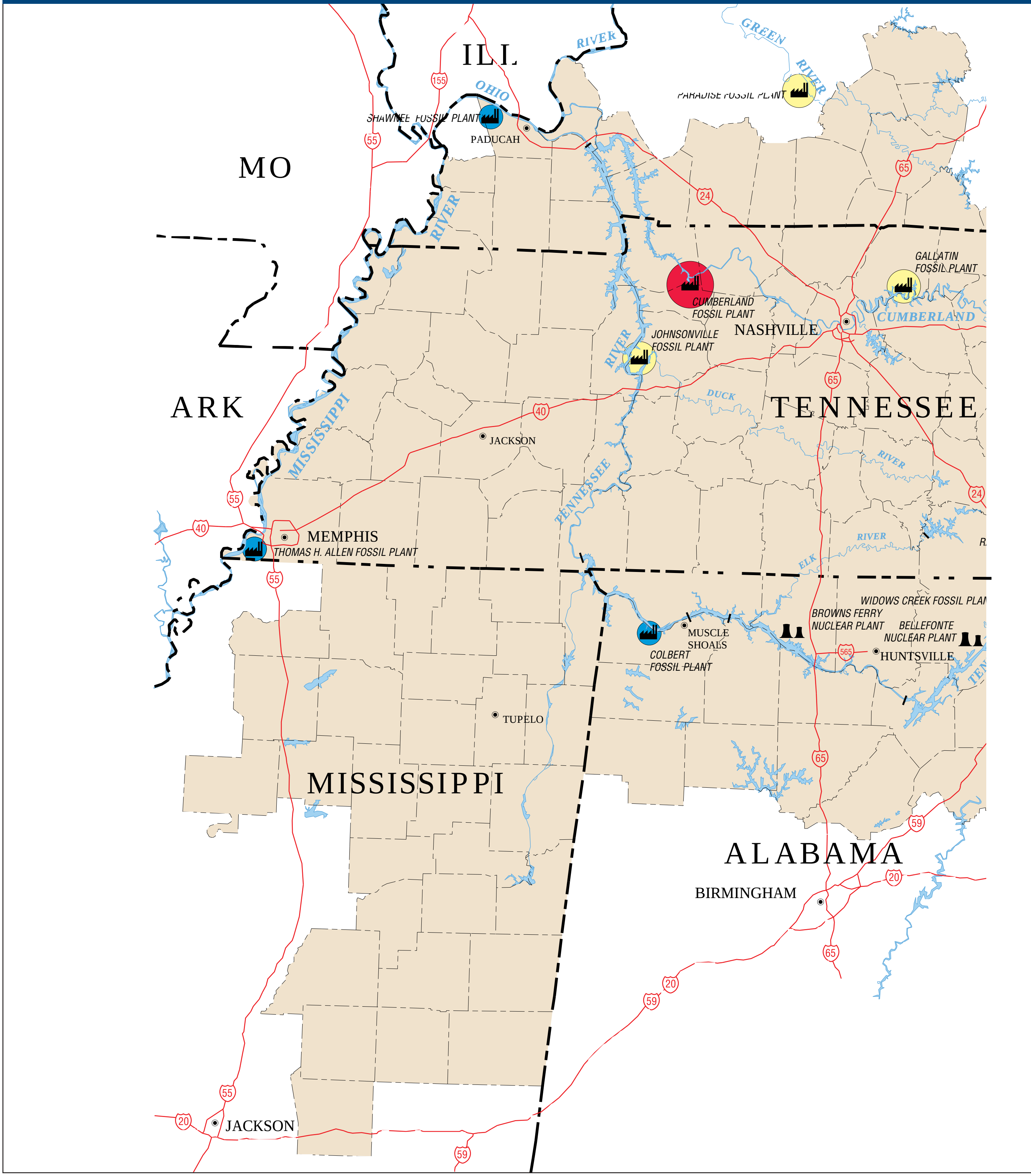
The graph in *Figure T1-26* illustrates TVA emissions of nitrogen oxides since 1975. The decline and rise of emissions between 1975 and 1990 is tied to coal use which varies with power system sales and the level of power production by nuclear

FIGURE T1-26. **Historic and Projected TVA Emissions of Nitrogen Oxides**



TVA nitrogen oxides emissions increased during the 1990s as coal-fired generation increased. Emissions will decrease as TVA complies with the 1990 Clean Air Act Amendments.

FIGURE T1-23. **Sulfur Dioxide Emissions From TVA Coal-Fired Power Plants in 1993 (Reductions From Cumberland Scrubbers Not Shown)**



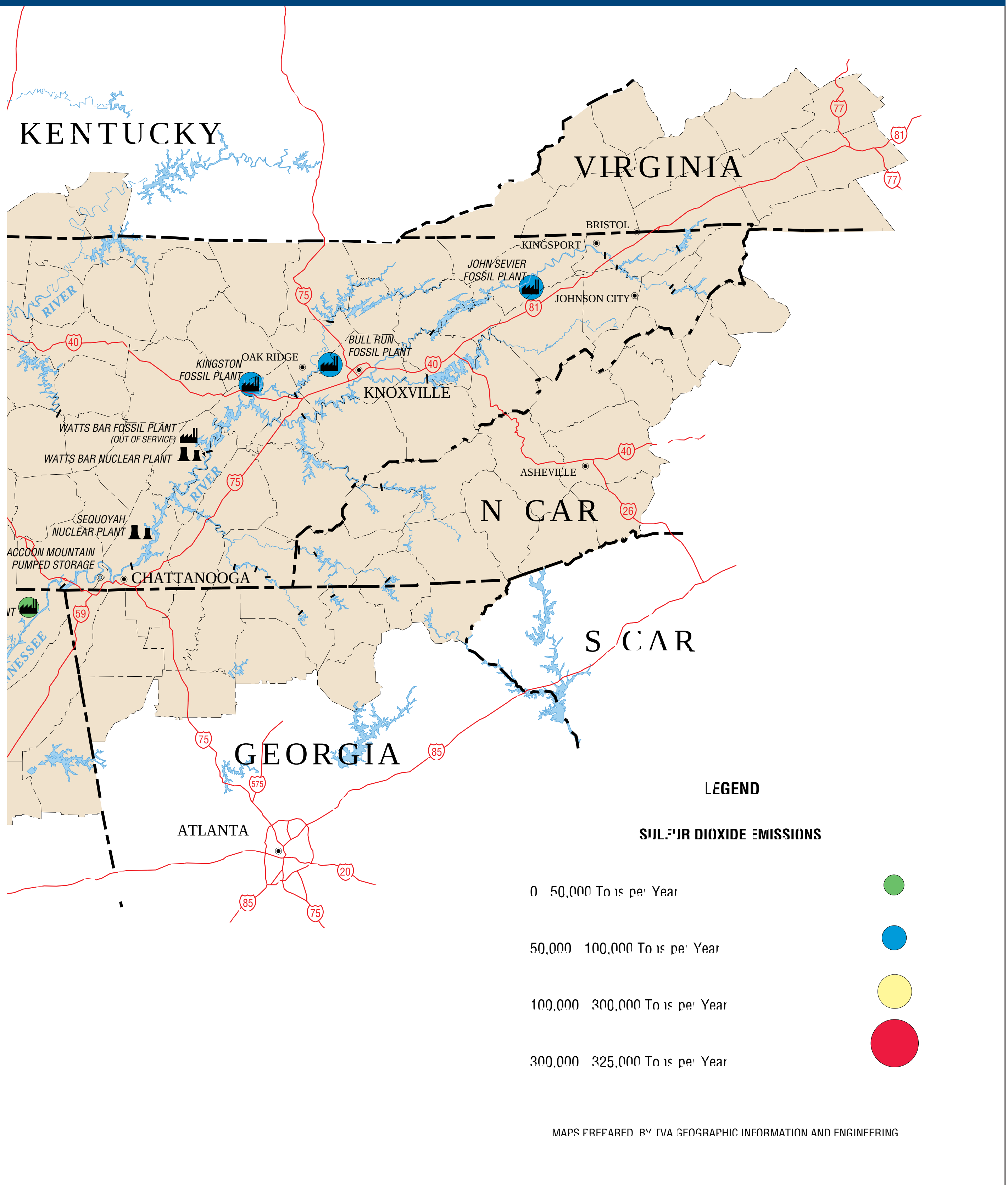
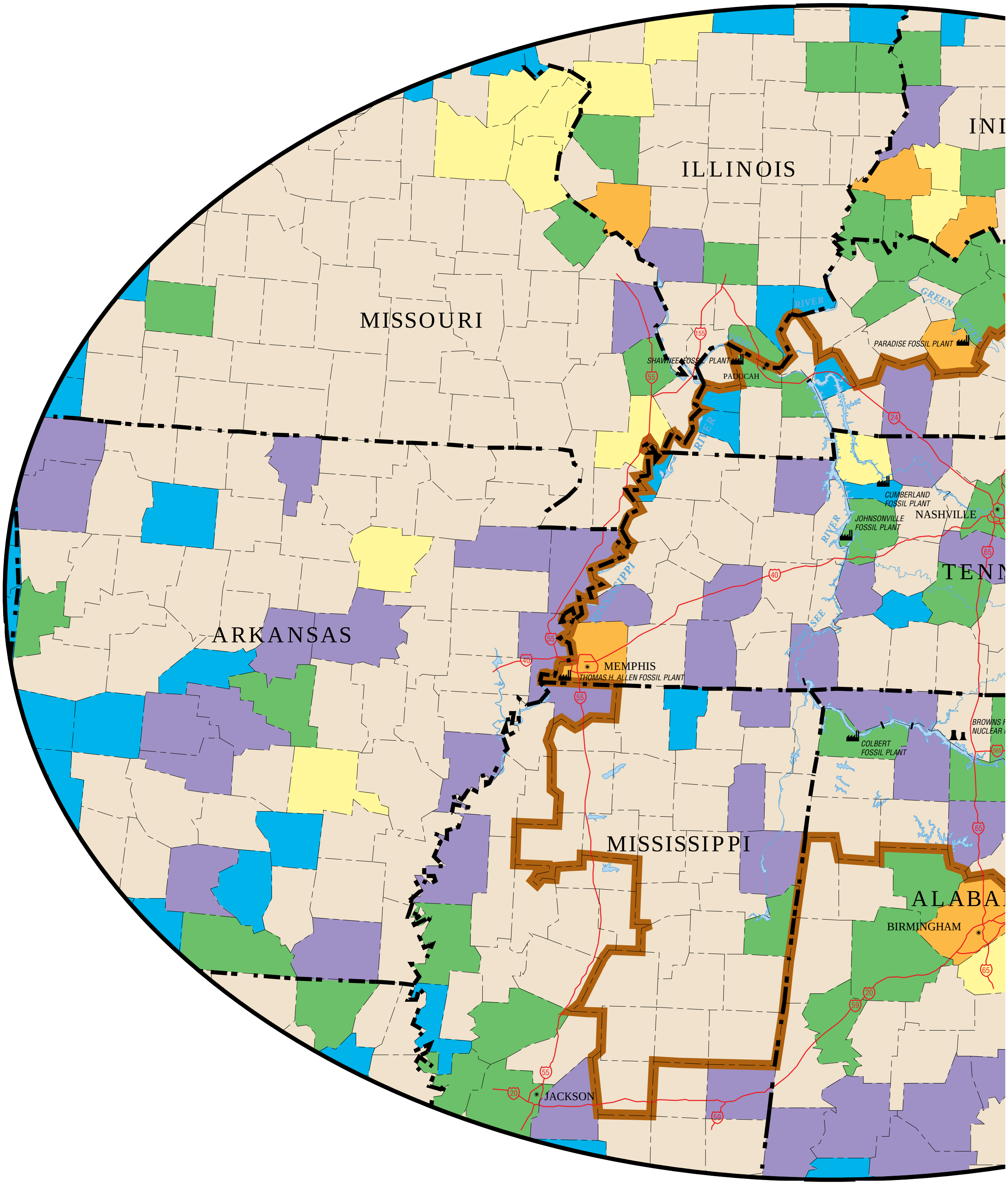
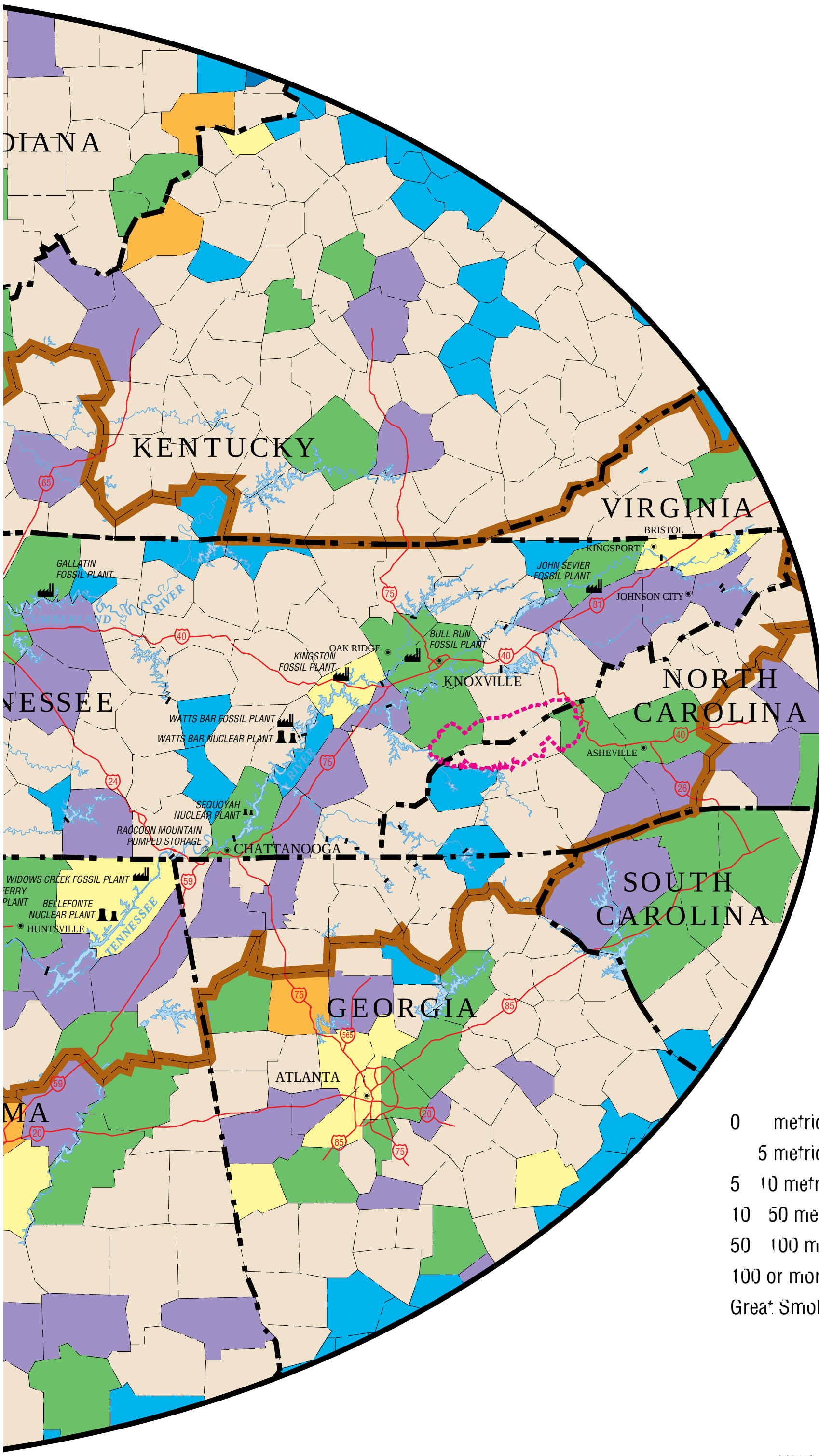

KENTUCKY
VIRGINIA
BRISTOL
KINGSPORT
JOHN SEVIER FOSSIL PLANT
JOHNSON CITY
RIVER
OAK RIDGE
KINGSTON FOSSIL PLANT
BULL RUN FOSSIL PLANT
KNOXVILLE
WATTS BAR FOSSIL PLANT (OUT OF SERVICE)
WATTS BAR NUCLEAR PLANT
RIVER
SEQUOYAH NUCLEAR PLANT
PUMPED STORAGE
CHATTANOOGA
ASHEVILLE
N CAR
S CAR
GEORGIA
ATLANTA
75
40
81
77
26
59
85
575
20
LEGEND
SULFUR DIOXIDE EMISSIONS
0 – 50,000 Tons per Year
50,000 – 100,000 Tons per Year
100,000 – 300,000 Tons per Year
300,000 – 325,000 Tons per Year
MAPS PREPARED BY TVA GEOGRAPHIC INFORMATION AND ENGINEERING

FIGURE T1-24. **Total Nitrogen Oxides Emissions from Point, Area, and Mobile Sources in the Greater Source Area for Energy Vision 2020**





LEGEND

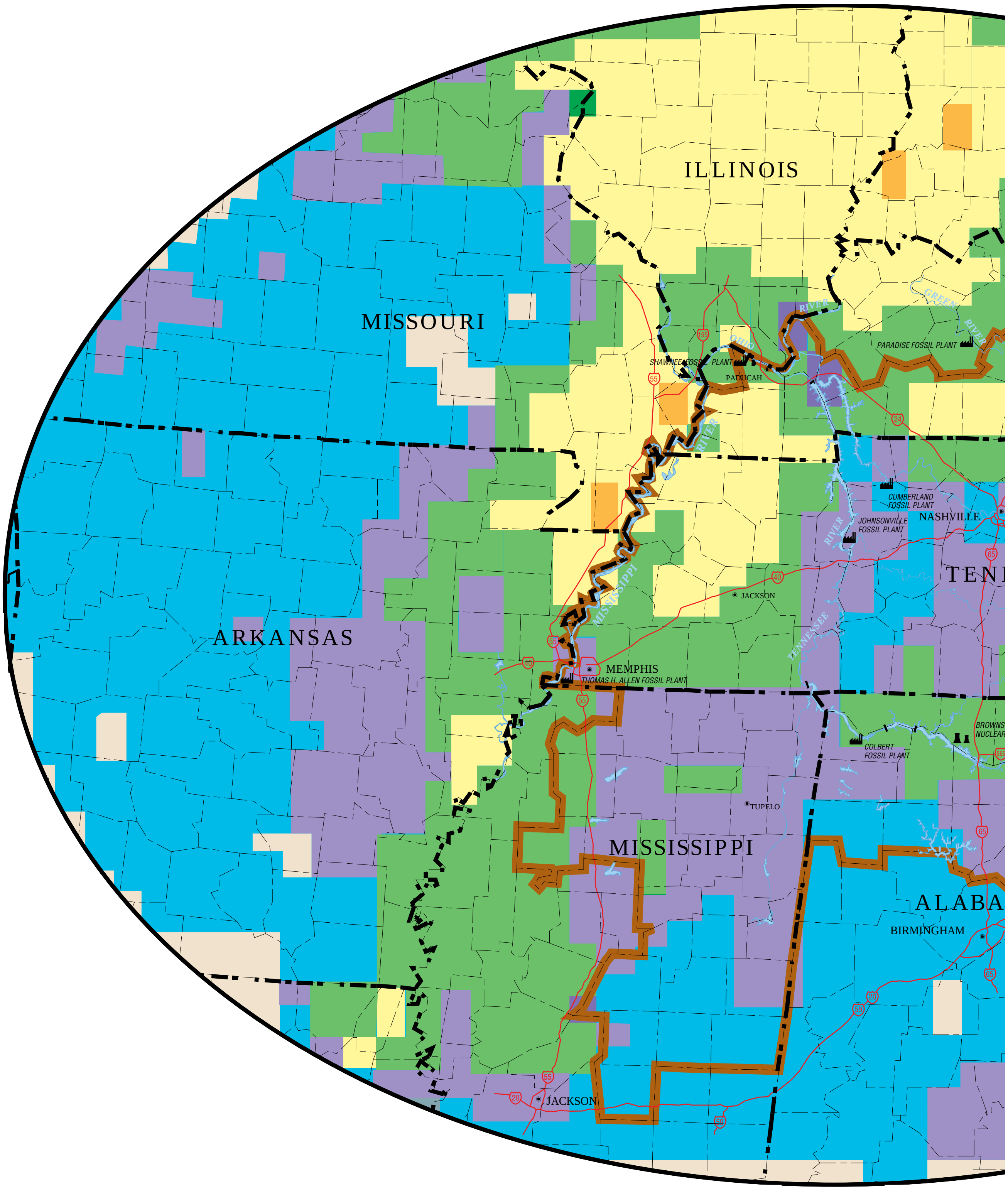
NITROGEN OXIDE EMISSIONS

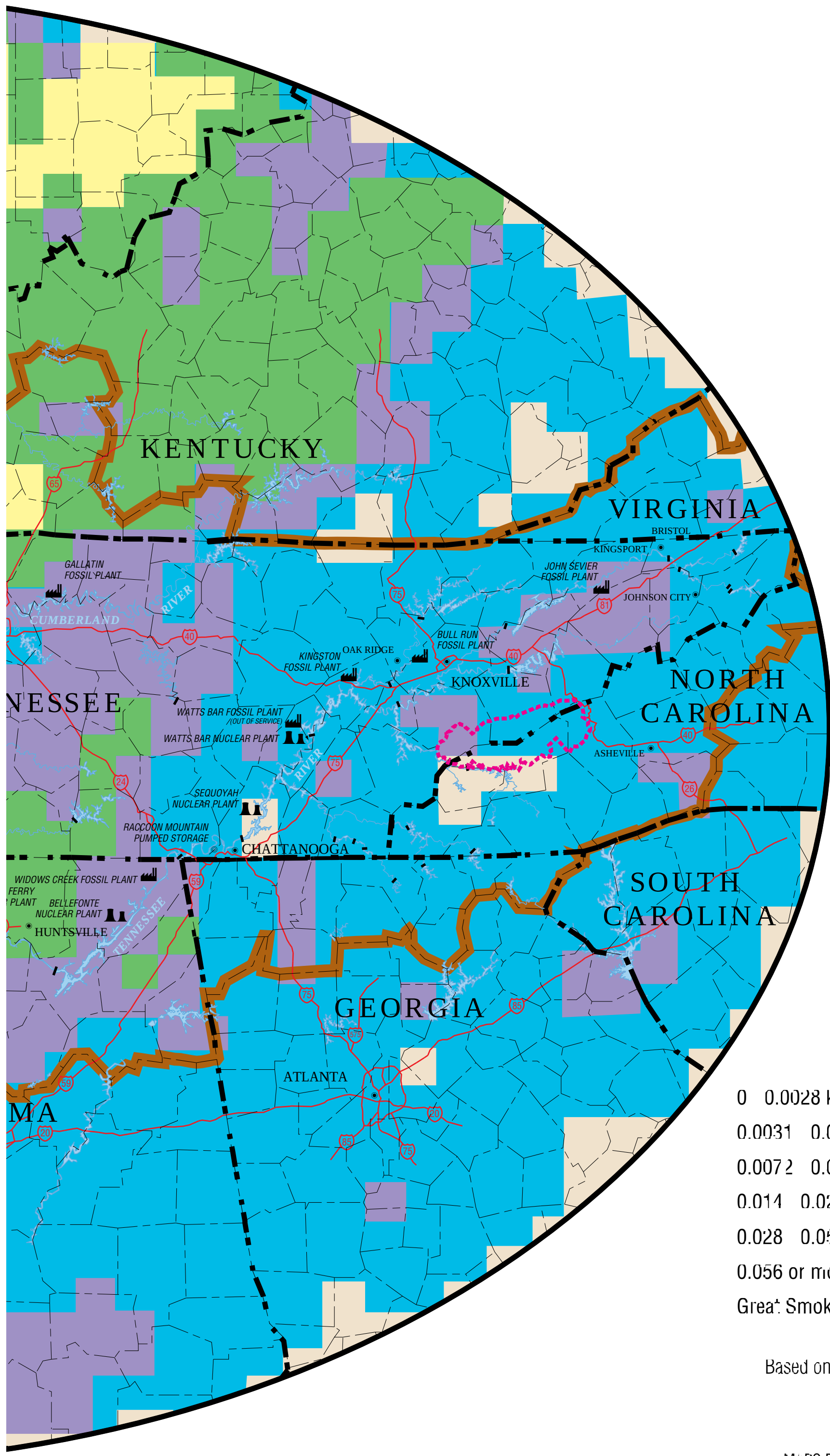
0 metric tons per day
5 metric tons per day
5 10 metric tons per day
10 50 metric tons per day
50 100 metric tons per day
100 or more metric tons per day
Great Smoky Mountains National Park

Interim 1990 Emissions Inventory

MAPS PREPARED BY TVA GEOGRAPHIC INFORMATION AND ENGINEERING

FIGURE T1-25. **Summer Nitrogen Oxide Emissions from Natural Sources in the Greater Source Area for Energy Vision 2020**





LEGEND

0 – 0.0028 kilogram per hectare per day
0.0031 – 0.007 kilogram per hectare per day
0.0072 – 0.0139 kilogram per hectare per day
0.014 – 0.028 kilogram per hectare per day
0.028 – 0.055 kilogram per hectare per day
0.056 or more kilograms per hectare per day
Great Smoky Mountains National Park

Based on results of EPA Biogenic Emissions Inventory System Model

MAPS PREPARED BY TVA GEOGRAPHIC INFORMATION AND ENGINEERING

power plants. Emissions, which have recently been about 500,000 tons per year, are projected to decline to approximately 300,000 tons per year following implementation of the 1990 Clean Air Act Amendments. They are also expected to increase roughly 17 percent over the years 2000 to 2020 as generation increases. *Figure T1-27* depicts fiscal year 1993 emissions of nitrogen oxides for each TVA coal-fired plant.

Future Regulations

In its 1994 review of the ambient air quality standard for nitrogen dioxide, the Environmental Protection Agency concluded that the current standard is adequate to protect human health and welfare. Additional nitrogen oxides control requirements are scheduled to be promulgated in 1997 under provisions of the 1990 Clean Air Act Amendments to address acid rain and ozone nonattainment areas.

CARBON MONOXIDE

Health and Welfare Concerns

Carbon monoxide is a colorless, odorless gas formed as a byproduct of fossil-fuel combustion. Exposure to carbon monoxide can reduce the oxygen-carrying capacity of the blood. At current ambient outdoor levels, carbon monoxide exposures are considered a low risk to human health.

Sources of Contribution

Natural sources of carbon monoxide are minor. The principal human-produced source is incomplete combustion of gasoline in motor vehicles. Carbon monoxide air pollution is primarily an urban problem, with highest levels occurring during heavy traffic under congested conditions. There has been a gradual but persistent improvement in average carbon monoxide levels throughout the last decade. In 1979 there were four nonattainment counties in the Tennessee Valley. Ambient levels of carbon monoxide in the Tennessee Valley are below the level of the National Ambient Air Quality Standards. Ambient concentrations of carbon monoxide should continue to decline as newer, less polluting vehicles make up an increasing portion of all vehicles driven in the region.

Future Regulations

The Environmental Protection Agency is not currently considering revisions to the carbon monoxide standard. TVA emissions account for less than 1 percent of total carbon monoxide emissions in the TVA service region and therefore will not be used as a factor to differentiate among strategies in Energy Vision 2020.

LEAD

Health and Welfare Concerns

The criteria pollutant lead is also one of a category of hazardous air pollutant that can be emitted from the combustion of coal. The Environmental Protection Agency established lead as a criteria pollutant because there was clear evidence of its sources and its impact on human health. Elevated exposures to lead can:

- Contribute to hypertension, heart attacks, and strokes in adults
- Increase the likelihood of birth defects and infant mortality
- Inhibit the growth and mental development of children

However, risk assessment models demonstrate that current lead emissions pose very little risk to human health (ORNL 1994).

Sources of Contribution

Lead exposure can occur through inhalation or ingestion. Children are the most vulnerable segment of the population because they ingest lead more often than do adults. Children swallow lead when they put toys or other objects bearing lead-contaminated dust in their mouths. Furthermore, a greater portion of ingested lead enters children's bodies than adults' bodies. Lead is now banned from use in gasoline, paints, solder, and metals that could contact drinking water, beverages, or foods. Concentrations of lead in the ambient environment have been reduced dramatically over the past two decades (ORNL 1994). Residual levels of lead in soils and flakes from lead-based paints remain a concern. Differences in lead emissions are not considered in evaluating TVA energy supply strategies.

TOTAL SUSPENDED PARTICULATE MATTER/PM10

Health and Welfare Concerns

Particulate matter is of concern because of the adverse effects it can have on visibility and on the respiratory function of sensitive individuals. Particulate matter was the focus of early air pollution control efforts because of the obvious visual impact of smoke and its association with acute air pollution episodes in England and the United States. Particulate matter consists of small aerosol particles in the atmosphere. Some particles are large enough to be seen with the naked eye, but the particulates of major concern for human health are less than 10 microns in size. Larger particles tend to be filtered out in the nose and throat and pose few health problems.

Particles emitted directly from a source are called primary particles. Those formed in the atmosphere from emitted gases are called secondary particles. Primary particles tend to be larger than 2.5 microns in size and are likely to be deposited within

50 kilometers of the source. Formation of secondary particles from sulfur dioxide and nitrogen oxides occurs in the atmosphere as the pollutants are transported downwind from the points of origin. Sulfate and nitrate particles are typically smaller than 1 micron in diameter and may remain aloft for days at a time (Mason 1971). Summer weather conditions favor the photochemistry that leads to sulfate and nitrate particle formation. Visibility is poorest in the summer because sulfate particles provide the major source for regional haze.

Sources of Contribution

Many natural and human sources produce particulate matter. Natural sources include wind-blown soil, volcanoes, forest fires, and the ocean. Human-produced sources include agriculture, waste incineration, industrial processing, fossil-fuel combustion, construction, and mining. On a global scale, natural emissions far exceed human-produced, but human-produced emissions predominate in urban and industrial areas. TVA contributed 5 percent of the total suspended particulates emitted in the 201 counties of the Tennessee Valley, according to the 1985 emissions inventory by the National Acid Precipitation Assessment Program *(See Figure T1-21)*. TVA emissions are primarily from coal-fired boilers. Particulate collection devices such as fabric filters or electrostatic precipitators have been installed on all TVA coal-fired boilers to remove particulates from the flue gases. Fugitive dust from TVA's operation of motor vehicles and from coal and other material-handling processes (e.g., coal transport and washing) also contributes low levels of fine particles.

Ambient Trends

Particulate control has been very successful, with removal efficiencies exceeding 95 percent. In 1979, parts of 21 counties in the Tennessee Valley did not attain the ambient particulate standard; now only 4 nonattainment areas remain. Loadings of fine particles are greatest in summer months. *Figure T1-28* illustrates the trend in particulate matter smaller than 10 microns from July through September, during 1986 to 1993, at 5 cities in the Tennessee Valley. These five cities are typical of trends for other cities in the Valley. For the majority of the sites, ambient concentrations of particles smaller than 10 microns decreased over this period.

Future Regulations

The National Ambient Air Quality Standard for particulate matter initially targeted concentrations of total suspended particulate matter. While this improved the visible particulate emissions problem, potential impacts to human health were still a problem. The total suspended particulate standard was amended in 1977 to address levels of particles smaller than 10 microns. Particulates of this size are respiratory irritants and pose greater risk to human health than the larger, more visible particles.

The Environmental Protection Agency is currently reviewing the adequacy of the particulate standard. A draft criteria document, which is the Environmental Protection Agency's state of science report on particulate matter, was published in November 1994, and peer review workshops were conducted in spring 1995. The final criteria document is to be completed by October 1995; the Federal Register proposal is due by April 1996; and the publication of final action is due not later than January 31, 1997. The draft criteria document reports an association between daily particulate matter concentrations and mortality rates, although the exact size fraction best predictive of health effects is not conclusively determined.

A comparative study of the health of individuals in six communities, including Kingston-Harriman in Tennessee, suggests

FIGURE T1-28. **Concentrations of Particulate Matter Less than 10 Microns (PM10) in Size During July-September for 5 Cities in the Energy Vision 2020 Study Area Have Been Decreasing**

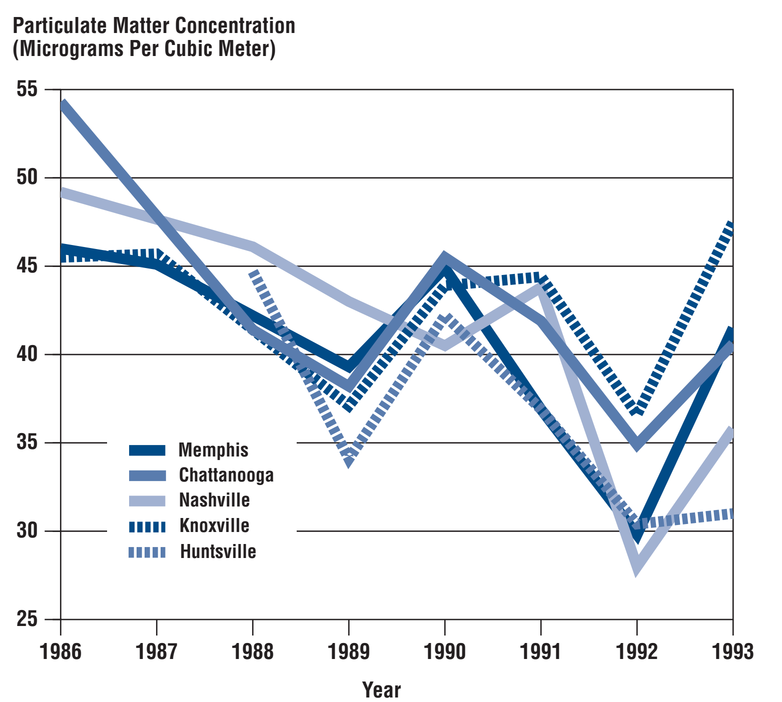
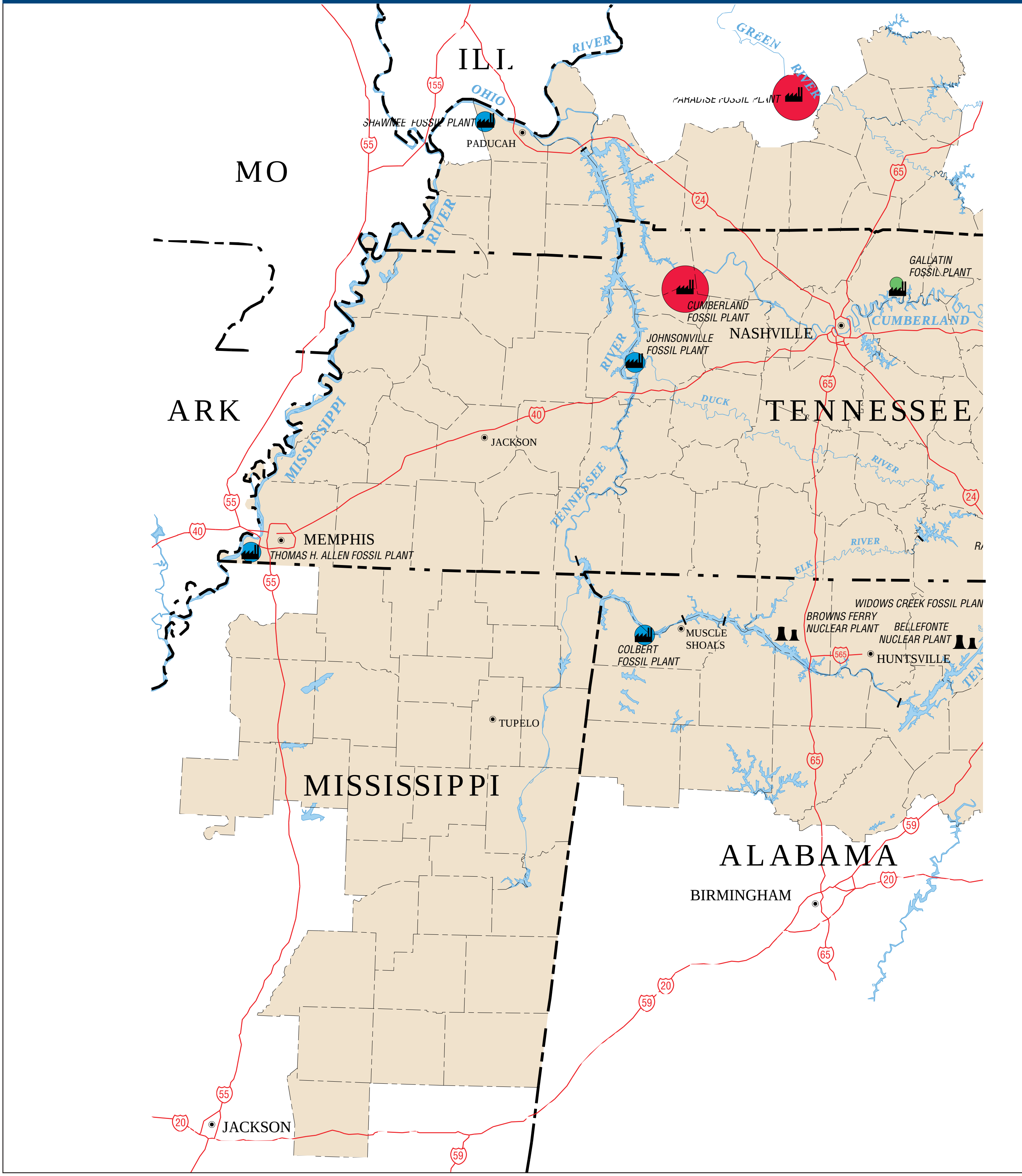
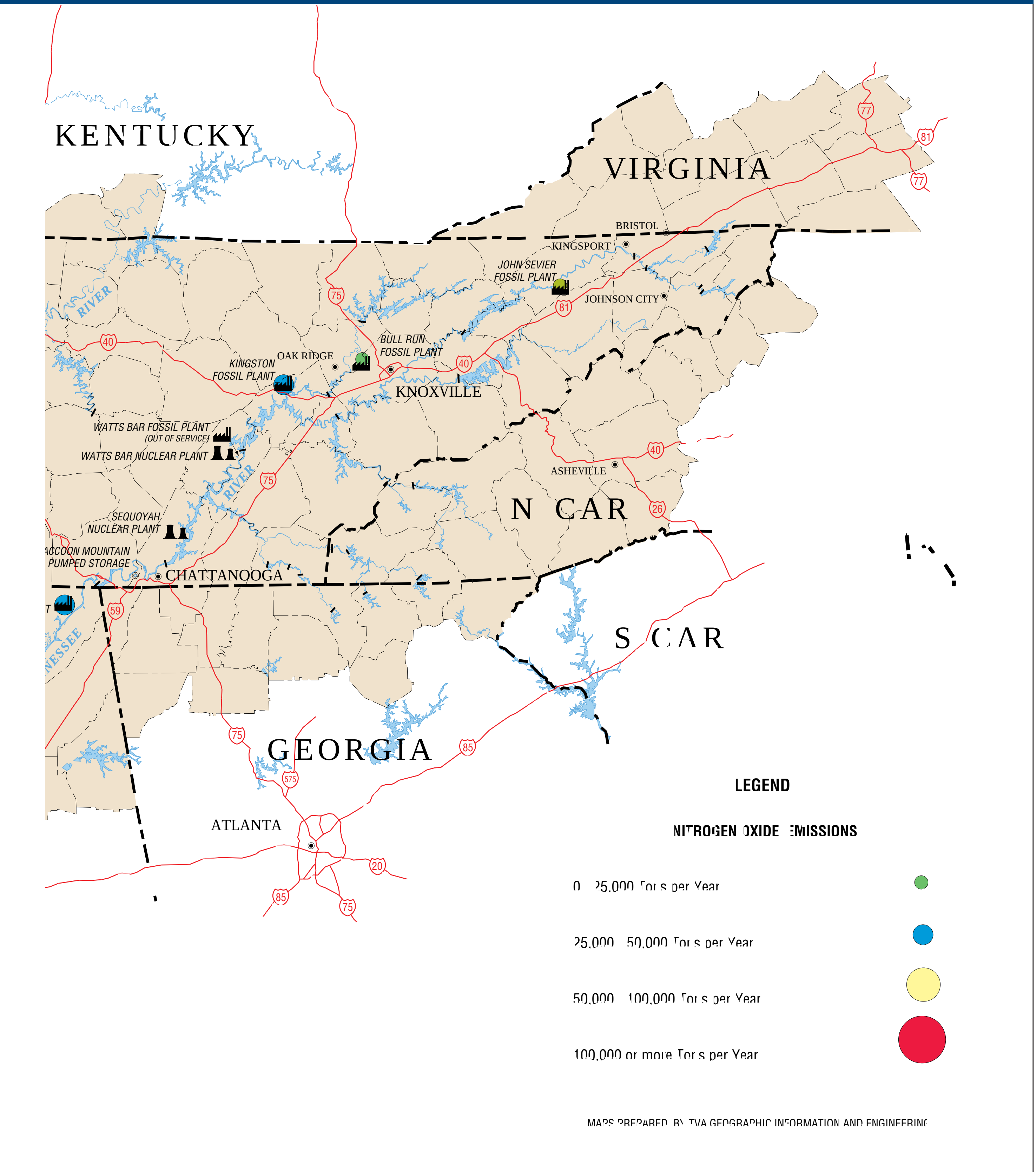


FIGURE T1-27. **Nitrogen Oxides Emissions From TVA Coal-Fired Power Plants in 1993**




KENTUCKY
VIRGINIA
BRISTOL
KINGSPORT
JOHN SEVIER FOSSIL PLANT
JOHNSON CITY
RIVER
BULL RUN FOSSIL PLANT
OAK RIDGE
KINGSTON FOSSIL PLANT
KNOXVILLE
WATTS BAR FOSSIL PLANT (OUT OF SERVICE)
WATTS BAR NUCLEAR PLANT
RIVER
ASHEVILLE
N CAR
SEQUOYAH NUCLEAR PLANT
ACCOON MOUNTAIN PUMPED STORAGE
CHATTANOOGA
NESSEE
S CAR
GEORGIA
ATLANTA
75
40
81
77
26
59
575
85
20
LEGEND
NITROGEN OXIDE EMISSIONS
0 - 25,000 Tons per Year
25,000 - 50,000 Tons per Year
50,000 - 100,000 Tons per Year
100,000 or more Tons per Year
MAPS PREPARED BY TVA GEOGRAPHIC INFORMATION AND ENGINEERING

that increased particulate exposure increases health risk (Dockery et al. 1993). Characterizing the relationship between particulate concentration and health impacts is complicated by contributions of weather, other co-occurring environmental pollutants, and a lack of extensive measurements of particle sizes other than 10 microns. It has been difficult to identify a single causal factor when several air pollutants are elevated at the same time.

A fine-particulate standard is now being considered for particles less than or equal to 2.5 microns. Available monitoring data suggests that large areas of the country would not be in attainment with such a standard.

In addition to possible health effects, the Environmental Protection Agency's draft criteria document also addresses the contribution of secondary particles to regional haze. Title I of the 1990 Clean Air Act Amendments authorizes the development of control strategies to mitigate visibility impacts. The Environmental Protection Agency could use Title I provisions to respond to the federal land managers' findings of visibility impairment in Class I areas. The Environmental Protection Agency could alternatively use the ambient standard process to set a visual range goal.

If the ambient standard were revised to limit fine particles (less than 2.5 microns in size), TVA would likely install higher efficiency electrostatic precipitators and add filters to coal-handling areas. Factors to differentiate among energy strategies do not include those to comply with uncertain future regulations of fine particles.

TROPOSPHERIC OZONE

Health and Welfare Concerns

Ozone is a secondary air pollutant produced in the presence of sunlight from the primary emissions of nitrogen oxides and volatile organic compounds in the lower atmosphere (troposphere). In some areas of the southeastern United States, ambient levels of ozone exceed levels demonstrated to impair human respiratory function and to impact crops, forests, and materials. Several urban areas in the Southeast do not attain the current National Ambient Air Quality Standard (maximum one-hour average concentration not to exceed 0.12 parts per million more than three times in three years). The Environmental Protection Agency is considering revisions to the current standard to address health impacts from extended exposures and cumulative impacts to crops and forests. The National Park Service has reported that ambient levels of ozone are adversely

FIGURE T1-29. **Maximum Hourly Ozone Concentrations at Five Monitoring Sites in the Energy Vision 2020 Study Area Have Shown Little Improvement**