GUIDANCE FOR USING AIR QUALITY-RELATED INDICATORS IN REPORTING PROGRESS IN ATTAINING THE STATE AMBIENT AIR QUALITY STANDARDS

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FOREWARD

On July 8, 1993, the California Air Resources Board (Board) approved Resolution 93-49, thereby endorsing the progress reporting indicators presented in this report. At that time, the Board directed the staff to incorporate into the report, a clarification of the Board's policy regarding the use of the progress reporting indicators.

The clarification has been incorporated into the report, the title has been changed (from "Proposed Guidance for Using Air Quality-Related Indicators in Reporting Progress in Attaining the State Ambient Air Quality Standards" to "Guidance for Using Air Quality-Related Indicators in Reporting Progress in Attaining the State Ambient Air Quality Standards"), and the revised report has been dated September 1993. In general, the revised report clarifies that although the Board recommends reporting documented progress at the 95 percent confidence level, the districts may report documented progress at other levels of confidence (for example, 90 percent, 80 percent, or 50 percent confidence).

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OVERVIEW

Health and Safety Code section 39607(f) requires the Air Resources Board (ARB or Board) to identify one or more air quality-related indicators (indicators) for the districts to use in assessing and reporting their progress in attaining the State ambient air quality standards. These "progress reporting indicators" are to provide a measure of the historical air quality improvement. Therefore, they must be able to measure the progress that has occurred.

The ARB staff consulted with the districts and other interested parties in developing three progress reporting indicators. These progress reporting indicators represent three aspects of air quality that the Board determined are important for measuring progress. They include a peak "hot spot" indicator, a "population-weighted" exposure indicator, and an "area-weighted" exposure indicator.

This guidance document provides relevant background information and describes for each of the three progress reporting indicators: the affected pollutants and areas, the appropriate data to use, and the computation procedure. The guidance document also provides several formats for presenting the results.

Although the Health and Safety Code requires the districts to include progress reporting indicators in their triennial progress reports, the Board does not intend that these requirements place an undue burden on any affected district. Therefore, if requested, the ARB staff will provide a district with trend analyses based on the procedures described in this guidance document and appropriate for inclusion in the triennial progress report. As an alternative to providing the results, the ARB staff will, if requested, provide districts with copies of the data and the computer software used for determining the progress reporting indicator values.

CHAPTER I

BACKGROUND

The Health and Safety Code (HSC) requires the Air Resources Board (ARB or Board) to evaluate and identify air quality-related indicators (indicators) for the districts to use in assessing their progress toward attainment of the State ambient air quality standards (State standards). The following sections provide background information on the indicators including the definition of an indicator, the requirements of the HSC, and the purpose of this guidance document. The last section of this chapter addresses the criteria the Board endorsed for evaluating indicators and explains how these criteria apply to the progress reporting indicators described in this guidance document.

A. Definition of an Air Quality-Related Indicator

The general concept of an indicator is simple: an indicator is a way of summarizing measured air quality data so as to represent one aspect of air quality in a specific area. An indicator summarizes and represents air quality in the same sense that the Dow Jones Industrial Average (DJIA) summarizes and represents the condition of the stock market. An air quality-related indicator is based on measured air quality data, whereas the DJIA is based on stock price data. One application for indicators is measuring and reporting the progress that has been made in attaining the State standards. In this case, progress means the change or improvement in air quality over time that can be attributed to a reduction in emissions rather than the influence of other factors, such as variable meteorology.

B. Requirements of the Health and Safety Code

The specific mandate for indicators is contained in section 39607(f) of the HSC. The State Legislature recently amended this section of the HSC and, in doing so, added to the requirements for evaluating and identifying indicators. Both the original requirements and the new requirements of the law are described in the following subsections.

1. Original Requirements

Before the legislative amendments became effective, Health and Safety Code section 39607(f) required the Board to evaluate and approve indicators for use in measuring or estimating progress in the attainment of the State standards. The HSC required the Board to establish an initial list of approved indicators by the end of 1989 and update the list every three years thereafter (refer to Appendix A). In the original law, HSC section 40914(a) specified a single use for an indicator approved under HSC section 39607(f): the approved indicator could be used as an alternative measure of progress.

Under the HSC requirements, districts with areas designated as nonattainment for ozone, carbon monoxide, nitrogen dioxide, or sulfur dioxide must develop attainment plans designed to achieve a five percent annual reduction in the emissions of each nonattainment pollutant or its precursors. However, under HSC section 40914(a), an "alternative measure of progress indicator" can be used in lieu of the five percent annual emission reduction requirement. The original language in HSC section 39607(f) did not specify any basis for developing an alternative measure of progress indicator.

In response to the original HSC requirement for alternative measure of progress indicators, the Board endorsed a plan for approving indicators, which is discussed further in Section D., below. This plan includes five criteria for the Board to use in evaluating a potential alternative measure of progress indicator. One of the most important criteria for an alternative measure of progress indicator is the "rate of progress" criterion. This criterion provides that the Board must be able to quantify how much an indicator would change in response to a five percent annual emission reduction. To date, adequate air quality modeling capability does not exist for determining what changes in indicators would result from a five percent annual emission reduction. As a result, the Board has not been able to approve an alternative measure of progress indicator.

2. New Requirements

Recognizing the limitations of the currently available tools, the State Legislature amended HSC section 39607(f), effective January 1, 1993 (refer to Appendix A). This section now specifies two types of indicators: the "alternative measure of progress indicators" and the "progress reporting indicators." The progress reporting indicators represent a new category of indicators for the districts to use in reporting their progress toward attainment of the State standards. Both types of indicators are described in the subsections below.

a. Alternative Measure of Progress Indicators

In contrast to the original HSC requirements, the amended language of HSC section 39607(f) contains more specific requirements for evaluating and identifying the alternative measure of progress indicators. The HSC requires the Board to continue its evaluation of the alternative measure of progress indicators. However, the law now requires that the alternative measure of progress indicators be based on air quality modeling. When the Board finds that adequate air quality modeling capability exists, the Board is to identify one or more alternative measure of progress indicators that a district may use in lieu of the required five percent annual emission reduction. The timetable for evaluating the air quality modeling capability for the alternative measure of progress indicators is found in HSC section 39609 (refer to Appendix A).

As described earlier, the HSC requires a district to design its attainment plan to achieve a five percent annual reduction in the emissions of each nonattainment pollutant or its precursors. (If a district cannot achieve the five percent annual emission reduction, the HSC requires a district to include all feasible control measures in its attainment plan.) The five percent annual emission reduction requirement applies unless the Board identifies an alternative measure of progress.

An alternative measure of progress indicator is not the only mechanism for supporting an alternative emission control strategy. The Board's "Technical Guidance Document: Photochemical Modeling" (1992; Modeling Guidance Document) includes a section on using photochemical models for planning purposes. Included in this section of the Modeling Guidance Document is a discussion about using photochemical models to compare and support alternative emission control strategies for ozone. Districts that wish to implement an alternative emission control strategy must demonstrate that the alternative strategy will be as effective at improving air quality as the five percent annual emission reduction strategy. As a practical matter, this must be done prospectively using photochemical models to compare the expected air quality benefits of the candidate alternative strategy with the expected benefits of the five percent annual emission reduction strategy.

b. Progress Reporting Indicators

In addition to the alternative measure of progress indicators, HSC section 39607(f) requires the Board to identify at least one indicator for the districts to use in assessing or reporting progress as required by HSC section 40924(b). The Board refers to this type of indicator as a "progress reporting indicator." HSC section 40924(b) requires districts to report their progress triennially (refer to Appendix A). Specifically, the triennial progress report must contain an assessment of the extent of air quality improvement during the previous three-year period. This assessment is to be based in part on the progress reporting indicators that the Board identifies under HSC section 39607(f).

C. Purpose of This Guidance Document

This guidance document meets the requirement in HSC section 39607(f) for identifying progress reporting indicators for use in the triennial progress reports to assess the air quality improvement as required under HSC section 40924(b). In addition, the Board intends that the progress reporting indicators described herein also satisfy the requirements in HSC section 40924(c). HSC section 40924(c) requires that in addition to the triennial progress reports, the districts report to the Board and make available to the public, information on their progress toward attainment using two standards of measurement. The Board is to determine these standards of measurement which may include population exposure, design value, and concentration hours over the State standard. The progress reporting indicators identified in Chapter III of this guidance document satisfy these requirements.

For each of the identified progress reporting indicators, this guidance document generally describes the affected pollutants and areas, the data to use, the computation procedure, and example formats for presenting the results. Consistent with the requirements of the HSC, the ARB staff consulted both with the districts and with other interested parties before developing the progress reporting indicators. In identifying progress reporting indicators for use in the triennial progress reports, the Board does not intend to place an undue burden on any affected district. Therefore, if requested by a district, the Board will compute the progress reporting indicator values for inclusion in the district's triennial progress report.

The progress reporting indicators described in this guidance document satisfy the minimum requirements for assessing air quality improvement in the triennial progress reports. While these are the minimum requirements, they do not preclude a district from including in its triennial progress report any additional analyses a district believes are important for its particular nonattainment area. The progress reporting indicators will provide information on the progress made in attaining the State standards. However, until alternative measure of progress indicators and their associated rates of progress are identified, the primary measure of progress will be emission reductions.

D. Criteria for Identifying a Progress Reporting Indicator

On November 8, 1990, the Board passed Resolution 90-66 which endorsed the ARB staff's "Plan for Approving Air Quality-Related Indicators" (Indicators Plan) [Reference 1]. The Indicators Plan includes five criteria the Board decided to use to evaluate a potential alternative measure of progress indicator. Four of the five criteria described in the Indicators Plan also are appropriate for evaluating the progress reporting indicators. These four criteria address the following issues:

1) The quality of the data used,

2) The need for a complete and unambiguous definition,

3) The characteristics of air quality that must be represented, and

4) The required degree of reliability.

Both the significance of and the requirements for each of these criteria as they apply to the progress reporting indicators are described in the following subsections (refer to Appendix B for the full text of the criteria for evaluating indicators). Note that a fifth criterion, the "rate of progress" criterion, is not described in the subsections below because it does not apply to the progress reporting indicators. The progress reporting indicators are used simply as an indication of the historical improvement in air quality. In this application, it is not necessary to establish the relationship between changes in air quality and changes in emissions. In contrast, the rate of progress criterion does apply to the alternative measure of progress indicators which must specify a rate of progress that is equivalent to the required five percent annual emission reduction.

1. Quality of Data

High quality data are essential for measuring progress accurately. The quality of data criterion assures the use of consistent and reliable data by limiting the data that are appropriate for computing a progress reporting indicator. A progress reporting indicator must be based on air quality "data for record." In general, data for record are those data that have been collected by or under the direction of the Board or the districts and which satisfy the federal government's published standards for monitor siting and quality assurance.

High quality and reliability also are important for other types of data used in computing a progress reporting indicator, such as demographic data and meteorological data. Because it is not possible to address all the various types of data that might be used in computing the progress reporting indicators, the Board will evaluate these data on a case-by-case basis. Such evaluation will assure that poor quality data do not compromise the reliability of a progress reporting indicator.

2. Complete and Unambiguous Definition

A progress reporting indicator must be consistent from one time period to the next. To achieve consistency, the complete and unambiguous definition criterion specifies the required level of detail for the definition of an indicator. The definition of a progress reporting indicator must specify the data to use, how to account for missing data, and how to compute the indicator value. The level of detail required for the definition is important for ensuring that the progress reporting indicator values can be compared for different years and that different analysts do not reach conflicting conclusions.

3. Important Characteristics of Air Quality

As described previously, an indicator is a way of summarizing air quality data so as to represent one characteristic of air quality in a specific area. This criterion establishes three specific characteristics of air quality that the Board considers important for measuring progress:

1) The peak concentrations in the peak "hot spot" subarea,

2) The population-weighted average of the total exposure, and

3) The area-weighted average of the total exposure.

Each characteristic represents a different aspect of air quality. The peak "hot spot" indicator represents the highest concentrations at individual locations. The population-weighted exposure indicator represents a composite of exposures at individual locations that are weighted to emphasize equally the exposure for each person in the area. Similarly, the area-weighted exposure represents a composite of exposures at individual locations that are weighted to emphasize equally the exposures throughout the area.

In general, these three characteristics of air quality represent the potential for various health effects. A peak "hot spot" indicator represents the potential for acute health effects. In contrast, an exposure indicator represents the potential for chronic health effects as measured by concentrations above the State standard at the ambient air quality monitoring stations. Each of the three air quality characteristics could have many progress reporting indicators associated with it. However, the Board has identified only one progress reporting indicator for each of the three important air quality characteristics.

4. Reliability

The reliability of a progress reporting indicator determines its usefulness for measuring or estimating progress--an improvement in air quality resulting from a reduction in emissions. However, air quality responds not only to changes in emissions but also to other factors, such as variable meteorology. The reliability of an indicator depends in part on how the indicator responds to meteorological variations. Some indicators are more sensitive than others to the effects of meteorology. As a result, it is more difficult to measure true progress with these indicators. For example, the annual maximum concentration and the number of days during a year with concentrations above the level of an ambient air quality standard have been widely used as indicators. However, these indicators are very sensitive to year-to-year changes in meteorology. Therefore, they are not very reliable because the indicator "signal" (the change due to progress) is small compared with the indicator "noise" (the change due to year-to-year meteorological variations). A reliable indicator has a large signal-to-noise ratio, whereas, an unreliable indicator has a small signal-to-noise ratio.

The progress reporting indicators described in this guidance document are among the "best" or most reliable of the potential progress reporting indicators that are available. Furthermore, to avoid confusion and to facilitate implementation and comparison of the progress reporting indicators from area-to-area, the Board has identified only one progress reporting indicator for each important air quality characteristic (refer to subsection 3., above).

CHAPTER II

GENERAL CONSIDERATIONS FOR PROGRESS REPORTING INDICATORS

The Board has identified three progress reporting indicators: a peak "hot spot" indicator, a population-weighted exposure indicator, and an area-weighted exposure indicator. Some of the considerations in computing the values of these progress reporting indicators are similar, regardless of which indicator is being computed. These general considerations include which data are appropriate, what time period is used, how transport is treated, what level of confidence is acceptable in the results, how the uncertainty of the results is estimated, and how the results will be interpreted. Each of these general considerations is described in the sections below. Because the following sections are specific to the progress reporting indicators, the terms "progress reporting indicator" and "indicator" are used interchangeably.

A. Data Considerations

1. Affected Pollutants

The Health and Safety Code requires the districts to attain the State standards for all pollutants as expeditiously as practical. However, the HSC requires the districts to develop attainment plans only for ozone, carbon monoxide, nitrogen dioxide, and sulfur dioxide. Similarly, HSC section 40924 mandates the development of triennial progress reports which summarize the progress toward attainment only for those pollutants addressed in a district's attainment plan. Consistent with these requirements, the peak "hot spot" indicator is to be used to assess progress for ozone, carbon monoxide, nitrogen dioxide, and sulfur dioxide. This progress reporting indicator is appropriate for all four pollutants because it is reported on a site-by-site basis, and the monitoring sites are located in the areas of expected high concentrations. Therefore, the spatial variation in the ambient concentrations does not affect the results for the peak "hot spot" indicator.

In contrast, because the population-weighted and area-weighted exposure indicators represent spatially averaged values, they are appropriate only for ozone. Since ozone tends to exhibit somewhat uniform concentrations over large areas, it is appropriate to apply a spatially averaged exposure indicator to ozone. The exposure indicators are not appropriate for carbon monoxide, nitrogen dioxide, and sulfur dioxide because of the extremely steep concentration gradients typically observed for these pollutants. A spatially averaged exposure indicator applied for these pollutants would be exaggerated because it would be heavily influenced by the sites with the highest concentrations. The results would not be meaningful.

2. Data for Record

The air quality data used for computing a progress reporting indicator must qualify as "data for record" (refer to Chapter I, Section D.1.). Data for record are defined in Title 17, California Code of Regulations (CCR), section 70301(a) (refer to Appendix C). In general, data for record are those data collected by or under the direction of the Board or the districts.

As defined in Title 17, CCR, section 70301(a), data for record comply with the siting and quality assurance procedures established in Part 58, Title 40, Code of Federal Regulations, as they existed on July 1, 1987. The federal Environmental Protection Agency established these procedures as the minimum standards for collecting air quality data. The procedures, which are in effect for all states, assure consistency in the quality of data. They provide the quality assurance procedures and guidelines for the air quality monitors in the National Air Monitoring System and the State and Local Air Monitoring System.

The Board currently maintains qualifying data for record in the California Aerometric Data System. This computer-compatible system comprises air quality measurements for more than 200 monitoring stations located throughout California. In addition to the data that the Board maintains, the Board may identify other data as data for record if a district demonstrates that these other data meet the same or equivalent quality assurance procedures.

3. Complete and Representative Data

In addition to being data for record, it is desirable that the air quality data used for computing a progress reporting indicator be both "complete" and "representative." Completeness implies that the data meet the minimum standards necessary to assure that sampling occurred at the times when a violation was most likely to occur. Representativeness implies that the amount of data available is sufficiently complete to characterize reliably the air quality during a particular time period. Complete and representative data assure that the indicator values adequately reflect the intent of the indicator and that the indicator values are consistent from year-to-year.

In determining whether the air quality data are complete and representative, the Board has elected to use the criteria it established for evaluating data used in designating areas as attainment or nonattainment for the State standards. These criteria for judging completeness and representativeness are specified in Appendices 3 and 1, respectively, to Title 17, CCR, sections 70300 through 70306 (refer to Appendix C). Gaseous pollutant data generally are monitored continuously and the concentrations reported on an hourly basis. However, gaps in the data record may occur because of instrument downtime caused by conditions such as calibration and failure. Generally, 100 percent data capture is not necessary to document the ambient air quality levels in an area. Under the established criteria, data are considered complete and representative if they are available for the hours and season of expected maximum concentrations. In general, this means that data are available for 75 percent or more of the hours and the season of expected maximum concentrations.

Although it is desirable that the data used in computing the progress reporting indicators be complete and representative, the data for some sites may be "incomplete." If these incomplete data are ignored, valuable information may be lost. Therefore, the ARB staff suggests that all available data be used in computing the progress reporting indicators. However, in reporting the results, indicators based on data that do not satisfy the established criteria for completeness and representativeness should be identified as incomplete and potentially unrepresentative.

B. Time Period of Assessment

The amount of progress that has occurred over time must be measured with respect to some base period or reference point. The value of a progress reporting indicator for the years 1986 through 1988 should be used as the base period for comparison in the triennial progress reports. The ARB staff selected this base period for two reasons. First, HSC section 40920(e) and 40920.5(a) establish the average value for the years 1986 through 1988 as the base period for setting specific goals for improvements in the population-weighted average ozone exposure in areas classified as "severe" or "extreme" ozone nonattainment areas. Second, HSC section 40914 requires that the level of emissions during 1987 be used as the base period for determining emission reductions for attainment planning. The base period for the progress reporting indicators, 1986 through 1988, reflects a three-year period centered on 1987. Although a single year is used for emissions, an indicator based on air quality data is more reliable if the value is based on or represents an average of three years of data (for example, a three-year moving average). Using multiple years of data for computing the progress reporting indicators tends to dampen the effect of variable meteorology. As a result, the indicator trends become more stable and, therefore, easier to interpret.

In addition to the base period, the progress reporting indicators also should be reported for the most recent three-year period for which suitable data are available. For the 1994 triennial progress reports, this final or end period will likely be 1991 through 1993. Comparing the indicator value for the end period with the indicator value for the base period provides a basis for determining whether any progress was achieved.

C. Consideration of Transport

Pollutants that are transported from an upwind area to a downwind area can have a significant impact on the ambient air quality in the downwind area. However, for the purpose of designating areas as attainment or nonattainment with respect to the State standards, air quality data affected by transport are neither modified nor removed from consideration. The rationale for this is that the people in the downwind area are exposed to the measured ambient concentrations, regardless of whether transport occurred. Because the progress reporting indicators are intended to represent the progress made toward attainment, it is appropriate that they be based on the same data as used to determine the area's attainment or nonattainment status. Therefore, air quality data affected by transport should not be modified or removed when computing the value of the progress reporting indicators described in this guidance document.

The Board recognizes that not considering the transport contribution may obscure the progress resulting from the local emission control efforts in some areas. Therefore, although transport-affected data are not considered in computing the progress reporting indicators described in this guidance document, districts that are significantly impacted by transport may wish to present additional information which adjusts for the impact of transport. This additional information may more accurately reflect the air quality improvement resulting from the control of the locally generated emissions.

D. Confidence in Results

As discussed in the Board's "Plan for Approving Air Quality-Related Indicators" [Reference 1], an alternative measure of progress indicator must meet a strict limit of confidence because the alternative measure of progress indicator is used in lieu of the five percent annual emission reduction requirement. In contrast, the progress reporting indicators do not need to meet such a strict test because they are not used alone in judging the success of a district's attainment plan.

The progress reporting indicators are intended to provide information about the improvement in air quality and how the air quality has changed in response to the emission reductions. Each of the progress reporting indicators presented in the triennial progress reports should include an estimate of the uncertainty for the base period and the end period, using a 95 percent confidence range. The procedures for estimating and interpreting the uncertainty of an indicator are discussed in the following section. Presenting the uncertainty associated with an indicator allows a district to attach some degree of confidence to its conclusion that some progress was achieved. This approach is far better than basing conclusions on a single value without any indication of how reliable that value is.

E. Estimating and Interpreting Uncertainty

The ARB staff has developed a general procedure for estimating the uncertainty associated with the progress reporting indicators. The results of this procedure are useful for determining the confidence one has in concluding that progress toward attainment was achieved. The procedure for estimating uncertainty also is useful for assessing quantitatively, the amount of progress that occurred. (Remember that "progress" is a change or improvement in air quality that can be attributed to a reduction in emissions.) The procedures for estimating the uncertainty of an indicator and documenting the amount of progress achieved are described in general terms, below. More detailed information about the procedures is found in Appendix D.

Several terms that may not be familiar are used in the following discussion. Three terms in particular are important for understanding the discussion:

"Composite Native Variability Limits,"
"Confidence Scale," and
"Documented Progress."

The composite native variability limits represent the range of uncertainty associated with the indicator values for both the base period and the end period. A confidence scale can be attached to the composite native variability limits such that conclusions regarding progress can be made for varying levels of confidence. Finally, documented progress is the amount of progress from the base period to the end period that can be attributed to changes in emissions only and can be claimed with a specified level of confidence.

1. Composite Native Variability Limits

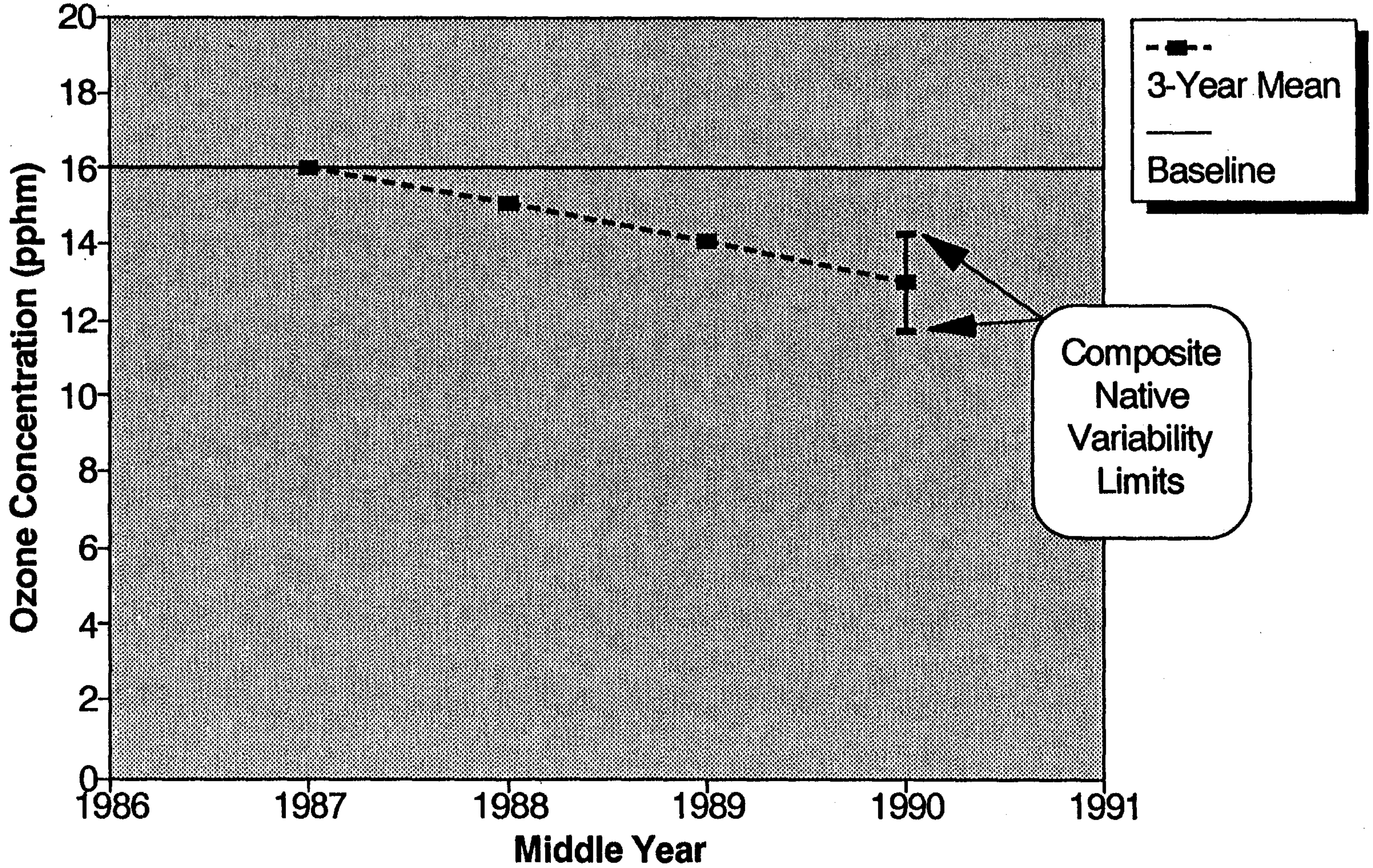
Each indicator value has a certain amount of variability associated with it. The range of this variability can be computed for a selected confidence level, such as the 95 percent confidence level that is used with the progress reporting indicators. "Native variability limits" is the term the ARB staff uses to refer an indicator's range of variability.

The native variability limits for a progress reporting indicator encompass the range of values--both above and below the computed indicator value--that might occur because of the influence of factors other than emissions (refer to Appendix D for computation procedure). Meteorology accounts for most of the variability. In essence, the native variability limits are meant to capture the range of values within which the indicator would be expected to fall, if the indicator were averaged over all possible meteorological conditions.

The native variability limits apply to individual indicator values. However, when comparing indicators to evaluate progress (comparing the indicator value for the base period with the indicator value for the end period), the ARB staff treats the base period as a fixed or nonvariable value. The native variability limits associated with the base period are not ignored, but rather, are combined with the native variability limits of the end period. The results are "composite native variability limits" around the indicator value for the end period (refer to Appendix D for computation procedure).

An example is shown in Figure 1. As shown in this example, the composite native variability limits represent two equal limits, one above and one below the indicator value. For example, assume that the indicator value for the end period is 13 parts per hundred million (pphm) ozone, and the composite native variability limit is 1.8 pphm. Therefore, the composite native variability limits would range from 11.2 pphm (13 - 1.8 = 11.2) to 14.8 pphm (13 + 1.8 = 14.8). While the composite native variability limit is 1.8 pphm in this example, the size of the limit will vary, depending on the particular indicator and time period being

FIGURE 1
Example of Composite Native Variability Limits



evaluated. For example, an indicator that is very stable will have a smaller composite native variability limit than an indicator that is less stable.

2. Confidence Scale

A confidence scale can be added to the composite native variability limits to identify the degree of confidence there is that some progress occurred. An example of the confidence scale is shown in Figure 2. The confidence scale goes from 5 to 95, reflecting 95 percent confidence at the top of the scale and 5 percent confidence at the bottom of the scale. As shown in Figure 2, the indicator value for the end period always lies at the midpoint of the confidence scale which corresponds to the 50 percent confidence level. Notice the confidence scale is not linear, but conforms to the familiar "bell-shaped" curve.

Figure 2 also illustrates how the confidence scale can be used in determining the degree of confidence in the conclusion that some progress was achieved. The indicator value for the base period is compared with the confidence scale. In Figure 2, the indicator value for the base period falls within the confidence scale--at about the 80 percent level. This indicates there is about an 80 percent confidence that some progress was achieved.

3. Documented Progress

The composite native variability limit and the confidence scale described above can be used to determine the amount of progress achieved. This "documented progress" is the progress that one can conclude was achieved, with a specified level of confidence.

Figure 3 provides an example of documented progress at a high level of confidence (i.e., 95 percent confidence). In this case, the indicator value for the base period is higher than the indicator value for the end period. Furthermore, the indicator value for the base period does not fall within the composite native variability limits. Figure 3 shows there is at least 95 percent confidence that some progress was achieved. The amount of documented progress at the 95 percent confidence level is determined by computing the difference between the indicator value for the base period and the upper composite native variability limit--in this case, (16 pphm - 14.8 pphm = 1.2 pphm). Documented progress can be reported in terms of a percentage by dividing the calculated difference by the indicator value for the base period and then multiplying the result by 100 percent ((1.2 pphm / 16 pphm) x 100% = 7.5% documented progress at the 95 percent confidence level).

Although the ARB staff recommends reporting documented progress at the 95 percent confidence level, sometimes there is no documented progress at this high level of confidence. Figure 4 provides an example. In this case, the indicator value for the base period falls within the composite native variability limit and consequently, there is no documented progress at the 95 percent confidence level. However, the indicator value for the base period intersects the confidence scale at about the 80 percent level,

FIGURE 2
Example of Confidence Scale

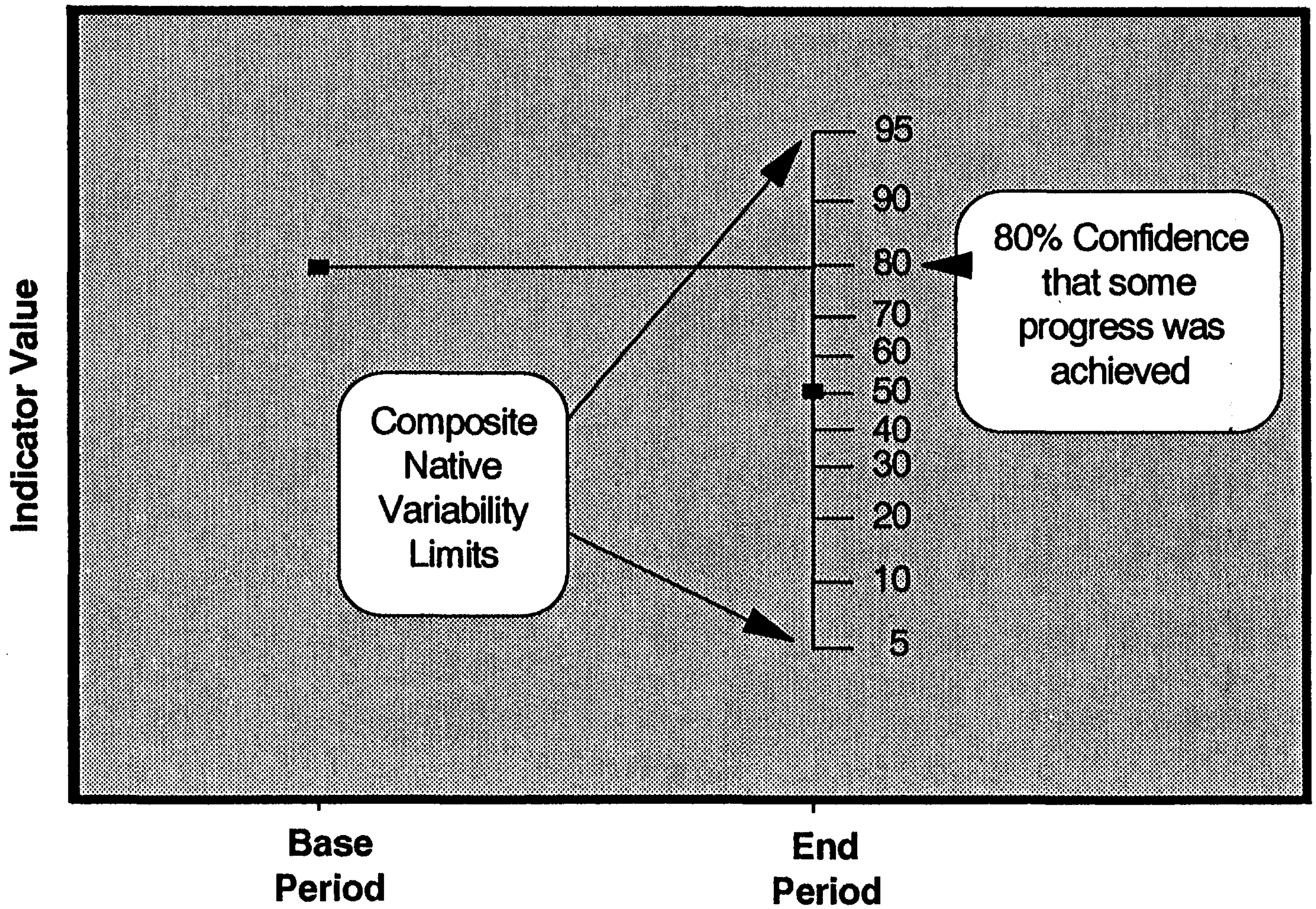


FIGURE 3
Example of Documented Progress at 95 Percent Confidence

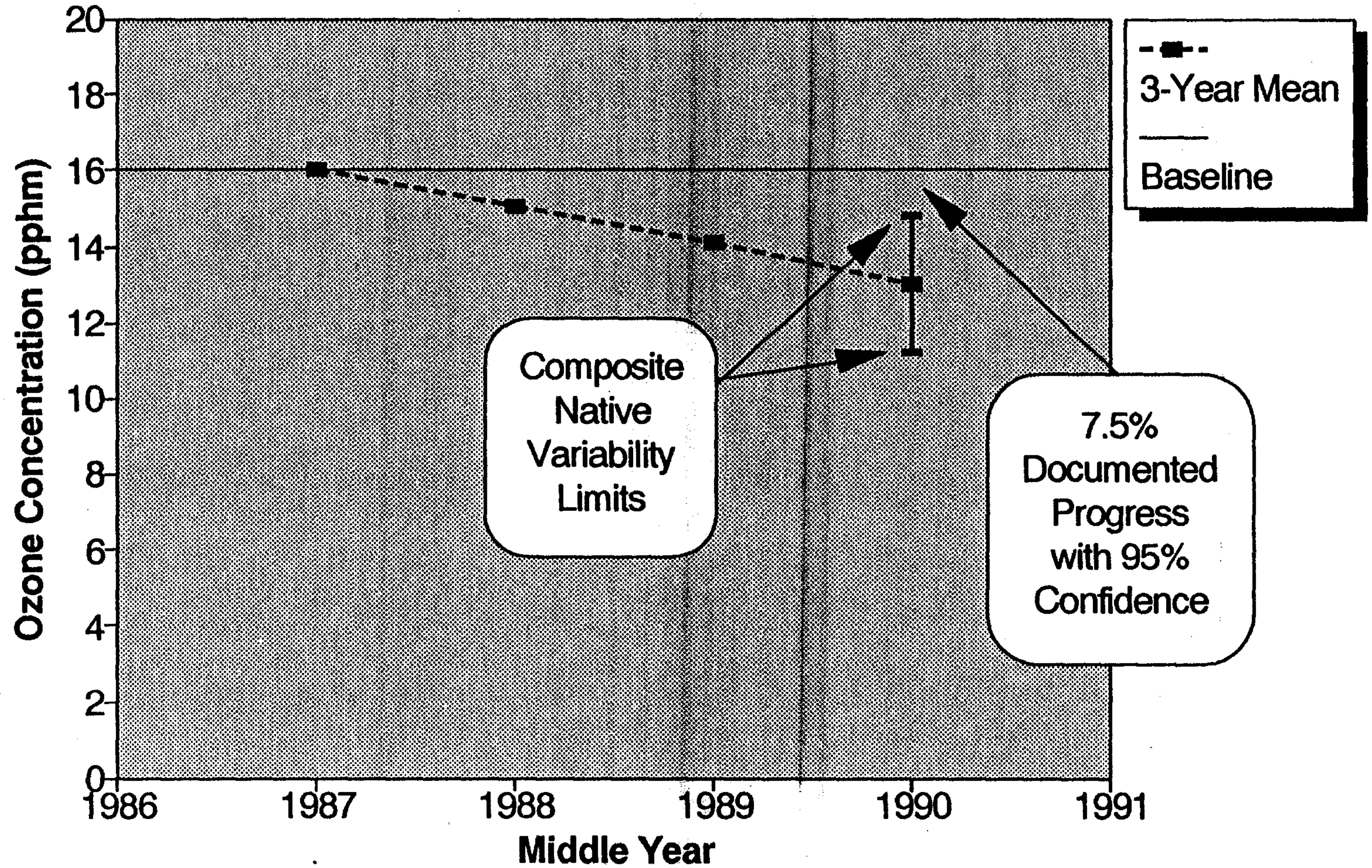
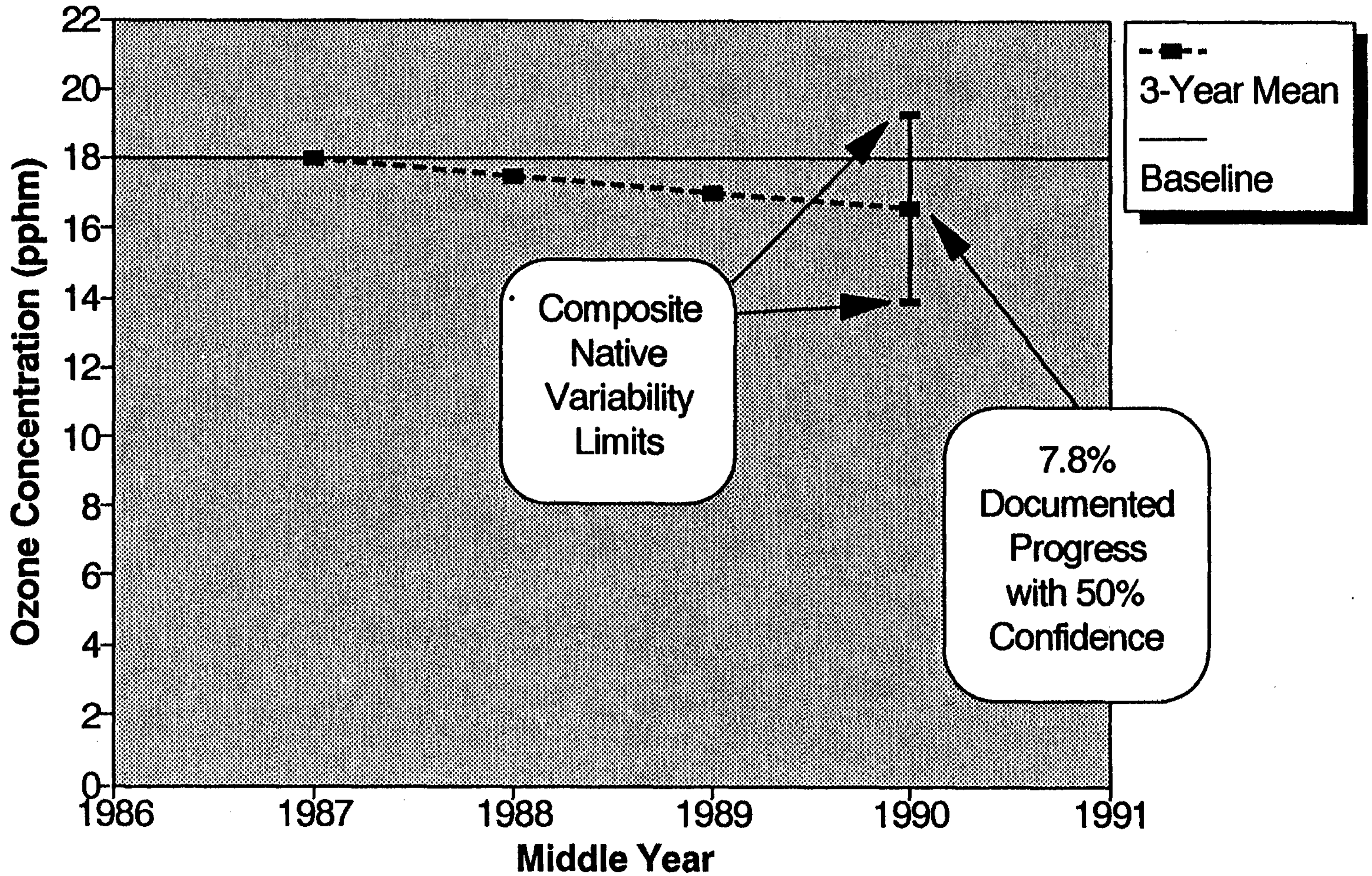


FIGURE 4
Example of Documented Progress at 50 Percent Confidence



indicating there is about an 80 percent confidence that <u>some</u> progress was achieved. An actual amount of progress can be quantified at a some lower level of confidence. For example, the difference between the indicator value for the base period and the indicator value for the end period (18.0 pphm - 16.6 pphm = 1.4 pphm) shows 2.4 pphm or 7.8 percent documented progress at the 50 percent confidence level. In this example, there is a 50 percent confidence that the amount of progress achieved from the base period to the end period was at least 7.8 percent. Alternatively, there also is a 50 percent confidence that the amount of progress achieved was less than 7.8 percent.

F. Interpretation of Meaning

HSC section 40924 requires districts to assess their progress in attaining the State standards using measurements of air quality, as well as measurements of emission reductions. The progress reporting indicators described in this guidance document provide a way to do this. In addition to presenting the results for the progress reporting indicators, a district should provide its interpretation of how the progress reporting indicators have responded to the attainment plan during the period of the assessment. This interpretation may compare the progress reporting indicators with other elements affecting progress, including the emission reductions actually achieved, the rate of population and industrial growth experienced in the area, or the potential impact of transport on air quality improvement. Because the district has the most immediate knowledge of the nonattainment area and the changes that have occurred, the district is well suited to provide this interpretation.

CHAPTER III

DESCRIPTION AND EXPLANATION OF THE PROGRESS REPORTING INDICATORS

As discussed in Chapter I, Section D.3., the Board has identified three characteristics of air quality that are appropriate for summarizing the improvement in air quality required in the triennial progress reports. These three characteristics are reflected by a peak "hot spot" indicator, a population-weighted exposure indicator, and an area-weighted exposure indicator. Each of these progress reporting indicators are described in more detail, below. The information provided for each progress reporting indicator includes a general description of the indicator, the scope of the analysis, the special data considerations, and formats for presenting the results. The details of the procedures the ARB staff uses for computing the progress reporting indicators are found in Appendix E. Similar to Chapter II, the following discussion is specific to the progress reporting indicators. Therefore, the terms "progress reporting indicator" and "indicator" are used interchangeably throughout this chapter.

A. Peak "Hot Spot" Indicator

1. General Description of the Peak "Hot Spot" Indicator

The peak "hot spot" indicator tracks progress at the locations where concentrations are highest, which also are the locations where the potential for acute adverse health impacts is greatest. As a result, the peak "hot spot" indicator ignores any improvement or deterioration in air quality that occurs elsewhere in an area. The "expected peak day concentration" is the peak "hot spot" indicator the Board has identified for use in the triennial progress reports.

The expected peak day concentration is defined as the air quality concentration that is expected to recur no more frequently than once per year. This is the same statistic the Board uses in determining how an area is designated with respect to the State standards [References 2, 3, and 4]. The expected peak day concentration is computed using an "exponential-tail" statistical model proposed by Breiman, Gins, and Stone for estimating air pollutant concentrations with infrequent recurrence rates [Reference 5]. In general, the procedure fits an exponential-tail model to the upper tail of the distribution of concentrations. The fitted distribution then is used to determine analytically the concentration expected to recur at a 1-in-1 year rate. The procedure for computing the expected peak day concentration is explained in Appendix E.

The ARB staff evaluated a number of other potential peak "hot spot" indicators. Many of these potential indicators (for example, the maximum annual concentration, the number of days with concentrations above the level of the State standard, and various percentile concentrations) were abandoned because they were not reliable. However, one other potential peak "hot spot" indicator was seriously considered: the mean of the top 30 concentrations (TOP30).

The TOP30 value is the average of the 30 highest daily maximum concentrations during the previous year. The Board previously endorsed the TOP30 as a reliable indicator for tracking the maximum concentrations [Reference 1]. In terms of reliability, the expected peak day concentration and the TOP30 value are comparable. The TOP30 value offers one advantage over the expected peak day concentration--it is easier to compute. However, the TOP30 value is not closely related to either the attainment criteria or the State standard. Therefore, the Board does not advocate using the TOP30 value for tracking progress toward attainment.

In contrast to the TOP30 value, the expected peak day concentration is closely tied to the attainment criteria--it is the same statistic the Board uses in making the attainment and nonattainment designations. When the expected peak day concentration for an area is equal to or less than the State standard, the area is assumed to have achieved attainment because concentrations greater than the expected peak day concentration are excluded. In addition to being tied to the attainment criteria, the expected peak day concentration also is closely tied to the State standard. Unlike the TOP30 value, the expected peak day concentration does not represent an average concentration. Rather, it represents the highest concentration that is statistically estimated to recur no more frequently than once per year. These characteristics of the expected peak day concentration make it more appropriate than the TOP30 value for tracking progress toward attainment of the State standards.

2. Scope of Analysis

The purpose of the peak "hot spot" indicator is to characterize the high concentrations in the "hot spot" subarea. HSC section 40924 requires the affected districts to include the expected peak day concentration in their triennial progress reports. It is appropriate to apply this progress reporting indicator for ozone, carbon monoxide, and nitrogen dioxide (refer to Chapter II, Section A.1.) The expected peak day concentration should also be applied for sulfur dioxide if any area becomes designated as nonattainment for this pollutant.

The expected peak day concentration should be computed for all sites located in the nonattainment planning area. At a minimum, this indicator should be calculated for the three-year base period of 1986 through 1988 and for the most recent three-year period for which appropriate data are available (refer to Chapter II, Section B.). For the 1994 triennial progress reports, the end period will likely be 1991 through 1993. In addition to the base period and the end period, the expected peak day concentration could be computed for the intermediate three-year periods. In other words, the expected peak day concentration also could be computed for 1987-1989, 1988-1990, 1989-1991, and 1990-1992. The results for all periods would provide an indication of how the air quality has changed throughout time rather than just in relation to the end points.

Although the expected peak day concentration should be computed for all sites in the nonattainment planning area, the results should be presented for the two highest sites. In addition, the results should be presented for all other sites with an expected peak day concentration for the end period that is within ten percent of the end period value computed for the high site. For example, if the high site shows an expected peak day concentration of 15 pphm ozone for the end period, all other sites with an expected peak day concentration for the end period of at least 13.5 pphm (15 pphm - (15 pphm x 0.1) = 13.5 pphm) also should be reported.

A district's triennial progress report should include a trend of the expected peak day concentration for each qualifying site. Each trend should include an estimate of the uncertainty for the base period and the end period, using a 95 percent confidence range. The method for computing the uncertainty of the expected peak day concentration is described generally in Chapter II, Section E., and the computation procedure is explained in Appendix D.

3. Special Data Considerations

There are no special data considerations for the expected peak day concentration beyond the data requirements described in Chapter II, Sections A.2. and A.3. In summary, the expected peak day concentration should be based on data for record. Ideally, the data for record should be complete and representative. However, following such strict requirements may limit the value of the information provided by the peak "hot spot" indicator. Therefore, expected peak day concentration trends should be presented for the two highest sites and for all other sites that satisfy the ten percent requirement (refer to subsection 2., above). The qualifying sites with data that do not meet the completeness and representativeness criteria should be identified as "incomplete," and, therefore, potentially unrepresentative.

At this time, the ARB staff suggests that only the actual monitored concentrations be used in computing the expected peak day concentrations. The ARB staff does not endorse any method for determining missing data values. However, the Board encourages any district that has developed a method for computing missing data to contact the ARB staff and discuss the suitability of applying the method for the peak "hot spot" indicator.

4. Presenting and Interpreting the Results for the Peak "Hot Spot" Indicator

Districts should present and interpret in their triennial progress reports, the results for the expected peak day concentration for each applicable nonattainment pollutant. This subsection provides examples of both tabular and graphic formats for presenting the results.

As discussed in Section A.2., above, the expected peak day concentration results should be presented for the two highest sites in the nonattainment planning area and for all other sites which meet the ten percent requirement. For example, assume that during the 1990 through 1992 end period, the highest expected peak day concentration for all sites in an area was 16.1 pphm ozone. Four other sites in the area had an expected peak day concentration for the end period that was within ten percent of 16.1 pphm. Based on these results, five sites should be reported in the triennial progress report.

Table 1 is an example of how the results for the expected peak day concentration could be presented in a tabular format. As shown below, the example table includes the expected peak day concentrations for each qualifying site for the base period (1986 through 1988) and the most recent three-year end period (in this example, 1990 through 1992). The table also includes for each site, the difference between the expected peak day concentrations for the end period and base period, the composite native variability limit (uncertainty), the percent documented progress at the 95 percent confidence level, and the percent confidence that some progress was achieved (refer to discussions in Chapter II, Section E.3. and Appendix D). Note that although the ARB staff recommends reporting documented progress at the 95 percent confidence level, documented progress at other levels of confidence (for example, 90, 80, or 50 percent confidence) might also be reported.

TABLE 1

EXAMPLE OF A TABULAR PRESENTATION OF THE EXPECTED PEAK DAY CONCENTRATION RESULTS

Site	Base Period 86-88	End Period 90-92	Difference (Base-End)	For 95% Confidence		Confidence Some Progress Achieved
				Uncertainty (CNVL*)	Documented Progress	
A	15.3**	16.1	-0.8	1.6	0 %	20 %
B	16.5	15.7	0.8	1.2	0 %	85 %
C	14.3	15.1	-0.8	1.3	0 %	15 %
D	17.7	14.6	3.1	1.5	9 %	>95 %
E	--***	14.5	--***	--	--	--

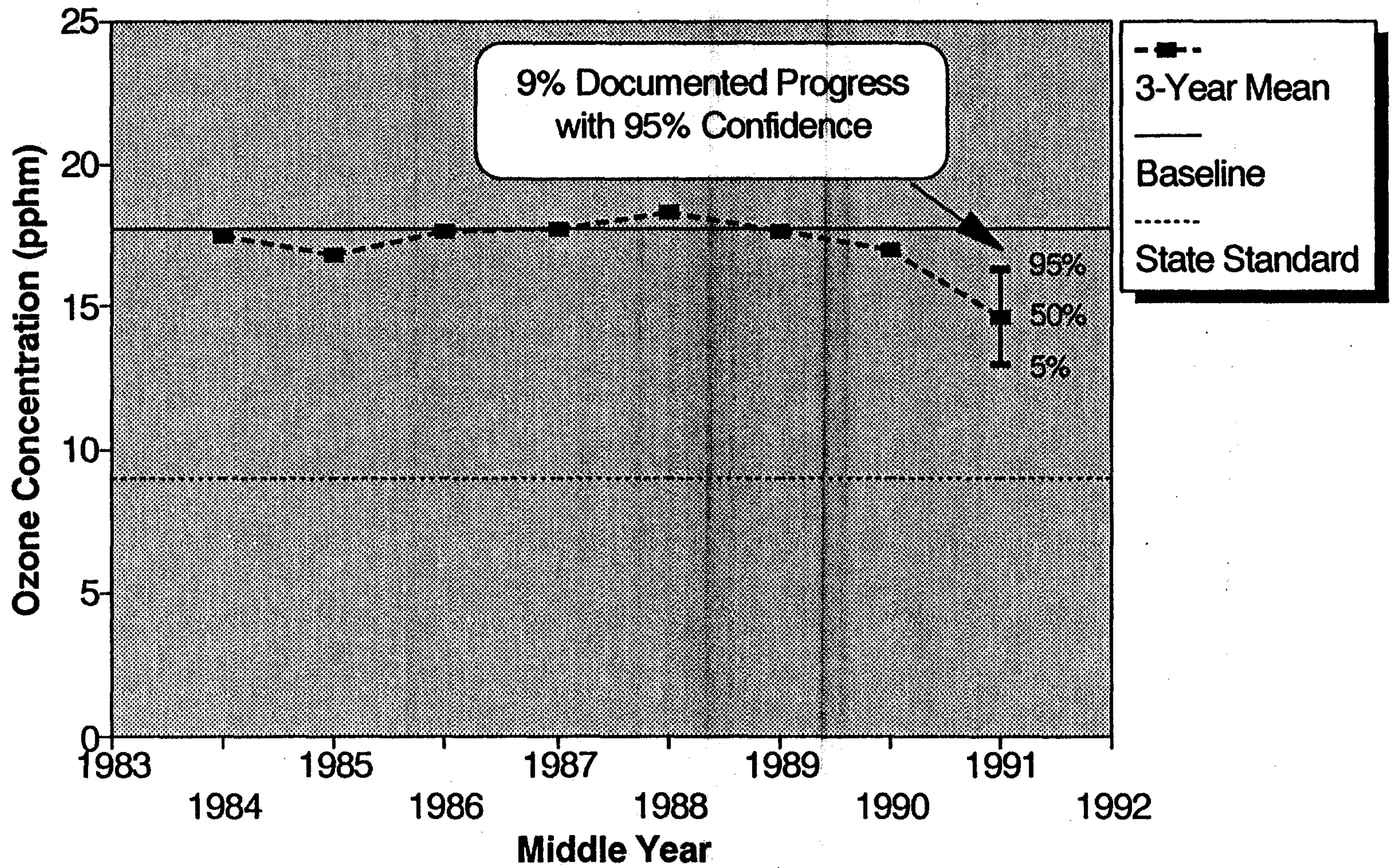
* Composite Native Variability Limit.

** Base period and end period ozone concentrations, differences, and uncertainties are in pphm.

*** No data are available for the base period.

Although the information presented in Table 1 is complete, it could be enhanced by a graphical presentation. Figure 5 shows how the results for

FIGURE 5
Progress in Reducing the Expected Peak Day Concentration



Site D in Table 1 could be graphed (for clarity, each site should be graphed separately). The graph includes the minimum suggested data: the expected peak day concentration for the base period, the expected peak day concentration for the end period, the composite native variability limit, and the 5 percent, 50 percent, and 95 percent points on the confidence scale. It is recommended that in addition to the data for the base period and end period, data for the years prior to the base period (for example, 1983-1985, 1984-1986, and 1985-1987) and the years between the base period and the end period (1987-1989, 1988-1990, and 1989-1991) be presented. Such additional information is included in Figure 5, providing a more complete assessment of the overall pattern of progress.

The interpretation of the expected peak day concentration depends on the results of the computations. At a minimum, the ARB staff recommends the interpretation consider the amount of progress that is documented with a high degree of confidence (i.e., 95 percent confidence). If no documented progress exists at the 95 percent confidence level, the confidence that some progress was achieved should be considered. The interpretation might also include consideration of additional information, such as meteorological data, that may be relevant to the evaluation of progress in attaining the State standards.

The composite native variability limits indicate the range of values through which the expected peak day concentration naturally varies, given the influence of factors other than emissions. On the other hand, progress is an improvement in the expected peak day concentration that can be attributed to emission reductions. Therefore, progress (or conversely, degradation) is <u>strongly</u> established only when the expected peak day concentration for the base period is not within the range of uncertainty represented by the composite native variability limits. When the expected peak day concentration for the base period is higher than the upper composite native variability limit, "documented progress" at the 95 percent confidence level has been achieved (refer to Appendix D for details). Conversely, when the expected peak day concentration for the base period is below the lower composite native variability limit, "documented degradation" has occurred. When the expected peak day concentration for the base period falls within the composite native variability scale, some progress may have occurred, but the confidence in that conclusion is not high--the actual degree of confidence can be determined on the confidence scale.

For the sites in Table 1, Site D achieved 9 percent documented progress at the 95 percent confidence level with respect to the 1986 through 1988 base period. Sites A, B, and C show 20, 85, and 15 percent confidence, respectively, that some progress was achieved. Because the indicator values for the base period at these sites are within the range of uncertainty represented by the composite native variability limits, neither progress nor degradation can be documented with 95 percent confidence.

Site E is not considered because there are no data for the base period. If a district wants to include such sites in its analysis, the first three years of operation could be used as the base period for evaluating the amount of progress achieved. Additionally, the progress achieved at such a site can be compared with other sites that operated during the entire time period, if progress is expressed in terms of percent progress per year. For example, one site may show 15 percent progress over 10 years while a second site shows 8 percent progress over 7 years. In this example, the first site shows 1.5 percent progress per year while the second site shows only 1.1 percent progress per year.

Some districts may wish to present more detailed evaluations of their progress than the minimum suggested above. An analysis of the meteorological conditions prevailing in the base period and other periods may assist in the interpretation of the expected peak day concentrations. In addition, the geographical locations of sites that differ in their responses may suggest specific causes for observed differences.

B. Exposure Indicators

1. General Description of the Exposure Indicators

The exposure indicators provide an indication of the potential for chronic adverse health impacts by tracking the progress in reducing the total annual exposure to ambient concentrations exceeding the State standard. As discussed in Chapter II, Section A.1., the exposure indicators apply only for ozone.

The term "exposure" is used here in reference to the ambient outdoor ozone concentrations. In this context, exposure refers to the annual sum of the positive differences between all of the measured ozone concentrations and the State ozone standard. For example, a measured concentration of 11 pphm ozone for one hour represents an exposure of 2 pphm-hours ((11 pphm - 9 pphm) x 1 hour = 2 pphm-hours) above the State ozone standard of 9 pphm. A measured concentration of 10 pphm for two hours also equals an exposure of 2 pphm-hours ((10 pphm - 9 pphm) x 2 hours = 2 pphm-hours). For the purposes of computing the exposure indicators, individuals are presumed to have been exposed to the concentrations measured by the ambient air quality monitoring network. Accordingly, the exposure indicators do not represent the potential for health effects for all individuals in an area because daily activity patterns (for example, being inside a residence or exercising outdoors) may diminish or increase exposures to some outdoor concentrations that exceed the State ozone standard.

Unlike the peak "hot spot" indicator which tracks progress for individual locations, the exposure indicators consolidate the hourly exposures at all locations into a single exposure value. The result is a value that represents the average exposure in an area. The Board has identified two exposure indicators for presentation in the triennial progress reports:

1) A "population-weighted" exposure indicator, and
2) An "area-weighted" exposure indicator.

The population-weighted exposure indicator represents a composite of exposures at individual locations that have been weighted or adjusted to emphasize equally the exposure for each individual in the area. In contrast, the area-weighted exposure indicator represents a composite of exposures at individual locations that have been weighted to emphasize equally the exposure in all portions of the area. The procedures for computing the population-weighted and area-weighted exposure indicators are explained in Appendix E.

2. Scope of Analysis

The purpose of the population-weighted annual exposure indicator is to characterize the average annual outdoor exposure per person to concentrations above the level of the State standard. In contrast, the purpose of the area-weighted annual exposure indicator is to characterize the average annual outdoor exposure per unit area. HSC section 40924 requires the affected districts to include the exposure indicators in their triennial progress reports. As explained in Chapter II, Section A.1., it is appropriate to apply the exposure indicators only for ozone.

The exposure indicators should reflect information from all sites in the nonattainment planning area that satisfy the data for record requirements described in Chapter II, Section A.2. In addition, data from sites located outside the nonattainment planning area, but within 50 kilometers of a census tract centroid, should be included if these data also qualify as data for record. (Note that exposures are interpolated to census tract centroids, using a 50 kilometer radius of representativeness; refer to Appendix E).

At a minimum, the exposure indicators should be computed for the 1986 through 1988 base period and for the most recent three-year end period for which appropriate data are available. For example, for the 1994 triennial progress reports, the three-year end period will likely be 1991 through 1993. In addition to the base period and the end period, the exposure indicators could be computed for the intermediate three-year periods. In other words, the exposure indicators also could be computed for 1987-1989, 1988-1990, 1989-1991, and 1990-1992. The results for all periods would provide an indication of how the exposures have changed throughout time rather than just in relation to the end points.

Ideally, the district's triennial progress report should include the trend for each exposure indicator for the entire nonattainment area. However, if results are available only for a portion of the nonattainment planning area, the information presented should include the percentage of both the nonattainment planning area and the population within the nonattainment planning area that are represented by the results. In addition to the exposure trends, the information presented should include an estimate of the uncertainty for the base period and the end period, using a 95 percent confidence range. The method for computing the uncertainty of the exposure indicators is described in Chapter II, Section E., and the computation procedures are explained in Appendix D.

3. Special Data Considerations

As stated in subsection 2., above, the air quality data used in computing the exposure indicators should be data for record. In addition, it is desirable that the data be complete and representative (refer to Chapter II, Section A.3.). However, if the criteria for completeness and representativeness are strictly followed, it is likely that the remaining data for some areas would not be spatially adequate for computing the exposure indicators. As a result, although complete and representative data are desirable, they are not mandatory for the exposure indicators--all available data for record for all sites should be used. At this time, the ARB staff does not endorse any method for determining missing data values. However, the Board encourages any district that has developed a method for computing missing data values to contact the ARB staff and discuss the suitability of applying the method for the exposure indicators.

In addition to the air quality data, the exposure indicators also rely on census data. The required census data include the center point or centroid of each census tract, the population residing in each census tract, and the land area of each census tract. The most current data should be used. For the 1994 triennial progress reports, the most recent data will likely represent the 1990 decennial census. In computing the exposure indicators for the base period and the end period, the census data do not need to be "updated." Although updates could be completed, such updates would not substantially affect the overall results of the exposure computations.

4. Presenting and Interpreting the Results for the Exposure Indicators

Districts with areas designated as nonattainment for ozone should present and interpret in their triennial progress reports, the results for the population-weighted and area-weighted exposure indicators. This subsection provides examples of both tabular and graphic formats for presenting these results.

Ideally, the exposure results should be presented for the entire nonattainment planning area. However, data limitations may dictate that only a portion of the area can be represented. Therefore, the presentation should include the percentage of both the population and the nonattainment planning area that are represented by the results. Table 2 is an example of how the results for the exposure indicators could be presented in a tabular format. As shown below, the example table includes information for both the population-weighted exposure and the area-weighted exposure for the base period (1986 through 1988) and the most recent three-year end period (in this example, 1990 through 1992). The table also includes for each exposure indicator, the difference between the exposure indicator for the end period and the base period, the composite native variability limit (uncertainty), the percent documented progress at a 95 percent confidence level, and the percent confidence that some progress was achieved (refer to discussions in Chapter II, Section E.3. and Appendix D). Note that although the ARB staff recommends reporting documented progress at the 95 percent confidence level, documented progress at other levels of confidence (for example, 90, 80, or 70 percent confidence) might also be reported.

The information presented in Table 2 could be enhanced by a graphical presentation. For clarity, the results for each exposure indicator should be graphed separately. Figures 6 and 7 show how the data in Table 2 could be presented for the population-weighted and area-weighted exposure indicators, respectively. The graphs show the minimum suggested information: the weighted exposure for the base period, the weighted exposure for the end period, the composite native variability limits, the 5 percent, 50 percent, and 95 percent points on the confidence scale, and the percentage of the population or the nonattainment planning area represented by the results. In addition to this minimum suggested information, it is recommended that data for the years between the base period and the end period (1987-1989, 1988-1990, and 1989-1991) also be included. Including information for these other years provides a more complete assessment of the overall pattern of progress.

TABLE 2

EXAMPLE OF A TABULAR PRESENTATION OF RESULTS FOR THE EXPOSURE INDICATORS

Type of Exposure	Base Period 86-88	End Period 90-92	Difference (Base-End)	For 95% Confidence		Confidence Some Progress Achieved
				Uncertainty (CNVL*)	Documented Progress	
Pop-Wtd	170**	205	-35	70	0 %	20 %
Area-Wtd	289***	315	-25	80	0 %	30 %

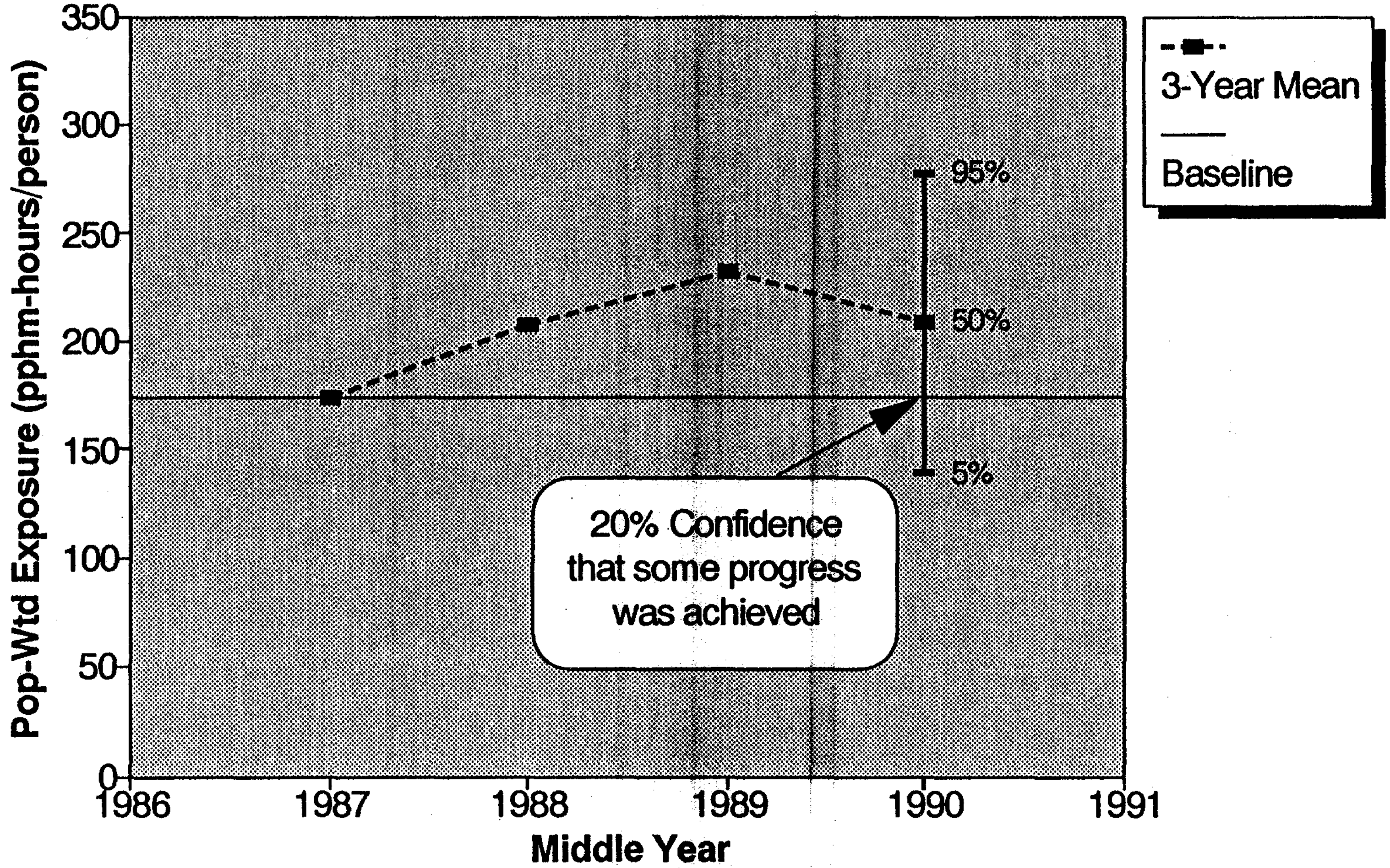
* Composite Native Variability Limit.

** Exposure as pphm-hours above the State standard per person, representing 93 percent of the total population in the nonattainment planning area.

*** Exposure as pphm-hours above the State standard per unit area, representing 52 percent of the total nonattainment planning area.

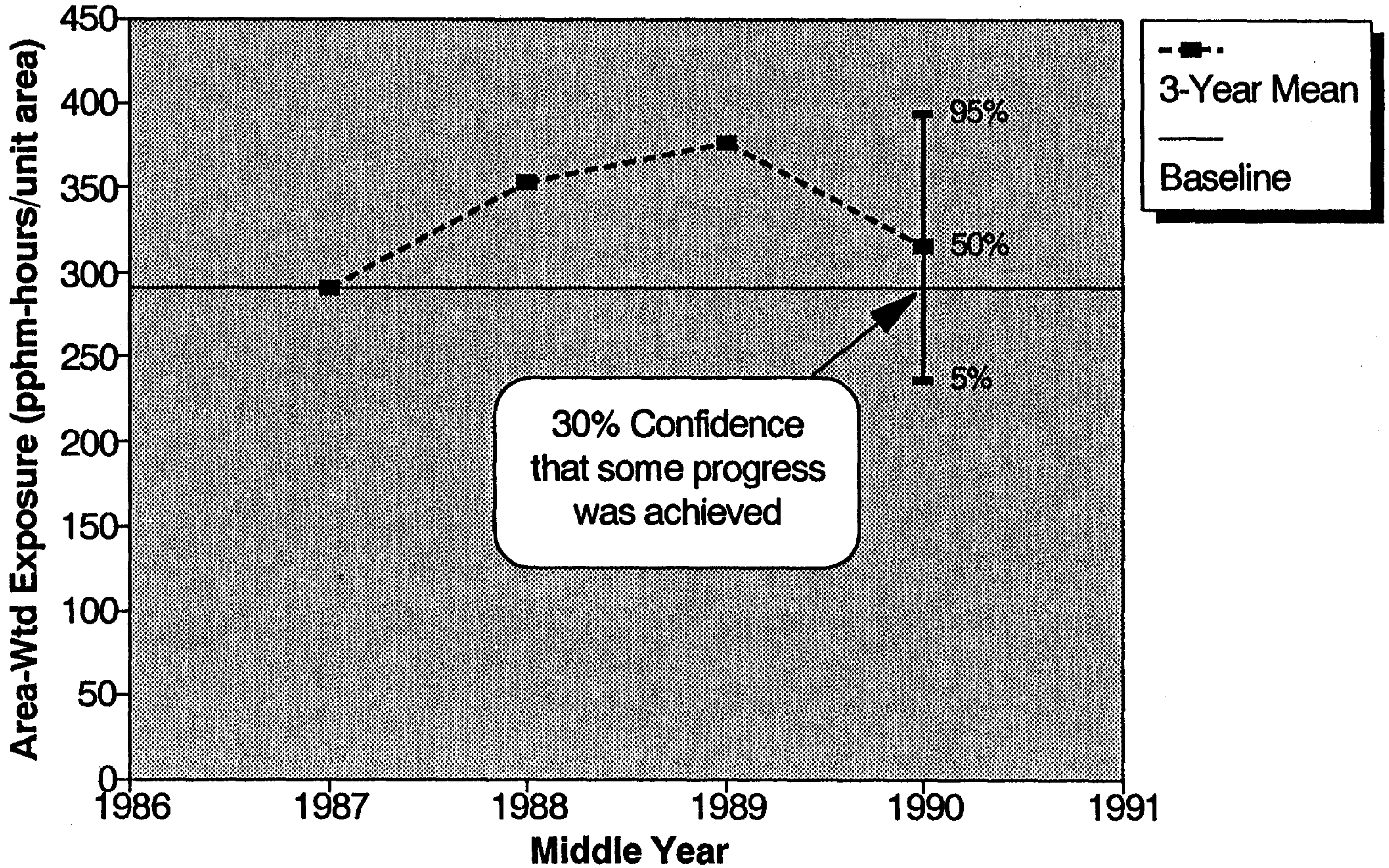
The interpretation of the exposure analyses depends on the exposure results. At a minimum, the ARB staff recommends the interpretation of the exposure results consider the amount of progress documented with a high degree of confidence (i.e., 95 percent confidence). If no documented progress at the 95 percent confidence level exists, the confidence that some progress was achieved should be considered. In addition, the interpretation might include consideration of other information, such as meteorological

FIGURE 6
Progress in Reducing Population-Weighted Ozone Exposure*



*** Results Represent 93% of the Total Population.**

FIGURE 7
Progress in Reducing Area-Weighted Ozone Exposure*



*** Results Represent 52% of the Nonattainment Planning Area.**

data, that may be relevant to the evaluation of progress in reducing exposure to ozone concentrations above the State standard.

The composite native variability limits indicate the range of values through which the exposure naturally varies, given the influence of factors other than emissions. On the other hand, progress is an improvement in the exposure that can be attributed to emission reductions. Therefore, progress (or conversely, degradation) is <u>strongly</u> established only when the exposure for the base period is not within the range of the composite native variability limits. When the exposure for the base period is higher than the upper composite native variability limit, "documented progress" at the 95 percent confidence level has been achieved (refer to Appendix D for details). Conversely, when the exposure for the base period is below the lower composite native variability limit, "documented degradation" has occurred. When the exposure for the base period falls within the range of uncertainty represented by the composite native variability limits, some progress may have occurred, but the confidence in that conclusion is not high--the actual degree of confidence can be determined on the confidence scale.

Based on the results in Table 2, both the population-weighted exposure and the area-weighted exposure increased from the base period to the end period. However, in both cases, the exposure result for the base period is well within the range of uncertainty represented by the composite native variability limits. Based on the confidence scale, there is a 20 percent confidence that some progress was achieved in reducing the population-weighted exposure and a 30 percent confidence that some progress was achieved in reducing the area-weighted exposure. Based on these results, there is no clear trend that might be expected to continue in the future.

Some districts may wish to present more detailed evaluations of their progress than the minimum suggested here. An analysis of the meteorological conditions prevailing in the base period and other periods may assist in the interpretation of the exposure results. Furthermore, there are additional ways of presenting annual exposure information. For example, the Board recognizes that reporting a single "average" exposure value for the nonattainment planning area does not show how emission reductions have affected the air quality spatially within the area. Some districts may wish to include in their triennial progress reports, additional information comparing the change in the annual average exposure for various subareas. This type of approach could be useful for assessing the effectiveness of the attainment plan by showing where exposures have increased or decreased over time. Finally, the population-weighted exposure and the area-weighted exposure often exhibit similar trends. The differences between the two measures of exposure may yield additional insights when detailed analyses of subareas are not conducted.

CHAPTER IV

ASSISTANCE IN COMPUTING THE PROGRESS REPORTING INDICATORS

A. Results of Computations

The Board does not intend that the progress reporting indicator requirements place an undue burden on the affected districts. Therefore, the ARB staff will provide the results of the computations for each of the progress reporting indicators to those districts that request such information. The information the ARB staff provides will include the following items: 1) a summary of the data completeness and data representativeness, 2) a list of the monitoring stations included in the computations, 3) the computed values for each applicable progress reporting indicator for the 1986 through 1988 base period and for the most recent three-year end period, and 4) the estimated uncertainty of the progress reporting indicators using a 95 percent confidence range.

B. Availability of Computer Software

For those districts that wish to determine their own progress reporting indicator values, the ARB staff can make available both the data and the computer software used for computing the progress reporting indicators. The software includes computer programs that format the air quality data, check the data for completeness and representativeness, compute the values of the progress reporting indicators, and compute the uncertainty of the progress reporting indicators using a 95 percent confidence range. The computer software is written in the Pascal language and is designed to run under the MS-DOS system. The documentation for implementing the software is limited.

REFERENCES

REFERENCES

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2. California Air Resources Board. Proposed Amendments to the Criteria for Designating Areas of California as Nonattainment, Attainment, or Unclassified for State Ambient Air Quality Standards. (1992).

3. California Air Resources Board. Technical Support Document for Proposed Amendments to the Criteria for Designating Areas of California as Nonattainment, Attainment, or Unclassified for State Ambient Air Quality Standards. (1992).

4. California Air Resources Board. Supplement to the Technical Support Document for Proposed Amendments to the Criteria for Designating Areas of California as Nonattainment, Attainment, or Unclassified for State Ambient Air Quality Standards. (1992).

5. Breiman, L., J. Gins, and C. Stone. Statistical Analysis and Interpretation of Peak Air Pollution Measurements. TSC-PD-A190-10. Technology Service Corporation. (1978).

APPENDIX A

RELEVANT SECTIONS OF THE HEALTH AND SAFETY CODE

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RELEVANT SECTIONS OF THE HEALTH AND SAFETY CODE

SECTION 39607(f) (prior to January 1, 1993):

"Evaluate, in consultation with the districts, air quality-related indicators which may be used to measure or estimate progress in the attainment of state standards and establish a list of approved indicators. The state board shall establish an initial list on or before December 31, 1989, and shall update the list at least every three years thereafter."

SECTION 39607(f) (after January 1, 1993):

"Evaluate, in consultation with the districts and other interested parties, air quality-related indicators which may be used to measure or estimate progress in the attainment of state standards and establish a list of approved indicators. On or before July 1, 1993, the state board shall identify one or more air quality indicators to be used by the districts in assessing progress as required by subdivision (b) of Section 40924. The state board shall continue to evaluate the prospective application of air quality indicators and, upon a finding that adequate air quality modeling capability exists, shall identify one or more indicators which may be used by districts in lieu of the annual emission reductions mandated by subdivision (a) of Section 40914. In no case shall any indicator be less stringent or less protective, on the basis of overall health protection, than the annual emission reduction requirement in subdivision (a) of Section 40914."

SECTION 39609:

"On or before December 31, 1989, and at least every three years thereafter, the state board shall complete a study on the feasibility of employing air quality models and other analytical techniques to distinguish between emission control measures on the basis of their relative ambient air quality impact. As part of this study, the state board shall determine whether adequate modeling capability exists to support the use of air quality indicators or alternative measures of progress as specified in subdivision (f) of Section 39607 and Section 40914. The state board shall consult with districts and affected groups in conducting this study, and, after a public hearing, shall prepare and transmit its findings to each district for its use in developing plans pursuant to Chapter 10 (commencing with Section 40910)."

SECTION 40914(a):

"Each district plan shall be designed to achieve a reduction in districtwide emissions of 5 percent or more per year for each nonattainment pollutant or its precursors, averaged every consecutive three-year period, unless an alternative measure of progress is approved pursuant to Section 39607."

SECTION 40924(b):

"On or before December 31, 1994, and once every three years thereafter, the district shall assess the overall effectiveness of its air quality program, the quantity of emission reductions actually achieved in the preceding three-year period, and the rate of population and industrial- and vehicular-related emissions growth experienced in the district and projected for the future, and shall contrast all of the preceding to the assumptions and goals contained in the district's attainment plan. The district shall also assess the extent of air quality improvement achieved during the preceding three years, based upon ambient pollutant measurements, best available modeling techniques, and air quality indicators identified by the state board for that purpose under subdivision (f) of Section 39607. Upon completion of each triennial analysis, the district shall adopt its findings at a public hearing and report its findings to the state board."

SECTION 40924 (c):

"In addition to the requirements established under subdivision (b), on or before December 31, 1994, and once every three years thereafter, the district shall report to the state board, and make available to the public, its progress toward attainment of state ambient air standards as measured by two or more standards of measurement, as determined by the state board. Standards of measurement may include, but are not limited to, population exposure, ozone and carbon monoxide design value, and pollutant concentration hours."

APPENDIX B

CRITERIA FOR EVALUATING AIR QUALITY-RELATED INDICATORS

APPENDIX B

CRITERIA FOR EVALUATING AIR QUALITY-RELATED INDICATORS

(Approved by the California Air Resources Board on November 8, 1990)

CRITERION 1:

An approved indicator must be based in whole or in part on air quality data that meet the specifications in section 70301(a), Title 17, California Code of Regulations concerning "data for record."

CRITERION 2:

An approved indicator must be defined for a specific pollutant and a specific area. The definition must specify the data to use, the method of handling the effects of missing data, and the computation procedure.

CRITERION 3:

An approved indicator must represent one of the following characteristics of air quality related to an area's nonattainment problem:

- The highest concentrations in the "hot spot" sub-area,
- The areawide average of the total exposure, or
- The population-weighted average of the total exposure.

CRITERION 4:

An approved indicator must include an associated rate of progress, and that rate must be consistent with the goals and requirements contained in the Health and Safety Code.

CRITERION 5:

An approved indicator must satisfy both of the following reliability requirements:

- Minimum Reliability - The indicator must be sufficiently reliable that when the indicator improves by an amount equal to 3 years of equivalent progress as determined under Criterion 4, there is at least 95 percent confidence that some progress was actually achieved, and

- Relative Reliability - If more than one indicator for a characteristic of air quality noted in Criterion 3 meets the minimum reliability requirement, the approved indicator must be among the most reliable for measuring progress.

APPENDIX C

THE REQUIREMENTS FOR AIR QUALITY DATA FOR RECORD
AND THE CRITERIA FOR COMPLETE AND REPRESENTATIVE AIR QUALITY DATA

APPENDIX C

THE REQUIREMENTS FOR AIR QUALITY DATA FOR RECORD AND THE CRITERIA FOR COMPLETE AND REPRESENTATIVE AIR QUALITY DATA

(Title 17, California Code of Regulations (CCR), section 70301(a) and Appendices 1 and 3 to Title 17, CCR, sections 70300-70306)

70301. **Air Quality Data Used for Designations**

(a) Except as otherwise provided in this article, designations shall be based on data for record. "Data for record" are those data collected by or under the auspices of the state board or the districts for the purpose of measuring ambient air quality, and which the executive officer has determined comply with the siting and quality assurance procedures established in Part 58, Title 40, Code of Federal Regulations, as they existed on July 1, 1987, or other equivalent procedures. The executive officer shall also determine within 90 days of submittal of complete supporting documentation whether any other data which are provided by a district or by any other person comply with the siting and quality assurance procedures and shall be data for record. If the executive officer finds there is good cause that 90 days is insufficient time to make a determination, he/she may after notification of the person requesting the data review extend the deadline for completion of the data review.

CRITERIA FOR DETERMINING DATA COMPLETENESS
(Appendix 3 to Title 17, CCR, sections 70300 through 70306)

This Appendix describes the criteria to be used in determining data completeness for the purpose of designating areas as attainment or nonattainment-transitional as described in Article 3, Subchapter 1.5, Chapter 1, Part III, Title 17 (commencing with Section 70300), California Code of Regulations. The purpose of these data completeness criteria is to specify the minimum data deemed necessary to assure that sampling occurred at times when a violation is most likely to occur.

<u>Complete Data</u>

Data for a site will be deemed complete if there are representative data (as determined in accordance with the Representativeness Criteria...) during the required hours (see below) of the day during the required months (see below) for the required years (see below).

<u>Required Hours</u>

The hours of potentially high concentration must be included. Unless a detailed evaluation determines different hours to be appropriate for a specific site, these hours are:

Pollutant	Hours (PST)
Ozone	9 am - 5 pm
Carbon Monoxide	3 pm - 9 am (next day)
Nitrogen Dioxide	8 am - 8 pm
Visibility Reducing Particles	10 am - 6 pm
Other Pollutants	Throughout day

<u>Required Months</u>

The months of potentially high concentrations must be included. Unless a detailed evaluation determines different months to be appropriate for a specific site, these months are:

Pollutant	Months
Ozone	July - September
Carbon Monoxide	January, November - December
Nitrogen Dioxide	October - December
Sulfur Dioxide	September - December
Sulfates	January, June - December
Lead (Particulate)	January, November - December
Other Pollutants	January - December

<u>Required Years</u>

The number of years to be included is:

a) Three; or
b) Two, if during these years the maximum pollutant concentration is less than three-fourths the applicable state ambient air quality standard; or
c) One, if during this year the maximum pollutant concentration is less than one-half the applicable state ambient air quality standard.

CRITERIA FOR DETERMINING DATA REPRESENTATIVENESS
(Appendix 1 to Title 17, CCR, sections 70300 through 70306)

This Appendix describes the criteria to be used in determining data representativeness for the purpose of designating areas as described in Article 3, Subchapter 1.5, Chapter 1, Part III, Title 17 (commencing with Section 70300), California Code of Regulations. Representativeness, as used here, is only related to whether or not the amount of data reported is deemed sufficiently complete to characterize reliably air quality during the respective time period. No other kind of representativeness is implied. The criteria for representativeness are summarized in the accompanying table and discussed further below.

Air quality statistics are usually computed from short term observed values. For example, an annual arithmetic mean is computed from all available hourly samples. If all the short term values for the statistical time period are available, the calculated statistic is representative. However, because all the short term values for a given period often are not available, a minimum number of observations are needed to provide reasonable assurance that the calculated value is a reliable estimate. In general, statistics are considered representative if 75 percent of the possible short term values are included and are distributed throughout the entire statistical time period.

To ensure that seasonal variations are accounted for, representative annual statistics are required to have four representative calendar quarters of data. For example, if an annual mean is based on 24-hour samples, such as that computed for suspended particulate matter (PM10) samples, three representative months are required for each calendar quarter. A 24-hour particulate sample is collected once every six days or a total of five samples per 31-day month. Therefore, three or fewer samples (less than or equal to 60 percent data recovery) do not meet the criterion for a reliable estimate of the monthly mean concentration. The lack of representativeness of the monthly mean concentrations precludes a reliable estimate of a representative calendar quarter, which in turn precludes the representativeness of an annual statistic. Each level of criteria--hour, day, month, quarter, and year--must be met in order to make a representative annual statistic.

For observations made at less than 24-hour intervals, for example, hourly samples, representativeness depends on whether all the individual values are to be used or only a single daily value is to be used. In general, for representative statistics computed from all of the individual values, such as the mean of all hours, 75 percent of the values in the respective period are required. For representative statistics computed from daily values, such as the monthly mean of daily maximum hours, data from 75 percent of the days in the month are required and the data within those days must meet the relevant representativeness criteria.

CRITERIA FOR REPRESENTATIVENESS OF AIR QUALITY MEASUREMENTS AND STATISTICS

Representative Calendar Statistic	Sampling Time Period	Basis of Statistic Or Requirement	Number Of Representative Periods Required
Year	Any		4 representative calendar quarters
Quarter	24-hour	Based on a daily sample	3 representative months
	<24-hours	Based on a daily statistic; or	69 or more representative calendar days
		Based on hourly samples	1,643 or more hours
Month	24-hour	Based on daily sample	4 or more 24-hour samples
	<24-hours	Based on a daily statistic; or	23 or more representative calendar days
		Based on all hourly samples; or	548 or more hours
		Based on all 2-hour samples; or	274 or more 2-hour samples
		Based on all 3-hour samples	183 or more 3-hour samples
Day	1-hour		6 or more hours in each 1/3 day (hours 0 thru 7, 8 thru 15, 16 thru 23), and missing no more than 2 consecutive hourly samples
	2-hour	Based on all 2-hour samples	9 or more samples
	3-hour	Based on all 3-hour samples	6 or more samples
	24-hour	Based on daily sample	22 but not more than 26 hours of sampling

	N	Number of Samples Needed
Mean of N Hour Period	24	18 or more hourly samples
	8	6 or more hourly samples
	6	5 or more hourly samples
	4	3 hourly samples
	3	3 hourly samples
	2	2 hourly samples
	1	30 minutes or more of sampling

APPENDIX D

PROCEDURES FOR COMPUTING THE NATIVE VARIABILITY LIMITS
AND DOCUMENTED PROGRESS ASSOCIATED WITH A PROGRESS REPORTING INDICATOR

APPENDIX D

PROCEDURES FOR COMPUTING THE NATIVE VARIABILITY LIMITS AND DOCUMENTED PROGRESS ASSOCIATED WITH A PROGRESS REPORTING INDICATOR

The following sections describe the procedures the ARB staff uses for computing the native variability limits and the documented progress associated with a progress reporting indicator. The discussion is based largely on the "Draft Criteria for Evaluating Air Quality-Related Indicators" (California Air Resources Board, 1989).

A. Characterization of Native Variability

This section presents the technical basis for the ARB staff's estimation of the "native variability" of indicators. Estimating the native variability of an indicator is an important task in the development of indicators that can accurately quantify progress. The following subsections provide an introduction to the general problem and a description of the ARB staff's method for computing the native variability of an indicator.

1. Introduction

Native variability is the variation in an indicator caused by factors other than progress (i.e., other than changes in emissions). Simply put, the native variability of an indicator is the range of values that the indicator could have because of the influence of factors other than progress.

A "standard deviation" is often used to characterize variation. The standard deviation of an indicator's native variability (native standard deviation) is a general measure of the native variability. The native standard deviation of an indicator could be computed directly from its values over many years <u>if</u> there were no changes in emissions. However, it is not possible to find a sequence of many years in California for which emissions have remained effectively constant. Therefore, the ARB staff has developed an adaptation of a general method called "bootstrapping" [Reference 1]. The ARB staff's adaptation is tailored for use with air quality data that exhibit a strong seasonal trend and day-to-day correlations. This new method is a means of simulating realistic years of daily data by "resampling" from the actual data.

The native standard deviation of an indicator must be evaluated before the indicator can be used effectively to determine progress quantitatively. Determining an indicator's native standard deviation is similar to identifying whether a measuring stick (an indicator of length) is one inch, one foot, or one yard in length. The stick may be used for measuring in any case, but the precision with which it can measure a given distance depends on its length: a one inch stick can measure to within one inch, a foot stick to within one foot, and a yard stick (without "inch" marks, etc.) to within one yard. Similarly, air quality-related indicators differ in the precision with which they can quantify progress. If one needs to quantify progress within 5 percent, an indicator that measures within 15 percent will not be helpful. In the same way, an indicator's native standard deviation determines the amount of progress it can quantify reliably.

It is one thing to define the native standard deviation and another to construct a method to estimate it. A new method is presented here for estimating the native standard deviation of indicators. The method is applicable to indicators in general. The method is applied here to a set of indicators based on daily maximum hour ozone concentration data.

2. A Simulation Method of Estimating the Native Standard Deviation

a. Data Driven Simulation

The ARB staff developed an adaptation of a method called "bootstrapping" which is frequently used to estimate standard deviations when restrictive assumptions are not appropriate. A bootstrapping procedure combines Monte Carlo simulation with real data to produce realistic data sets. The fundamental assumption in bootstrapping is that the observed data adequately represent the full distribution of possible values which yielded the observed data. The observed data are then randomly resampled as if they were the "parent population" to produce new, but realistic sets of data.

Air quality data for the criteria pollutants present certain difficulties when devising a bootstrapping procedure. Strong seasonal trends and day-to-day correlations must be taken into account when "random" resampling takes place. The ARB staff developed a method of random resampling that "simulates" an entire year of daily maximum hour ozone concentrations. Repeated simulation allows many comparable "years" to be generated for which emissions are constant. The ARB staff believes this method is the best method available at this time for estimating the native standard deviation of an indicator.

b. A Markov Process Adapted to Ozone Data

Measured ozone data exhibit certain prominent features: seasonal patterns within years, episodic clustering (sequential association), and weekday/weekend effects. A Markov process was constructed that mimics these and perhaps other characteristics of daily maximum hour ozone data.

A Markov process describes a sequence of values where each value is associated with the preceding one [Reference 2]. In sequences of observed daily maximum hour ozone concentrations, the value "Today" and the value "Tomorrow" are frequently closely related to each other. The preparation of a Markov process simulation involves extracting (from real data) information on the day-to-day transitions from one concentration to another.

The ARB staff addressed seasonal patterns by defining five seasons: (1) November, December, January, and February; (2) March and April; (3) May and June; (4) July and August; and (5) September and October. These "seasons" were selected because ozone daily maximum hour concentrations are often similar within the same season, but are often dissimilar in different seasons. Even so, months within seasons were handled so that higher concentrations were either encouraged or discouraged as appropriate. Higher concentrations were encouraged by adjusting the random nature of the Markov process so that transitions to higher values would be more likely. Similarly, for some months transitions to lower concentrations were favored. For each season and for each site, a separate set of transition relationships was derived from the data so that seasonal and site differences were maintained as the simulations progressed.

Persistent meteorological conditions may cause data from successive days to appear as a cluster of similar values. The presence of clusters in the data is important because they will frequently (but, not necessarily) cause "Tomorrow's" value to be similar to "Today's" value in a subsequent simulation.

Clustering (within a month group) in the Markov process is governed by a table of relative frequencies associated with transitions from the concentration on one day (a row in the table) to various concentrations on the following day (columns in the table). For example, Table D-1(a) shows the transition table derived from the data for the November, December, January, and February season at an example site. If we look at the row in Table D-1(a) that corresponds to "Today's maximum hour concentration is 0.10 ppm" (parts per million), we see the value on the next day was 0.10 ppm 4 times, 0.05 ppm 2 times, and 0.14 ppm 1 time. Table D-1(b) expresses the observed transitions in terms of cumulative frequencies with which the real data changed from a concentration today to another concentration tomorrow. The tables of cumulative frequencies are used to drive the program developed by the ARB staff.

A year of daily maximum hour ozone data is simulated using the derived transition tables, one for each month group. The example in Table D-2 is a simple illustration of the general process outlined in the following steps:

1. Save "Today's" concentration and continue to Step 2 if 365 days have not yet been saved. Otherwise QUIT.

2. From the table, select the row corresponding to "Today's" concentration.

3. Generate a random number between zero and one.

4. Based on the random number and the cumulative frequencies stored in the row, select the concentration for "Tomorrow."

5. Go on to the next day so that "Tomorrow" in Step 4 becomes "Today" for beginning again at Step 1.

TABLE D-1

(a) Observed frequencies of transitions from ozone concentration Today (Row) to concentration Tomorrow (Column) for an example site for November, December, January, and February (1981-1985).

	Concentration Tomorrow (ppm)																
	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10	0.11	0.12	0.13	0.14	0.15	0.16
0.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.02	0	0	0	2	1	1	0	0	0	0	0	0	0	0	0	0	0
0.03	0	0	2	16	21	4	0	1	0	0	0	0	0	0	0	0	0
0.04	0	0	0	18	84	44	12	4	3	0	1	0	0	0	0	0	0
0.05	0	0	1	6	29	38	25	15	14	3	2	0	0	0	0	0	0
0.06	0	0	0	0	13	14	23	16	9	3	4	2	0	0	0	0	0
0.07	0	0	0	0	14	11	13	10	6	3	4	0	1	0	0	0	0
0.08	0	0	1	2	2	12	3	11	8	2	3	1	2	1	1	0	0
0.09	0	0	0	0	1	2	2	2	2	2	0	2	0	0	0	0	0
0.10	0	0	0	0	0	2	4	2	2	0	4	3	0	2	1	0	0
0.11	0	0	0	0	0	1	2	0	3	1	1	0	0	0	1	0	0
0.12	0	0	0	0	0	0	0	1	0	0	2	1	1	1	0	0	0
0.13	0	0	0	0	0	1	0	1	0	0	0	0	1	0	1	0	1
0.14	0	0	0	0	0	0	0	1	2	0	0	0	0	1	0	0	0
0.15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.16	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0

(b) Cumulative frequencies of transitions from ozone concentration Today (Row) to concentration Tomorrow (Column) for an example site for November, December, January, and February (1981-1985).

	Concentration Tomorrow (ppm)																
	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10	0.11	0.12	0.13	0.14	0.15	0.16
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.02	0.00	0.00	0.00	0.50	0.75	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0.03	0.00	0.00	0.04	0.41	0.89	0.98	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0.04	0.00	0.00	0.00	0.11	0.61	0.88	0.96	0.98	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0.05	0.00	0.00	0.01	0.05	0.27	0.56	0.74	0.86	0.96	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0.06	0.00	0.00	0.00	0.00	0.15	0.32	0.59	0.79	0.89	0.93	0.98	1.00	1.00	1.00	1.00	1.00	1.00
0.07	0.00	0.00	0.00	0.00	0.23	0.40	0.61	0.77	0.87	0.92	0.98	0.98	1.00	1.00	1.00	1.00	1.00
0.08	0.00	0.00	0.02	0.06	0.10	0.35	0.41	0.63	0.80	0.84	0.90	0.92	0.96	0.98	1.00	1.00	1.00
0.09	0.00	0.00	0.00	0.00	0.08	0.23	0.39	0.54	0.69	0.85	0.85	1.00	1.00	1.00	1.00	1.00	1.00
0.10	0.00	0.00	0.00	0.00	0.00	0.10	0.30	0.40	0.50	0.50	0.70	0.85	0.85	0.95	1.00	1.00	1.00
0.11	0.00	0.00	0.00	0.00	0.00	0.11	0.33	0.33	0.67	0.78	0.89	0.89	0.89	0.89	1.00	1.00	1.00
0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.17	0.17	0.50	0.67	0.83	1.00	1.00	1.00	1.00
0.13	0.00	0.00	0.00	0.00	0.00	0.20	0.20	0.40	0.40	0.40	0.40	0.40	0.60	0.60	0.80	0.80	1.00
0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.75	0.75	0.75	0.75	0.75	1.00	1.00	1.00	1.00
0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00

TABLE D-2

The sequence of daily ozone values results from applying the example transition table below. If the process were repeated, a different set of random numbers would dictate a different sequence of daily values.

Sequence of Daily Ozone Values

Day	Value Today	Random Number	Value Tomorrow
1	2	0.18	0
2	0	0.79	2
3	2	0.71	3
4	3	0.81	3
5	3	0.38	2
6	2	0.96	3
7	3	0.19	1
8	1	0.61	2
9	2	0.43	2
10	2	0.28	1
11	1	0.98	3
12	3	0.09	0
13	0	0.17	0
14	0	0.62	2
15	2	0.94	3
16	3 ...		

Table of Cumulative Transition Frequencies

Value Today \ Value Tomorrow	0	1	2	3
0	0.40	0.60	0.80	1.00
1	0.30	0.50	0.70	1.00
2	0.20	0.40	0.60	1.00
3	0.10	0.30	0.50	1.00

Procedure:

- Start with the value "Today" (start with Day 1).
- Locate the row in the table of cumulative transition frequencies for which the "Value Today" corresponds to today's ozone in the sequence of daily ozone values above.
- Generate a random number between 0 and 1 (example sequence has random numbers already generated).
- In the selected row, move from left to right and stop when the random number is <u>not greater than</u> the value in the row of the table.
- The value for "Tomorrow" is given by the value at the top of the column in the table where you stopped.
- "Tommorow's" value then becomes "Today's" value for the next iteration at the beginning of this procedure.

This procedure results in a natural clustering of similar concentrations because the frequencies of concentrations "Tomorrow" are greatest for those values close to the concentration "Today." These simulated years of daily data retain a direct connection with the real world and are remarkably similar to their real world counterparts because the transition tables are assembled from the transitions in the observed data.

Recent analyses by Zeldin and Horie [Reference 3], Hoggan et. al. [Reference 4], and the ARB staff indicate that the largest effects on ozone concentrations associated with days of the week appear to reflect a lack of scavenging by nitric oxide (NOx) on Saturday and renewed scavenging on Monday. Specific transition tables may be compiled for Friday to Saturday and from Sunday to Monday. When the ARB staff explored this approach, the data were too sparse to adequately fill out the tables. Instead, the weekend versus weekday effect was approximated by adjusting the random nature of the process, adding or subtracting a small amount to the random number generated by the program. In this way, higher concentrations are "encouraged" on Saturdays and "discouraged" on Mondays which is typical of many sites in California. Although the simulation program written by the ARB staff provides an option to adjust for weekday/weekend effects, the ARB staff did not use that option in their final analyses because its effect on the magnitude of the native standard deviation appeared negligible.

The ARB staff selected the years 1981 through 1985 as a base period from which to extract information on the daily transitions of ozone values. For many places in California, this sequence of years shows only modest changes in ozone air quality.

For more than 20 sites, 200 years were simulated and 25 indicators were computed for each year. The ARB staff found that the 200 years were sufficient to achieve a suitable precision in the estimates of the native standard deviations. The 25 indicators included means, percentiles, the frequency of days exceeding a threshold, and the maximum hour exposure over a threshold, with variations on each of these general types.

The resources required to carry out these simulations were not excessive. The ARB staff wrote the simulation program and associated utility programs in Turbo Pascal version 4.0 from Borland International (the source code is available as an example of the method). The programs were executed on a COMPAQ Deskpro/386. The process of creating transition tables, generating 200 years of data, and computing and saving the 25 indicators required approximately five minutes for each site.

3. Generalizing the Method to Other Indicators

Although some indicators are computed from hourly concentrations at multiple sites simultaneously, the simulations performed by the ARB staff focused on indicators based on daily maximum hour data for single sites. The method developed by the ARB staff can be easily generalized for application to a wider variety of indicators. For example, indicators such as exposure and health risk assessments are typically based on hourly data from more than one monitor, and an interpolation routine is used to produce concentrations for areas between monitors. The "exposure" indicators evaluated by the ARB staff were based on data from a single monitor. Referred to as "maximum hour exposure," these indicators are based on daily maximum hour concentrations and are surrogates of true hourly integrated exposure. In addition, the native standard deviation of an indicator computed on a site-by-site basis may need to be re-evaluated when averaged across sites to provide a districtwide indicator. The results of site-by-site estimation of the native standard deviation cannot take into account the "correlated" nature of measurements at different sites on the same day. Such inter-site correlations may influence the native standard deviation of indicators based on simultaneous multi-site data.

Fortunately, indicators that rely on simultaneous air quality data from more than one monitor can be simulated in a straightforward manner. The basic approach is to process all data for one day and store the "daily increment" relevant to the indicator in question. The daily increments are then processed by a utility program that compiles information on day-to-day transitions from the value of the increment "Today" to the value of the increment "Tomorrow." The appropriate transition tables are then produced to drive the Markov process simulation. For example, the population-weighted average exposure is based on accumulated daily exposure increments throughout the year. A program that calculates this indicator would need only minor modification to store each of the daily exposure increments over several years. Transition tables based on the observed transitions between "increment" values would govern the simulation of realistic sequences of daily exposure increments. The standard deviation for the annual totals for each of 200 simulated years would be an appropriate estimate of the native standard deviation of an exposure indicator.

B. Computing the Native Variability Limits

The native standard deviation of an indicator is a general characterization of native variability. A native variability limit is based on the native standard deviation and is specific for a selected confidence level. Once the native standard deviation is estimated (refer to Section A., above), native variability limits can be determined. Native variability limits are a fundamental part of "measuring" progress, taking into account uncertainty. This section presents some technical information related to the computation of appropriate native variability limits. The following subsections address two topics:

The assumptions underlying native variability limits, and
The procedure for computing native variability limits.

1. Assumptions

The following assumptions provide the basis for the statistical estimates and tests associated with the progress reporting indicators:

- The procedure for estimating the native standard deviation described in Section A. of this Appendix has acceptable accuracy and precision.

- The random components of the progress reporting indicators are <u>effectively</u> independent of each other.

- The stochastic (random) nature of the indicator's values allows the use of statistics based on a normal distribution.

These assumptions are not easy to verify or to debunk. However, the ARB staff has conducted a realistic review of the assumptions and believes they are appropriate.

The first assumption relates to the appropriate estimation of the native standard deviation and is straightforward. A large standard deviation implies that large random differences occur between the observed value of an indicator and its "true" value (that value which incorporates only the effects of emission changes). Large random differences make it difficult to recognize emission-related indicator changes unless those changes are larger than the native standard deviation. Without reasonably accurate estimates of this parameter, there is little hope of interpreting indicator trends quantitatively and reliably. The ARB staff believes that the method of computing the native standard deviation described in Section A. of this Appendix is the best approach currently available.

The second and third assumptions relate to the use of methods based on normal distributions (the familiar "bell-shaped" curve). The central limit theorem of statistics provides the justification for these methods. The central limit theorem says that the distribution of an average becomes closer and closer (i.e., converges) to a normal distribution as the number of observations averaged together increases **<u>if</u>** the observations are independent. The ARB staff acknowledges that some doubt exists concerning the assumption that year-to-year indicator values are independent. For example, atmospheric scientists recognize that some large-scale phenomena such as "El Nino" events can have an impact on weather patterns for more than one year. Even so, it is very difficult to quantify the impact of large-scale weather phenomena on air quality because their effects appear to be small relative to other sources of variation. The ARB staff considers the assumption of effective independence to be sufficiently realistic to apply in this context.

However, factors other than independence can affect the rate at which the distribution of a mean converges to a normal distribution. In some circumstances, as few as two or three values are sufficient to result in a distribution very close to normal. Given the smoothness and shape of the distributions of the progress reporting indicators, there is good reason to expect that they are approximately normally distributed if emissions are constant. The ARB staff believes it is generally appropriate in this context to rely on methods based on normal distributions.

2. Computation Procedure

A native variability limit is determined by: (1) an estimate of the native standard deviation, (2) a specified confidence level, and (3) the number of independent values in an average (typically the number of "years"). The native standard deviation may be estimated according to procedures described in Section A. of this Appendix.

The ARB staff uses "one-tailed" confidence limits when calculating documented progress or degradation (refer to Section C. of this Appendix for further details). The reader who is familiar with statistical confidence intervals may find this use of "one-tailed" limits surprising. Similar calculations would customarily call for "two-tailed" construction of confidence intervals. However, the ARB staff uses the "one-tailed" limits in this case for two reasons. First, the trends for precursors of ozone are down (collectively at least) in all locations analyzed. Thus, one is focused in one direction anticipating progress not degradation. Second, when the Board evaluates whether progress has occurred in an area, the evaluation is a "one-tailed" problem. The method for documenting progress is one-tailed because progress is defined as an "improvement" in air quality, which is one direction. Under other circumstances, a "two-tailed" application of native variability limits requires only the substitution of appropriate values for the normal deviates in the formulae.

The three determinants referred to above (the native standard deviation, the confidence level, and the number of years) are used in the following formula for computing a native variability limit:

$$NVL = \frac{Z(alpha) * nv}{SQRT(Y)}$$

and

$$NVL_{95\%} = \frac{1.64 * nv}{SQRT(Y)}$$

WHERE:

NVL	=	The native variability limit.
alpha	=	The confidence level (e.g., 95%).
Z(alpha)	=	The normal deviate corresponding to alpha (e.g., 1.64 for a 95% confidence level).
nv	=	The indicator's native standard deviation.
SQRT	=	The square root function.
Y	=	The number of years in an average (1 for the expected peak day concentration and 3 for the exposure indicators).
$NVL_{95\%}$	=	The native variability limit for a 95% confidence level.

C. Composite Native Variability Limit

When reporting progress, the variability of the base period must be considered along with the variability of the end period. The composite variability is larger than the variability of each of the separate periods. The following formula is used in computing the composite native variability limit:

$$CNVL = Z(alpha) * (SQRT\ (nv_1^2 / Y) + (nv_2^2 / Y))$$

and

$$CNVL_{95\%} = 1.64 * (SQRT\ (nv_1^2 / Y) + (nv_2^2 / Y))$$

WHERE:

CNVL	= The composite native variability limit.
alpha	= The confidence level (e.g., 95%).
Z(alpha)	= The normal deviate corresponding to alpha (e.g., 1.64 for a 95% confidence level).
SQRT	= The square root function.
nv_1	= The native standard deviation for the base period.
nv_2	= The native standard deviation for the end period.
Y	= The number of years in an average (1 for the expected peak day concentration and 3 for the exposure indicators).
$CNVL_{95\%}$	= The composite native variability limit for a 95% confidence level.

D. Computing "Documented" Progress

The ARB staff recommends assessing documented progress for each site at the 95 percent confidence level. The procedure the ARB staff uses for determining documented progress at the 95 percent confidence level is described in the following subsections which address two topics:

The problem of assessing progress, and
The ARB staff's formulation of "documented progress."

1. The Problem

To document the progress achieved, the progress reporting indicators must be compared for two periods--the base period and the end period. The difference between these two three-year means is the result of changes in emissions as well as the effects of other factors, such as meteorology.

Therefore, it is important to determine the portion of the observed difference that may be attributed to changes in emissions. The problem can be stated in this way:

> Given two non-overlapping three-year time periods, how much of the observed difference between the three-year averages can be attributed to factors other than changes in emissions? The remaining portion of the difference then can be clearly attributed to progress.

2. The Formulation

A general solution to this problem can be derived in the following manner:

- Let A be the three-year average from the base period.
- Let B be the three-year average from the end period.
- The difference, (A-B), is the "observed" change.

From the amount of the observed change, we subtract the amount that may be explained by native variability. The amount subtracted is the value of the composite native variability limit described in Section C. of this Appendix.

If the observed change (A-B) is positive and is greater than the composite native variability limit, the remainder can be cleanly interpreted as progress at the 95 percent confidence level. Conversely, if the observed change (A-B) is negative (in the direction of degradation) and the absolute value of the change is greater than the composite native variability limit, the remainder can be considered documented degradation. If the observed change (A-B) is negative and the absolute value of the change ($|A-B|$) is smaller than the composite native variability limit, then neither progress nor degradation is documented. The "documented" difference is computed from the following formula:

$$|A-B| - CNVL_{95\%} = \text{"Documented" Difference}$$

WHERE:

$|A-B|$ = The absolute value of the observed difference between the indicator values (base period - end period).

$CNVL_{95\%}$ = The composite native variability limit for the 95 confidence level (refer to Section C. of this Appendix).

When neither progress nor degradation can be documented at the 95 percent confidence level, the confidence that some progress was achieved can still be examined. The following steps outline the procedure:

STEP 1:

$$Z = \frac{1.64 * (A - B)}{CNVL_{95\%}}$$

WHERE:

- Z = The normal deviate corresponding to a certain confidence level.
- 1.64 = The normal deviate for the 95% confidence level.
- A-B = The observed difference between the indicator values (base period - end period).
- $CNVL_{95\%}$ = The composite native variability limit for the 95% confidence level (refer to Section C. of this Appendix).

STEP 2: Use the table below to find the closest value of "Z" (from Step 1) and the corresponding confidence that some progress was achieved.

Value of "Z"	Confidence that Some Progress was Achieved
1.64	95%
1.28	90%
1.04	85%
0.84	80%
0.67	75%
0.52	70%
0.40	65%
0.25	60%
0.14	55%
0.00	50%
-0.14	45%
-0.25	40%
-0.40	35%
-0.52	30%
-0.67	25%
-0.84	20%
-1.04	15%
-1.28	10%
-1.64	5%

REFERENCES FOR APPENDIX D

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APPENDIX E

PROCEDURES FOR COMPUTING THE PROGRESS REPORTING INDICATORS

APPENDIX E

PROCEDURES FOR COMPUTING THE PROGRESS REPORTING INDICATORS

A. Computing the Expected Peak Day Concentration

The following subsections describe the procedure the ARB staff uses for computing the expected peak day concentration. The discussion is taken largely from the "Supplement to the Technical Support Document for Proposed Amendments to the Criteria for Designating Areas of California as Nonattainment, Attainment, or Unclassified for State Ambient Air Quality Standards" ("Supplement;" California Air Resources Board, 1992).

The computation procedure, referred to as the "expected peak day value procedure" in this Appendix is referred to as "RECRATE3" in the Supplement. The procedure is an improved version of a method discussed by Larsen and Bradley [Reference 1]. In general, the expected peak day value procedure estimates a concentration with a specified rate of recurrence by fitting an exponential model to the upper tail of the distribution of concentrations. The fitted distribution is then used to determine analytically the concentration expected to recur with the specified frequency. For the expected peak day concentration, a 1-in-1 year recurrence rate is used. The following subsections describe the important aspects of the practical implementation of the exponential-tail model to calculate the expected peak day concentration.

1. Time Period

The procedure uses three years of daily data to compute the expected peak day concentration (for example, daily maximum hour ozone data or daily maximum 8-hour carbon monoxide data). Expected peak day concentrations should be computed for at least two periods: the 1986 through 1988 base period and the most recent three-year end period. By using three years of data, the procedure achieves reliability while limiting the influence of differing (and perhaps higher) rates of emissions in the more distant past (more than three years earlier).

2. Air Quality Data

The expected peak day value procedure estimates concentrations based on the upper tail of the distribution of air quality data. The procedure should be applied for all sites in the nonattainment planning area. However, if there are significant gaps in the data for record for a three-year period, an estimate could be unreliable. Therefore, the results for sites with data that do not satisfy the criteria for completeness and representativeness (refer to Chapter II, Section A.3.) should be identified as incomplete and potentially unrepresentative.

3. Interpolating Rounded Data

Because air quality data are rounded numbers, the expected peak day value procedure interpolates concentrations within the rounding range. The interpolation is important because it removes a source of bias and also because it simplifies the "goodness-of-fit" calculations described in subsection 7., below.

The interpolation procedure compensates for bias that is introduced when pollutant concentrations are rounded. This bias occurs because more concentrations tend to be rounded up than rounded down. For example, in an exponential-tail, the expected frequency of concentrations between 9.5 parts per hundred million (pphm) and 10.0 pphm is greater than the frequency of concentrations between 10.0 pphm and 10.49 pphm. Nevertheless, ozone concentrations in both of these ranges are rounded to 10 pphm.

The ARB staff analyzed representative exponential-tail distributions and found that about two-thirds of the data should be interpolated as less than the rounded concentration while one-third should be interpolated as greater than the rounded concentration. The interpolation procedure approximates the overall results that are expected for an appropriate exponential-tail distribution.

4. Tail Selection

The expected peak day value procedure does not rely on a single upper tail, such as the upper 20 percent. Instead, an expected peak day value is computed for each tail from the top 20 percent through the top 5 percent. For example, using a three-year period with 1095 days, the procedure computes 165 separate expected peak day values--one value for the tail with the 219 highest concentrations (top 20 percent of the data), one value for the tail with the 55 highest concentrations (top 5 percent of the data), and one value each for all tails in between. To produce a final result, the expected peak day value procedure computes a weighted average of the individual values (see subsection 7., below, for details).

5. Fitting the Exponential-Tail Model to the Data

The expected peak day value procedure uses the maximum-likelihood approach for fitting the exponential-tail model to each tail. The base of the tail is first set to zero by subtracting a base value from all the data in the tail. The base value used is the average of the nine concentrations that are centered on the lowest concentration included in the tail. For example, if the tail includes the highest 100 concentrations, the base value is the average of the 104th through the 96th highest concentrations.

After adjusting the base of the tail to zero by subtracting the base value from all of the concentrations, the maximum likelihood estimate of the exponential parameter ("LAMBDA") is simply the inverse of the average of the zero-based data.

6. Calculating the Expected Peak Day Value for a Single Tail

Using LAMBDA, find the value "x" for which:

$$1-F(x) = 1/(D*P)$$

WHERE:

F(x) = 1-exp(-LAMBDA*X), the exponential distribution function.
D = The number of days in the recurrence interval.
P = The proportion of the whole data set included in the tail.

For the expected peak day concentration (assuming a 1-in-1 year recurrence interval), D would equal 365 days (1 year * 365 days/year = 365 days). For the top 20 percent tail, P would equal 0.20. The expected peak day concentration for an individual tail is the sum of the base value and the value of "x" determined in this Step.

7. Determining Weights for the Weighted Average of the Expected Peak Day Values for All Tails

For each tail, the expected peak day value procedure computes a "Chi-square goodness-of-fit" statistic. The fitted distribution is partitioned into ten classes, each with an expected frequency of ten percent. The actual data in the tail are tabulated to determine the "observed" frequencies within each of the ten classes. The goodness-of-fit statistic is the standard Chi-square statistic based on the differences between the expected and the observed frequencies. The weights used in the weighted average are the inverses of the goodness-of-fit values. To avoid division by zero and to limit the influence of any single tail result, any Chi-square value less than 1.0 is set equal to 1.0. The usual Chi-square result in this application is greater than 10, with a corresponding weight of less than 0.1.

If a calibration factor is not needed or is not available, the final expected peak day concentration is the weighted average of the expected peak day concentrations for all of the tails analyzed. If a calibration factor is needed and is available, it is applied to the weighted average as described in subsection 8., below.

8. Applying a Calibration Factor

Although the general exponential-tail method provides fairly accurate results, a final "calibration" may be needed to ensure that the actual rates of exceedances measured in an area over time agree with the specified rate. For example, the expected peak day concentration represents the concentration that is expected to recur (on average) at a rate of once every year. Therefore, the observed rate of concentrations that exceed the expected peak day concentration should average very close to one per year. If a calibration factor is needed, it is applied as an exponent to the final weighted average of the separate tail results.

The ARB staff determined that the appropriate calibration factor for ozone is 0.983. This calibration factor is included in the computer code developed and used by the ARB staff. Calibrations have not been developed for the other pollutants. Until such calibrations are performed, the calibration factor for the other pollutants defaults to 1.

9. Data for Estimating Uncertainty

The procedure for estimating the uncertainty or native variability associated with the expected peak day concentration is generally described in Chapter II, Section E. of the guidance document. A native variability must be computed for each monitoring site presented in the triennial progress report in order to determine whether the expected peak day concentration for that monitoring site has improved from the base period to the end period. The procedure for computing the native variability of the expected peak day concentration for a particular monitoring site relies on a sequence of daily data for an individual site. In particular, the procedure requires input of the observed maximum ozone concentrations during each day of the three-year end period. These values are input to the computer program and the native variability computations completed as described in Chapter II, Section E. of the guidance document.

B. Computing the Population-Weighted and Area-Weighted Exposures

1. Time Period

The exposure computations for ozone are based on three years of hourly data. The population-weighted and area-weighted exposures are computed for each year. The exposure estimates for each individual year are then averaged to provide an estimate of the average annual exposure. At a minimum, an average annual exposure should be computed for the three-year base period (1986 through 1988) and the three-year end period.

2. Air Quality Data

The air quality data used for computing the exposure indicators should be data for record (refer to Chapter II, Section A.2. of the Guidance Document). All available data for sites in the nonattainment planning area should be used, regardless of whether the data satisfy the completeness and representativeness criteria. Because the individual exposure values are interpolated from data for several sites, it is not critical that the data for all the sites be complete for all the hours. In addition to data from sites in the nonattainment planning area, air quality data from other sites may be used if they qualify as data for record and are located within the 50 kilometer radius of representativeness (refer to subsection 4., below).

3. Census Data

The exposure computations are based in part on census data collected by the federal government. For the 1994 triennial progress reports, it is most likely that census data for 1990 will be available and should be used. The federal government has divided the nation into census tracts for the purpose of counting population and obtaining demographic information. Each of these census tracts has associated with it, the centroid of the census tract, the population residing within the census tract, and the land area of the census tract.

The population within each census tract is used in computing the annual population-weighted exposure, whereas, the land area of the census tract is used in computing the annual area-weighted exposure. The centroid of the census tract is used in computing both exposure indicators. In computing the centroid of a census tract, the ARB staff assumes there is a box surrounding the census tract. Two lines are drawn, connecting the opposite corners of the box. The point at which the two lines intersect is the centroid of the census tract. Depending on the shape of the census tract, the centroid may or may not be located within the boundary of the census tract.

4. Interpolating Exposures

Hourly ozone concentrations are interpolated to each census tract centroid for a period of three years. For example, 8760 hourly concentrations are interpolated to each census tract centroid for each of the three years in the 1986 through 1988 base period (a total of 26,280 interpolated concentrations). Each hourly concentration is interpolated from data for all sites located within 50 kilometers of the census tract centroid (a 50 kilometer radius of representativeness). The interpolation algorithm utilizes a $1/r^2$ weighting factor, where "r" is the distance from the monitoring site to the census tract centroid. Using this algorithm, monitoring sites located closer to the census tract centroid have a greater influence on the interpolated concentration than do monitoring sites located farther away.

Hourly ozone exposures are computed for each centroid by subtracting the value of the State ozone standard (9 parts per hundred million (pphm)) from each interpolated hourly concentration. For example, if the interpolated concentration for one hour is 12 pphm, the resulting exposure is 3 pphm-hours ((12 pphm - 9 pphm) x 1 hour = 3 pphm-hours). In contrast, if the interpolated concentration is equal to or less than the State ozone standard, the resulting exposure for that hour is zero and does not contribute to the overall exposure.

5. Determining Annual Average Weighted Exposure

To determine the annual population-weighted exposure for each census tract, the hourly exposures for each census tract (described in subsection 4., above) are multiplied by the number of people residing in the census tract. These hourly exposures are then added together and divided by the total number of people residing in all the census tracts for which interpolated exposure values are available. The result represents an hourly population-weighted exposure for the represented portion of the nonattainment planning area. The hourly exposures are aggregated into a daily population-weighted exposure (note that the daily population-weighted exposures are saved for use in computing the uncertainty of the indicator; refer to subsection 6., below). The daily exposures are then aggregated into an annual population-weighted exposure. When this has been done for each of the three years, the annual exposures are summed and divided by three to provide an overall annual average population-weighted exposure.

The procedure for computing the area-weighted exposure is similar. In this case, the hourly exposures for each census tract (described in subsection 4., above) are multiplied by the square kilometer land area of the census tract. These hourly exposures are then added together and divided by the total land area of all the census tracts for which interpolated exposure values are available. The result represents an hourly area-weighted exposure for the represented portion of the nonattainment planning area. The hourly exposures are aggregated into a daily area-weighted exposure (again, the daily area-weighted exposures are saved for use in computing the uncertainty of the indicator; refer to subsection 6., below). The daily exposures are then aggregated into an annual area-weighted exposure. When this has been done for each of the three years, the annual exposures are summed and divided by three to provide an overall annual average area-weighted exposure.

In reporting the results for the annual average population-weighted exposure and the annual average area-weighted exposure, it is important to include the percentage of the total population and total nonattainment planning area, respectively, represented by the annual average exposures. For example, the exposure estimates may represent 90 percent of the population but only 50 percent of the nonattainment planning area.

6. Data for Estimating Uncertainty

The procedure for estimating the uncertainty or native variability associated with the exposure indicators is generally described in Chapter II, Section E., of the guidance document. The native variability is used to determine whether progress has occurred (in other words, whether the overall annual average weighted exposure has decreased) and, if it has, how much progress has been achieved from the base period to the end period. The procedure for computing the native variability of the exposure indicators relies on the daily total exposure data (refer to subsection 5., above). To compute the native variability of the population-weighted exposure, the native variability procedure requires input of the daily population-weighted exposures. Similarly, to compute the native variability of the area-weighted exposure, the native variability procedure requires input of the daily area-weighted exposures. These values are input to the computer program and the native variability computations completed as described in Chapter II, Section E. of the guidance document.

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