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Volume VIII

THE BENEFITS OF PRESERVING VISIBILITY IN THE NATIONAL PARKLANDS OF THE SOUTHWEST

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Volume 6, The Value of Air Pollution Damages to Agricultural Activities in Southern California, EPA-230-12-85-024.

This volume contains three papers that address the economic implications of air pollution-induced output, input pricing, cropping, and location pattern adjustments for Southern California agriculture. The first paper estimates the economic losses to fourteen highly valued vegetable and field crops due to pollution. The second estimates earnings losses to field workers exposed to oxidants. The last uses an econometric model to measure the reduction of economic surpluses in Southern California due to oxidants.

Volume 7, Methods Development for Assessing Acid Deposition Control Benefits, EPA-230-12-85-025.

This volume suggests types of natural science research that would be most useful to the economist faced with the task of assessing the economic benefits of controlling acid precipitation. Part of the report is devoted to development of a resource allocation process framework for explaining the behavior of ecosystems that can be integrated into a benefit/cost analysis, addressing diversity and stability.

Volume 9, Evaluation of Decision Models for Environmental Management, EPA-230-12-85-027.

This volume discusses how EPA can use decision models to achieve the proper role of the government in a market economy. The report recommends three models useful for environmental management with a focus on those that allow for a consideration of all tradeoffs.

Volume 10, Executive Summary, EPA-230-12-85-028.

This volume summarizes the methodological and empirical findings of the series. The concensus of the empirical reports is the benefits of air pollution control appear to be sufficient to warrant current ambient air quality standards. The report indicates the greatest proportion of benefits fran control resides, not in health benefits, but in aesthetic improvements, maintenance of the ecosystem for recreation, and the reduction of damages to artifacts and materials.

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ABSTRACT

The nation needs to know how much visibility is worth in order to evaluate the benefits of air pollution control for the purpose of visibility protection. This study was designed to measure the economic value of preserving visibility in the National Parklands of the Southwest. During the summer of 1980, over six hundred people in Denver, Los Angeles, Albuquerque and Chicago were shown sets of photographs depicting five levels of regional visibility (haze) in Mesa Verde, Zion and Grand Canyon National Parks. Although our calculations suggest that projected emissions with existing and currently planned S02 controls would not produce a perceived decline in visibility, complete decontrol of S02 emissions by projected power plants in the region in 1990 would result in a decrease in typical summer visibility from that which was represented in the photographs as "average" visibility to that which was represented as "below average" visibility. On the basis of this, the survey participants were asked how much they would be willing to pay in higher electric utility bills to preserve the current average condition--middle picture--rather than allow visibility to deteriorate, on the average, to the next worse condition as represented in the photographs (an estimate of total preservation value). They were also asked about their willingness to pay in the form of higher monthly electric power bills to prevent a plume from being seen in a pristine area. To represent plume blight, two photographs were taken from Grand Canyon National Park, one with a visible plume. The surveying had a very high response rate (few refusals). Individual household bids ranged from an average of $3.72 per month in Denver to $9.00 per month in Chicago for preserving visibility at the Grand Canyon. These average bids were increased by $2.89 to $7.10 per month per household in the four cities if visibility preservation was to be ext.ended to the Grand Canyon Region as a whole as represented by the photographs taken from Mesa Verde and Zion. Prevention of a visible plume at the Grand Canyon was worth on the average between $2.84 and $4.32 per month for the four cities surveyed. Extrapolating these bids to the nation implies that preserving visibility in the Grand Canyon Region is worth almost 6 billion dollars per year. This is the base figure from which the benefits of power plant S02 controls, projected to be in place in the region in 1990, are determined. Adjusting this number for 1990 population levels and using a 10 percent discount rate over a thirty year power plant life gives an annualized value of 7.6 billion dollars as the benefits of power plant SO_2 control. The corresponding control costs are estimated to be approximately three billion dollars annually. Therefore, the existing and proposed control level in the Region is not without economic justification. Additionally, prevention of a visible plume at the Grand Canyon is worth almost two billion dollars to the nation. These results suggest that preservation values derived from knowledge that a unique natural wonder remains preserved may be very large for the Grand Canyon Region. Finally, the methodology used must be considered experimental since this is the first study, to our knowledge, to include an estimate of preservation value for a unique national treasure.

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We thank Phil Wondra and Dave Shaver of the National Park Service for their helpful guidance during the design of the survey methodology. We thank the Park Service for permission to use the photographs taken from the photographic monitoring program at several parks. Additionally, George Tolley and John Hoehn of the University of Chicago and Glen Blomquist of the University of Kentucky collected data in Chicago for this study and contributed greatly to the research preparation. Ralph d'Arge and Thomas Crocker also provided helpful suggestions throughout the research effort. Our thanks also go to LeAnn Lively and Ema Bixler for editing and manuscript preparation. Research Assistants at the University of Wyoming who worked on the project include Morteza Rahmatian, John Hovis, Laura Bibo, William Weirick, Colleen Kalsbeck, Lou Murdoch, Jim Murdoch, Kim Case, Cale Case, and Patricia Smith.

EXECUTIVE SUMMARY

THE BENEFITS OF PRESERVING VISIBILITY IN THE NATIONAL PARKLANDS OF THE SOUTHWEST

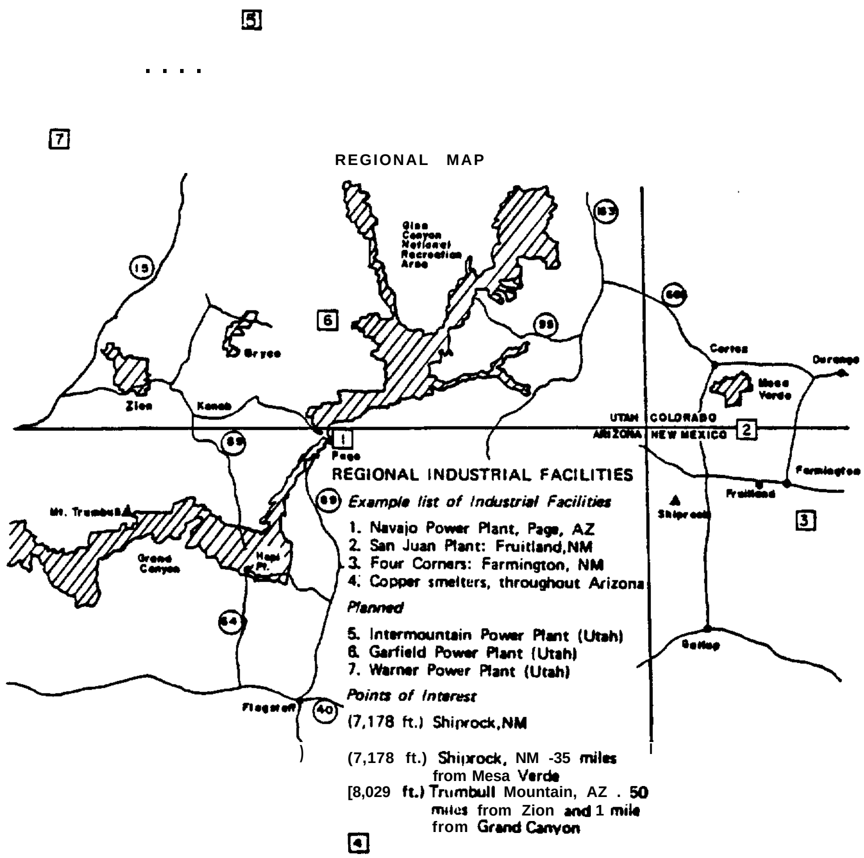
The nation needs to know how much visibility is worth in order to evaluate the benefits of air pollution control for the purpose of visibility protection. This study was designed to measure the economic value of preserving visibility in the National Parklands of the Southwest.

Historically Americans have placed a high value on good visibility, that is, the ability to see distant objects clearly. This yearning for and appreciation of atmospheric visual clarity is evidenced in the country's early literature and art, including the Journals of Lewis and Clark as well as the masterpieces of the great American landscape artists of the 19th century. Today that love of visibility is demonstrated not only by the millions who flock each year to our western parks, but also in the high prices brought by those artists' work of a century ago and by the interest in Ansel Adams' simple, yet dramatically clear black and white photographs of Yosemite and other wonders of the U.S. National Park Service.

Over the past 100 years, Congress has acted to preserve many of our nation's natural wonders. [t did so by creating and continually expanding the National Parks, National Wilderness Areas, National Monuments, National Recreation Areas, and Wild and Scenic Rivers.

Since the 1950s there seems to have been an increasing concern that this beauty is threatened by industrial development and population growth. Pollution from coal-fired power plants became a special concern with the advent in 1963 of the first unit of the Four Corners Power Plant near Farmington, New Mexico. It produced a plume that could be seen clearly for many miles, reducing the clarity of the visual experience in areas of northwestern New Mexico, southeastern Utah, southwestern Colorado and northeastern Arizona.

By the late 1960s and the early 70s, smog began to appear in Yosemite Valley on warm summer days. Battles erupted over proposed coal-fired power plants on the Kaiparowits Plateau and near Capitol Reef National Park, both in southern Utah, because of their possible effects on visibility. The increased publicity and concern resulted in magazine and newspaper articles decrying the loss of visual clarity, particularly in the western United States, and precipitated political pressures in Congress for legislative steps to protect visibility. Those pressures culminated in the August 1977 adoption by Congress of the nation's first specific visibility protection requirements for national parks and national wilderness areas as amendments to the Clean Air Act of 1970. One of the large issues raised by these developments is whether the value of visibility protection outweighs the cost, including air pollution control equipment and the regulatory requirements. The study reported on here is designed to improve our ability to measure the benefits of visibility and to provide some actual estimates of the value of that visibility in several major national parks and for the region in which they are located. The region and the parks located in it are shown on the map below. We refer to this area as the Grand Canyon Region.



Visibility is the ability to clearly see both color and detail over long distances. Human perception of visual air quality is associated with the apparent contrast of distant visual targets with respect to their surroundings. As contrast is reduced, a scene "washes out" both in color and in the ability to see distant detail.

What then is the nature of the preservation value of visibility? That value has at least two possible components.

First, a scenic resource such as the Grand Canyon attracts millions of recreators each year. The quality of the experience of these recreators depends in great part on air quality, because scenic vistas are an integral part of the Grand Canyon "experience." Thus, air quality at the Grand Canyon is valuable to recreators. We might call this economic value user value, or. the willingness to pay by users for air quality at the Grand Canyon. Thus ; recreators in the National Parklands of the Southwest should be willing to pay some amount to preserve air qual ity for each day of their own use if their recreation experience is improved by good air quality. One hypothetical market for collecting user value is an increase in entrance fees to parks to be used to finance preservation of air quality, i.e., purchase of air pollution control equipment. Survey questionnaires can be designed to estimate user value based on such a hypothetical market.

The second component of preservation value is termed existence value. Individuals and households which might never visit the Grand Canyon can still value visibility there simply because they wish to preserve a national treasure. Visitors also may wish to know that the Grand Canyon retains relatively pristine air quality even on days when they are not visiting the park. Concern over preserving the Grand Canyon may be just as intense in New York or Chicago as it is in nearby states and communities.

Thus, preservation value has two additive components, user value and existence value. However, it is difficult to construct even a hypothetical market to capture existence value alone. Rather one could imagine a lump sum fee added, for example, to electric power bills to preserve air quality in the Grand Canyon and the surrounding parklands. Such a hypothetical fee would capture total preservation value, the sum of existence plus user value, if used as the basis of a survey questionnaire. In fact, the survey conducted for this study asked approximately one-third of the respondents a pure user value question (how much would they be willing to pay in higher entrance fees per day for visibility at the Grand Canyon or other parks). The other two-thirds of the respondents were asked how much they would be willing to pay at most as a higher monthly electric power bill to preserve visibility first at the Grand Canyon and second throughout the region as represented by photographs of vistas at the Grand Canyon, Mesa Verde and-Zion National Parks (total preservation value questions). Clearly, if total preservation value is much larger than total user value, then existence value must be large.

During the summer of 1980, over six hundred people in Denver, Los Angeles, Albuquerque and Chicago were shown sets of photographs depicting both clear visibility conditions and regional haze conditions. Each set consisted of 5 photographs ranging from poor to excellent visibility. The middle picture in each case approximated average visibility during the summer (the season of peak visitation). The vistas were 3 different views from the Grand Canyon, 1 view from Mesa Verde and 1 view from Zion. The 8 by 10 inch textured prints were placed on display boards, each vista a separate row, and each row arranged with 5 photographs from left to right in ascending order of visual air quality (i.e., photograph A = “poor” visibility and photograph E = “excellent” visibility).

The relationship between the five levels of visibility shown in the photographs to regional emissions can be summarized as follows: if (1) all controls on SO_2 for existing power plants in the region were removed; (2) proposed power plants (through 1990) in the region were to emit SO_2 at the maximum uncontrolled rate; (3) existing smelter emissions were held constant; and (4) particulate emissions remain at current levels, visibility would then decline from current average conditions (middle photographs) by one step to the level presented in the photographs just to the left of center. Thus, where the photographs can be described as representing “poor,” “below average,” “average,” “above average” and “excellent” visibility, complete decontrol of

SO_2 emissions by projected power plants in the region in 1990 would result in a decrease in typical summer visibility from that which is represented in the photographs as "average" visibility to that which is represented as "below average" visibility. The calculations which form the basis of the relationship between the levels of visibility which were shown in the photographs and regional emissions are presented in Chapter 3.

The survey participants were asked either (1) how much they would be willing to pay for visibility as shown in the five sets of photographs from worst to best on the day of a visit to the Grand Canyon (an estimate of user value) or (2) how much they would be willing to pay in higher electric utility bills to preserve the current average condition--middle picture--rather than allow visibility to deteriorate, on the average, to the next worse condition as represented in the photographs of the Grand Canyon or of the region (an estimate of total preservation value). They were also asked about their willingness to pay in the form of higher monthly electric power bills to prevent a plume from being seen in a pristine area. To represent plume blight, two photographs were taken from Grand Canyon National Park. Both photographs are essentially identical except one has a plume, a narrow gray band, crossing the entire vista in the sky. The source was not industrial or municipal pollution but a controlled burn in the area around the Grand Canyon. However, the effect was comparable to what a large uncontrolled industrial source might produce.

The bidding game reveals the household's willingness to pay for preserving visibility in specific locations as represented in the photographs. For the interviewees asked the preservation value questions in the survey, the bids include both existence value and user value. Therefore, we concentrate on the preservation value section of the survey here, since user values are included in the preservation estimates.

The surveying had few refusals, partly because of the nature of the interviews. Typically, interviews were conducted in the late afternoon or early evening hours in residential neighborhoods. Due to the large size of the display boards, most interviews were conducted on the front lawn of the respondent's home. Often, both husband and wife participated jointly in answering the questions. This was viewed as appropriate since the principal question was "how much would you be willing to pay in higher monthly electric utility bills to preserve visibility at the Grand Canyon or in the entire Grand Canyon region?" Household members would often engage in extensive discussion before giving a dollar amount. Individual bids ranged from an average of $3.72 per month in Denver to $9.00 per month in Chicago for preserving visibility at the Grand Canyon. These average bids were increased from $2.89 to $7.10 per month per household in the four cities if visibility preservation was to be extended to the Grand Canyon region as a whole. Prevention of a visible plume in the Grand Canyon was worth on the average between $2.84 and $4.32 per month for the four cities surveyed.

The. validity of these survey results depends on the perception by individuals of visibility conditions as represented by photographs. A linear relationship has been shown to exist between perceived visibility as quantified by individuals in a numerical one to ten ranking of visual air quality as represented in an actual view and with the scientific measure of the apparent contrast in the vista by a multiwavelength teleradiometer. This close linear relationship between perception of an actual vista and the apparent contrast of the vista also extends to perception of visibility conditions represented by slides or 8" x 10" color photographs as is shown in the research presented in Chapter 4.

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The benefit estimates derived from the interview results can be extrapolated from the sample population to the country as a whole by applying statistical extrapolation techniques to the results of the survey. The bids offered by interviewees to preserve visibility are statistically related to income as well as other demographic characteristics. Using the estimated linear relationship of bids to population characteristics, it is possible to estimate the value of benefits to residents both for the entire Southwest region and for the entire nation. This is done by substituting the average value for these characteristics for each state into the relationship and calculating the average value of the bid of a person in that state. This value is then multiplied by the number of households in the state to get a total bid or benefit.

When the analysis is performed for the southwestern U.S. (for residents of California, Colorado, Arizona, Utah, Nevada, and New Mexico), the following values are obtained.

Yearly Benefits from:	Total ($million)
Preserving Visibility at the Grand Canyon	470
Preserving Visibility at the Grand Canyon Region	889
Preventing Plume Blight at the Grand Canyon	373

To estimate the aggregate national benefits for preserving visibility, a similar analysis is done for the entire U.S. and the following values are obtained.

Yearly Benefits from:	Total ($million)
Preserving Visibility at the Grand Canyon	3,370
Preserving Visibility in the Grand Canyon Region	5,76o
Preventing Plume Blight at the Grand Canyon	2,040

The benefits of preserving visibility can be related to emissions by noting the following. Projected emissions with existing and currently planned levels of SO_2 control would not produce a perceived decline in visibility in 1990 according to our calculations as shown in Chapter 3. However, complete decontrol of projected regional power plant emissions of S02 in 1990 would decrease visibility by approximately the same amount as the decrease shown in the photographs which form the basis of the preservation value questions in the survey. Thus, the regional benefit figure forms the base from which benefits from power plant S02 controls, projected to be in place in 1990, are calculated.

Two modifications of the regional benefit figure are necessary. First, benefits in 1990 must reflect the expected population levels in that year. Second, the present value of future benefits, based on a thirty year power plant life and a 10 percent real discount rate which is consistent with the Office of Management and Budget guidelines, must be determined. These modifications yield an annualized value of 7.6 billion dollars as the benefits of power plant S02 controls.

The corresponding control costs, which include initial capital expenditures, recurring expenditures and the regulatory system cost, are estimated to be approximately three billion dollars annually. Therefore, estimated national benefits exceed control costs and the proposed level of S02 control is not without some economic justification.

Several other observations on the outcomes of the analysis of the interview results are worth mentioning.

First, in the conventional view of the demand for environmental quality, there is a smooth tradeoff between higher successive levels of environmental quality and economic benefits, with successive units commanding less incremental willingness to pay.

The survey respondents in the user portion of the study, however, placed a much higher value on a small initial diminution in visual clarity than on comparable subsequent decreases. This would produce a very unusual upward sloping demand curve for visibility.

Second, again somewhat contrary to expectations, neither past nor prospective visits to the Grand Canyon Region were shown to be important determinants of preservation value. On the average those who had never seen the Canyon valued it as highly as those who had.

Third, once more unexpected, distance from the region had no significant relationship to the size of household bids. People in Chicago bid fully as high as those closer by for preserving visibility at the Grand Canyon.

Fourth, whereas total annual preservation value of the Grand Canyon Region for the nation approaches six billion dollars, user value is on the order of tens of millions of dollars. Thus, existence value dominates the benefits of preserving visibility.

Because the Grand Canyon is the dominant feature in a region with many visitor attractions, one must be especially cautious in extending these findings to other recreational attractions. It seems likely that there are only a very few natural phenomena in the United States about which Americans have such strong feelings. Obvious candidates for this short list would be Old Faithful in Yellowstone National Park, Niagara Falls and perhaps a few others.

The main conclusion of this study is that the magnitude of the annual yearly benefits for preserving visibility when aggregated across households is impressive: nearly one billion dollars in the southwest and about six billion in the nation.

While these are necessarily rather crude extrapolations, the survey results reveal that Americans place great value on preservation of air quality in the Grand Canyon Region and that this valuation is not localized in the southwest. Again, it is worth noting that pure existence value overwhelms user value for the National Parks in the region.

The accuracy of these estimates, given the difficulty of quantifying environmental value in dollar terms, is probably on the order of plus or minus 50 percent. However, the methodology used must still be considered experimental.

The report is organized as follows: Chapter 1 presents the historical, legal and institutional background for visibility protection. Chapter 2 describes the photographs of vistas in the National Parklands used in surveying people in four metropolitan areas about the value of preserving visibility in National Parks. Chapter 3 relates the levels of air quality shown in the photographs to regional industrial emissions under three alternative scenarios. Chapter 4 reports on a study of the relationship between perception of air quality by direct observation as opposed to that presented in slides and photographs. Chapter 5 describes the economic theoretical basis for the survey design, which is presented in Chapter 6. Chapter 7 gives the survey results while Chapter 8 develops an aggregate benefit measure for preserving visibility in the National Parklands of the southwest. The overall study thus brings together work from atmospheric physics (Chapters 2 and 3), psychology and sociology (Chapter 4), and economics (Chapters 5-8) to provide an estimate of the benefits of preserving visibility in the Grand Canyon Region. Only with knowledge of (1) how emissions affect visibility, (2) how people perceive changes in visibility and (3) how people value changes in perceived visibility in dollar terms can a valid estimate of such benefits be made.

CHAPTER 1

INTRODUCTION

. . .

A. Why This Study?

The nation needs to know how much visibility is worth in order to evaluate the benefits of air pollution control for the purpose of visibility protection. This study was designed to measure the economic value of preserving visibility in the National Parklands of the Southwest.

B. The Value of Good Visibility to Society

Historically Americans have placed a high value on good visibility, that is, the ability to see distant objects clearly. This yearning and appreciation of atmospheric visual clarity is evidenced in the country's early literature and art, including the Journals of Lewis and Clark as well as the masterpieces of the great American landscape artists of the 19th Century. Today that love of visibility is demonstrated not only by the millions who flock each year to our western parks, but also in the high prices brought by those artists' work of a century ago and by the interest in Ansel Adams' simple, yet dramatically clear black and white photographs of Yosemite and other wonders of the U.S. National Park Service.

Over the past 100 years, Congress has acted to preserve many of our nation's natural wonders. It did so by creating and continually expanding the National Parks, National Wilderness Areas, National Monuments, National Recreation Areas, and Wild and Scenic Rivers.

Since the 1950s there seems to have been an increasing concern that this beauty is threatened by industrial development and population growth. Pollution from coal-fired power plants became a special concern with the advent in 1963 of the first unit of the Four Corners Power plant near Farmington, New Mexico. It produced a plume that could be seen clearly for scores of kilometers, reducing the the 'clarity of the visual experience in areas of northwestern New Mexico, southeastern Utah, southwestern Colorado and northeastern Arizona.

By the late 1960s and the early 70s, smog began to appear in Yosemite Valley on warm summer days. Battles erupted over proposed coal-fired power plants on the Kaiparowits Plateau and near Capitol Reef National Park and Zion National Park, both in southern Utah. The increased publicity and concern resulted in magazine and newspaper articles decrying the loss of visual clarity, particularly in the western United States, and precipitated political pressures in Congress for legislative steps to protect visibility. Those pressures culminated in the August 1977 adoption by Congress of the nation's first specific visibility protection requirements for national parks and national wilderness areas as amendments to the Clean Air Act of 1970.

c. History of Federal Visibility Protection

The 1977 Clean Air Act Amendments

The increasing public concern about and Congressional interest in protecting visibility resulted in specific visibility provisions-being included in the Clean Air Act Amendment of 1977 (P.L.95-95; August 7, 1977). The House Commerce Committee in its report accompanying the amendments to the Clean Air Act, summarized the Congressional intent as follows:

> There are certain national lands, including national parks, national monuments, national recreation areas, national primitive areas, and national wilderness areas, in which protection of clean air quality is obviously a critical national concern. In fact the 1916 National Parks Organic Act states the purpose of such lands "is to conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such a manner and by such means as will leave them unimpaired for the enjoyment of future generations" (16 U.S.C.I). Similarly, the 1964 Wilderness Act provides that wilderness areas:
>
> Shall be administered in such manner as will leave them unimpaired for future use and enjoyment as wilderness, and so as to provide for the protection of these areas (and) the preservation of their wilderness character. (16 U.S.C. 1131 (c))
>
> In the Committee's view, these unique national lands should not be despoiled or heavily shrouded in dense industrial pollution. Indeed, the millions of Americans who travel thousands of miles each year to visit Yosemite or the Grand Canyon or the North Cascades will find little enjoyment if, for example, upon reaching the Grand Canyon it is difficult if not impossible to see across the great chasm. if that were to come to pass - and several of our great national parks, including the Grand Canyon, are threatened today by such a fate - the very values which these unique areas were established to protect would be irreparably diminished, perhaps destroyed. Former Secretary of Interior Rogers Morton recognized the value of these lands and their threatened loss when in June 1973 speaking of the national park lands in the southwest, he stated:
>
>> The scenic beauty of the rugged Southwest landscape, coupled with the clarity of the air in the vicinity, are national assets of major importance, worthy of protection for the enjoyment of future generations of Americans.
>
> Unless a policy of prevention of significant deterioration of air quality provides special protection for these national lands belonging to all Americans, their beauty may be lost forever.

1980 Visibility Regulations

On December 2, 1980, the Environmental Protection Agency promulgated regulations[1] to implement the Clean Air Act's visibility protection provisions. Key provisions of these regulations include:

a) Phased Approach - The regulations recognize two distinct types of air pollution which impair visibility:

1) smoke, dust, colored gas plumes or layered haze emitted from stacks which obscure the sky or horizon and are reasonably attributable to a single source or a small group of sources, called "plume blight"; and

2) widespread regionally homogeneous haze from a multitude of sources which impairs visibility in every direction over a large area, called "regional haze."

Because of ". . . certain scientific and technical limitations . . ." EPA promulgated a phased approach to visibility protection regulations. Phase I of[2] the program requires control of impairment that can be traced to a single existing stationary facility or small group of stationary facilities.[3]

b) BART Analysis/Re-analysis and implementation - The States must perform a "Best Available Retrofit Technology" (BART) analysis on any applicable existing source to which the State can reasonably attribute (through visual observation or other monitoring technique) visibility impairment in any applicable Class I area or integral vista. In the Bart Analysis, the States determine what additional controls, if any, are needed on the sources of existing impairment in order to remedy or reduce the visibility impairment.

In this analysis, the States should consider the cost of control, energy and environmental impacts of control, air pollution controls already in place at the source, the remaining useful life of the source, and to what degree the control alternatives would improve visibility.

c) New Source Review - The regulation also requires the melding of the visibility protection requirements of Section 165(d) with those of Section 169A, for purposes of preventing new impairment resulting from proposed major emitting facilities.

Section 165(d) applies to air pollution impacts within a Class I area and does not provide for the balancing of economic, energy and other non-air factors with air quality factors. Under Section 169A, the States may weigh other factors, such as economics, with protection of integral vistas.

d) Long-Term'-'Strategy - The regulations require each applicable State to develop and include in its State Implementation Plan (SIP) a long-term (10 to 15 year) strategy for making reasonable progress toward remedying existing and preventing future visibility impairment.

In judging reasonable progress, the States may weigh economics, energy, and other non-air qual ity factors against improvements in air quality.

D. Issues

The overall issue is the value of visibility protection compared to the cost, including air pollution control equipment and the regulatory system. Part of the value of visibility is economic, expressed in many ways such as the extra price people pay for homes with good vistas and the price people pay to travel long distances to see vistas with high visual air quality. A related issue is what people see when they look at a vista. What instrument measurement and visibility-related variables describe visibility in a way consistent with human perception? How should vistas be presented to people in order to question them about the economic value of visibility? These issues are the subjects of on-going research. This study is based on the most up-to-date understanding of these issues, much of which was developed by our research efforts.

E. Organization of the Report

Chapter 2 describes the photographs of vistas in the National Parklands used in surveying people in four metropolitan areas about the value of preserving visibility in National Parks. Chapter 3 relates the levels of air quality shown in the photographs to regional industrial emissions under three alternative scenarios. Chapter 4 reports on a study of the relationship between perception of air quality by direct observation as opposed to that presented in slides and photographs. Chapter 5 describes the economic basis for the survey design, which is presented in Chapter 6. Chapter 7 gives the survey results while Chapter 8 develops an aggregate benefit measure for preserving visibility in the National Parklands of the Southwest. The overall study thus brings together work from atmospheric physics (Chapters 2 and 3), psychology and sociology (Chapter 4), and economics (Chapters 5-8) to provide an estimate of the benefits of preserving visibility in the Grand Canyon Region. Only with knowledge of (1) how emissions effect visibility, (2) how people perceive changes in visibility and (3) how people value changes in perceived visibility in dollar terms can a valid estimate of such benefits be made.

REFERENCES

1. 45 FR 8008 4 December 2, 1980.

2. Impairment - Visibility impairment is defined as "any humanly perceptible change in visibility (visual range, contrast, coloration) from that which would have existed under natural conditions."

3. EPA has determined ". . . that the present mathematical models and monitoring techniques show promise for being used in regulatory manner. However, these techniques must be further evaluated . . . ." Teleradiometry and photography are two visibility monitoring approaches that have been widely used over the past three years.

CHAPTER 2

REPRESENTING VISIBILITY WITH PHOTOGRAPHS

. . .

A. Photographs Used In The Survey

During the summer of 1980, over 600 people in Denver, Los Angeles, Albuquerque and Chicago were shown 5 sets of photographs depicting regional haze, each set consisting of 5 photographs of a national park vista with different visual air quality. The vistas are from Grand Canyon, Mesa Verde and Zion National Parks. The observation sites, vista names and specifications are given in Table 1. Summer visibility conditions were chosen for the survey because it is the season of peak park visitation.

These photographs were placed on display boards as full frame 8 by 10 inch textured prints, arranged from left to right in ascending order of visual air quality with each vista a separate row (see Figure 1 representing visibility at the Grand Canyon and Figure 2 representing visibility conditions throughout the Grand Canyon Region). The participants were asked how much they would be willing to pay for visibility as shown in the five sets of photographs.

Participants in the survey were also asked about their willingness to pay to prevent a plume from being seen in a Class I area. Two photographs were used, one with and the other without a plume. The photographs were taken from Grand Canyon National Park at the Hopi firetower observation point and towards Mt. Trumbull (west). These two photographs, shown in Figure 3, were both taken at 9 a.m. so the lighting on the canyon wall and other features are the same. Both photographs have the same light high cirrus cloud layer. The plume is a narrow gray band crossing the entire vista in the sky, except where it is in front of the top of Mt. Trumbull. We believe the source was a controlled burn near the Grand Canyon. The photograph specifications are in Table 2.

B. Data Base

The photographs were taken with a 35mm lens on single lens reflex automatic exposure came-ras at Grand Canyon, Mesa Verde and Zion National Parks during the periods shown in Table 1. These cameras are operated as part of the photographic program in the EPA/NPS regional visibility monitoring network. The network also provides teleradiometer measurements of the apparent green contrast of targets viewed from these parks, from which standard visual range, attenuation coefficient and other visibility-related variables are computed. The apparent green contrast is measured on each slide with a manual multiwavelength teleradiometer. To do so, the slide is projected on a screen and the apparent green radiance N_r is measured on the target used in the network and the adjacent sky. The apparent contrast C_r is computed with equation (2) from

Table 1

Vistas for Survey

Park	Observation Site	Vista	Direction (°true)	Time of Day (Local)	Target Distance (km)	Period Photographed
Grand Canyon	Hopi Point	Desert View	96	9AM	30	Oct. 79 to present
Grand Canyon	Hopi Point	Trumbull Mt.	293	9AM	96	Oct. 79 to present
Grand Canyon	Hopi Point	Trumbull Mt.	293	3PM	96	Oct. 79 to present
Mesa Verde	Far View Visitor Center	Shiprock and Lukachukai Mts.	208	9AM	68 to Shiprock 130 to Lukachukai Mts., Target Number 1	Oct. 79 to present
Zion	Lava Point	Trumbull Mt.	190	10AM	105	July-November 1979

Figure 1
Grand Canyon Photograph Board

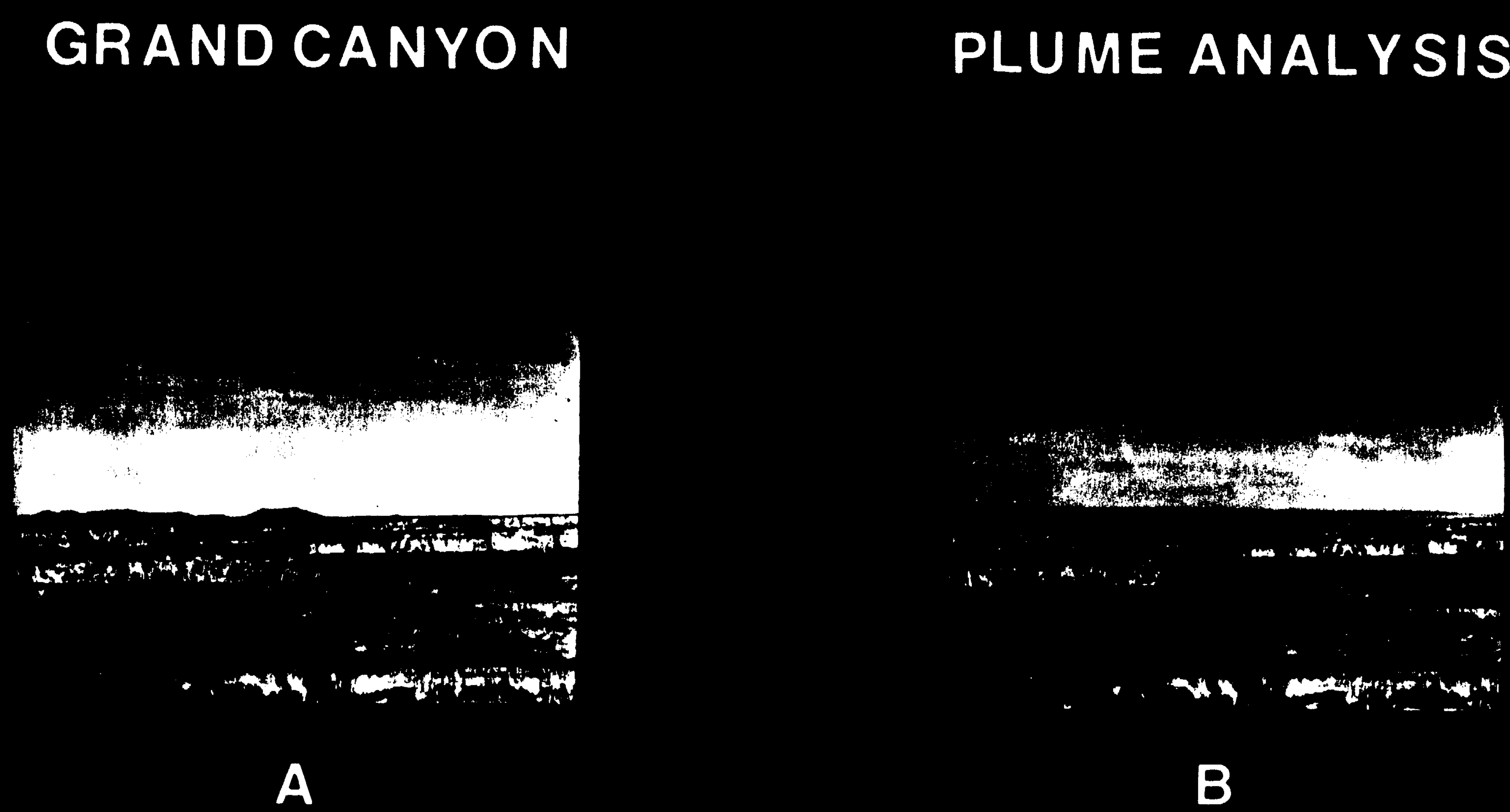


Figure 3
Grand Canyon Plume Board

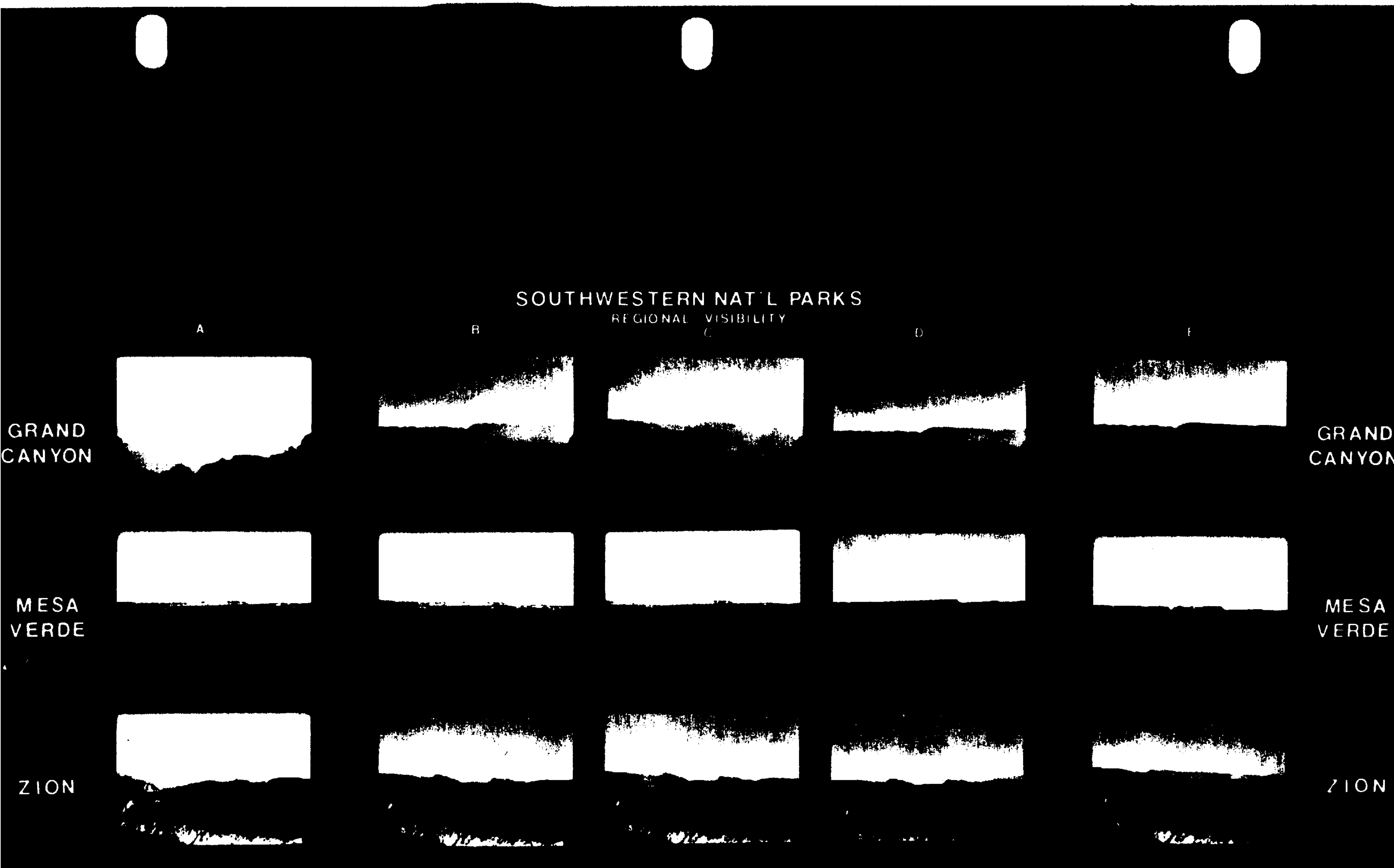


Figure 2
Regional Photograph Board

Table 2

Photographs for Plume Question

Photograph	Archive #	Date	Time (MST)	Cloud
without plume	GC 395	27 Nov. 1979	8:5o a.m.	Cirrus
with plume	GC 405	28 Nov. 1979	9:20 a.m.	Cirrus

Table 3

Target Specifications and Slides for Summer 1980 Survey

Target	Observation Site	Time of Day (local time)	C_o	α_R (km^{-1})	r (km)	Photograph Archive Number	C_r	F(%)[a]	X_{fp} ($\frac{\mu g}{m^3}$)
Trumbull	Hopi Fire Tower, Grand Canyon	9AM	-.735	.00927	96	GC 84	-oh	8	4.21
						GC 92[b]	-.10	35	2.30
						Median	-.12	50	1.92
						GC 171	-.20	92	0.86
						GC 268	-.26	99	0.31
						GC 204	-.30	99.9	0.01
Trumbull	Hopi Fire Tower Grand Canyon	3PM	-.8	.00927	96	GC 519	-.08	9	2.94
						GC 102	-.14	30	1.78
						Median	-.17	50	1.37
						GC s36	-.18	55	1.25
						GC 313	-.24	85	0,6s
						GC 54s	-.30	97	0.19
Desert View	Hopi Fire Tower Grand Canyon	9AM	-.88	009349	30	GC 9	-.26	4	6.26
						GC 501	-.37	23	3.91
						GC 94	-.43	44	2.90
						Median	-.45	50	2.6o
						GC 311	-.59	90	0.80
						GC 406	-.71	99.1	0
.ukachuka I I ;hiprock View)	Far View Visitor Center, Mesa Verde	9AM	-.7	.009076	106	MV 54	-.02	3	4.89
						MV 48	-.04	8	3.59
						MV 133	-.08	32	2.28
						Median	-.10	50	1.86
						MV 234	-.14	89	1.22
						MV 21	-.24	99.99	0.20
Trumbull	Lava Point, Zion	10AM	-.82	.009181	105	2 2	-.02		5.24
						z 16	-.07		2.85
						Median	-.12	50	1.82
						2 190	-.15		1.40
						2 119	-.18		1.05
						2 146	-.24		0.50

[a]Cumulative frequency (less than or equal) of occurrence of specified target apparent green contrast

[b]Median of measurements taken during Summer 1979.

Appendix A which gives a summary of the theory of visibility applicable to this study.

It is important to know the frequency of occurrence of the photographed visual air quality at each of the vistas. The cumulative frequency of the apparent contrast of the official network target in each photograph is computed from teleradiometer measurements taken during summer 1979 (see Table 3). The 5 photographs for each vista were chosen to have perceptible differences (Maim, et al. 1980a), between adjacent pairs, and the middle photograph is nearest the median visibility observed during summer 1979. Only the Mt. Trumbull morning series is slightly skewed, with the observed median being closer to the second photograph.

CHAPTER 3

REGIONAL EMISSIONS AND VISIBILITY

A. Introduction

The principal objective of this study is to measure the benefits of preserving visibility. However, benefit measures associated with ambient air quality must be related to emissions by industrial sources so that a comparison of benefits to control costs can be made. This chapter, along with Appendix A, provides the basis for relating benefits to industrial emissions.

B. Relating Visibility to Emissions

The apparent target contrast, C_r, distance between the target and observer, r, and inherent green contrast, C_o, of the target allow us to compute the mean attenuation coefficient, α, of the sight path, using equation (11) from Appendix A.

$$\alpha = \frac{1}{r} \ln \frac{C_o}{C_r} \quad (1)$$

The mean attenuation coefficient comprises three parts, contributed by fine particulate, NO_2 and the normal gaseous constituents of air, so that

$$\alpha = \alpha_{fp} + \alpha_{NO_2} + \alpha_R \quad (2)$$

where α_{fp} = fine particulate attenuation coefficient (km^{-1}),
α_{NO_2} = NO_2 attenuation coefficient (km^{-1}) and
$\bar{\alpha}_R$ = sight path weighted Rayleigh attenuation coefficient (km^{-1}).

Only the fine particulate is shown here, rather than total particulate, because the fine particulate dominates the coarse particulate contribution to visibility (Macias, et al., 1979), except possibly in dust storms.

In order to evaluate the relative magnitude of α_{NO_2}, information is needed on its concentration in clean air and the attenuation per unit path length and per unit concentration. The attenuation coefficient for a gas that absorbs light much more than one that scatters light is given by:

$$\alpha \simeq A = aC$$

where A = absorption coefficient (km^{-1}), a = absorptivity (km^{-1} mole liter^{-1}) and C = concentration (liter mole^{-1}). Background concentrations of NO_2 in the Southwest are about 6 parts per billion (Walther, et al., 1978) and the absorptivity (Hall and Blacet, 1952) at 550 nm is 31.1 mole^{-1} cm^{-1}, hence the NO_2 absorption coefficient is $8.3 \cdot 10^{-4}$ km^{-1}. In comparison, a typical Rayleigh attenuation coefficient is about 10^{-2} km^{-1}, over one magnitude larger. The fine particulate attenuation coefficient is usually at least as large as the Rayleigh attenuation coefficient (Malm, et al., 1980c), and hence also *over* one magnitude larger than the NO_2 attenuation coefficient. Therefore, we assume the nitrogen dioxide concentration is low enough, so that

$$\alpha \simeq \alpha_{fp} + \alpha_R. \qquad (3)$$

Combining (1) and (2), we get

$$\alpha_{fp} + \alpha_R = \frac{1}{r}\ln\frac{C_o}{C_r}$$

or

$$\alpha_{fp} = \frac{1}{r}\ln\frac{C_o}{C_r} - \bar{\alpha}_R. \qquad (4)$$

We know $\bar{\alpha}_R$ for the sight path because we know the elevation of the observation sites and each target.

A constant of proportionality, k, between fine particulate attenuation coefficient and concentration, was derived by others (Macias and Husar, 1976):

$$\alpha_{fp} = k\chi_{fp} \qquad (5)$$

where $k = 5 \cdot 10^{-3} \text{km}^{-1}(\mu g m^{-3})^{-1}$ and

χ_{fp} = fine particulate concentration ($\mu g m^{-3}$).

In the EPA/NPS regional visibility network, standard visual range (SVR) is computed with the relation

$$SVR = \frac{3.912}{\bar{\alpha} - \bar{\alpha}_R + .01} \qquad (6)$$

Combining (3) and (6),

$$SVR \simeq \frac{3.912}{\alpha_{fp} + .01} \qquad (7)$$

and combining (5) and (7), we get the equation for k as a function of SVR and χ_{fp}:

$$k = \frac{1}{\chi_{fp}}\left(\frac{3.912}{SVR} - .01\right) \qquad (8)$$

From the EPA/NPS network, computations for 19 locations over 6 seasons from summer 1978 through fall 1979 indicate an overall geometric mean standard visual range of 165 km. If we assume $\chi_{fp} = 3 \mu gm^{-3}$ over the test region (to be described in Chapter 2B) and time period, then use of (8) leads to $k = 4.6 \cdot 10^{-3} (\mu gm^{-3})^{-1}$. This agrees within 10% to the value found by Macias and Husar (1976).

Using airport observations in the southwest, NASN (National Air Sampling Network) data, and emissions data, the rate of change of attenuation coefficient with SO_2 emissions has been studied by Marians and Trijonis (1979). We will define such a change by the coefficient b:

$$b = d\alpha/dE_{SO_2}.$$

Because we assume that fine particulate dominates the variation of attenuation coefficient, then

$$d\alpha \simeq d\alpha_{fp}, \text{ so } b \simeq \frac{d\alpha_{fp}}{dE_{SO_2}}.$$

Solving for the change in fine particulate concentration as a function of changing SO_2 emissions,

$$\frac{d\chi_{fp}}{dE_{SO_2}} = \frac{d\alpha_{fp}}{dE_{SO_2}} \cdot \frac{d\chi_{fp}}{d\alpha_{fp}} = b/k.$$

Marions and Trijonis (1979) found

$$\frac{d\alpha_{fp}}{dE_{SO_2}} \sim 2 \cdot 10^{-3} km^{-1} (1000 \text{ tons } SO_2 \text{ per day})^{-1}.$$

If we let $k = 5 \cdot 10^{-3}\ km^{-1} (\mu gm^{-3})^{-1}$, then $\frac{d\chi_{fp}}{dE_{SO_2}} = 0.4\ \mu gm^{-3} (1000 tpd\ SO_2)^{-1}$.

This rough relationship is used here with projected changes in the SO_2 emission inventory affecting the region to estimate the resulting change in fine particulate concentration. It is a rough relationship because the regression analysis used to produce the coefficient does not take careful account of different categories of sources, the various mechanisms by which these sources lead to ambient fine particulate concentrations, and the resulting attenuation coefficient.

We can derive an estimate of the fine particulate concentration prevailing in a picture. Combining (4) and (5), we get

$$\chi_{fp} = \frac{1}{k}\left(\frac{1}{r} \ln \frac{C_o}{C_r} - \bar{\alpha}_R\right). \tag{9}$$

Equation (9) is used to compute the fine particulate concentration we expect to be associated with each photograph used in the survey, assuming the particulate concentration is uniform throughout the vista.

c. Emission Scenarios

Now we want to develop scenarios of future anthropogenic effects on visibility in a test region defined as southern Utah, southwestern Colorado, northern Arizona and.northwestern New Mexico (see Figure 4). One of the important driving forces will be the increase in energy related activities, including coal mining, coal combustion to generate electricity, coal conversion to liquid and gaseous fuels and the diverse activities of new people moving into the region.

All these activities create pollutant gases and particulate, some emitted in the region and some transported into the region from similar activities upwind. Fully recognizing the possibility that other sources may be more important, we will arbitrarily simplify this complex set of sources and pollutants by focusing on only coal-fired power plants, the SO_2 they emit and the resulting sulfate fine particulate that affects visibility. This approach seems justified in this specific test region because the proposals for coal-fired power plants there far outweigh the proposals for other major sources of air pollution in the same region (Walther and Comarow, 1979).

The scenarios are developed for sources that are proposed to be constructed by 1990-1995, because information from various energy projections is available only to this future time period.

Scenario O

There may be no appreciable change in SO_2 emissions (EPA, 1979; Mitre Corp., 1979) because the increase in power plant emissions may be offset by the decrease in smelter emissions. If we assume natural SO_2 emissions also do not change, then we are led to a projection of no change in sulfate fine particulate. If we also assume that sulfate dominates fine particulate, then we project no change in ambient fine particulate concentration, hence no change in the attenuation coefficient of fine particulate. There would be no change in apparent contrast of any target in the test region. This 'no change' scenario provides no basis for asking people about the economic value of a regional change in visibility related to energy development.

Scenario 1

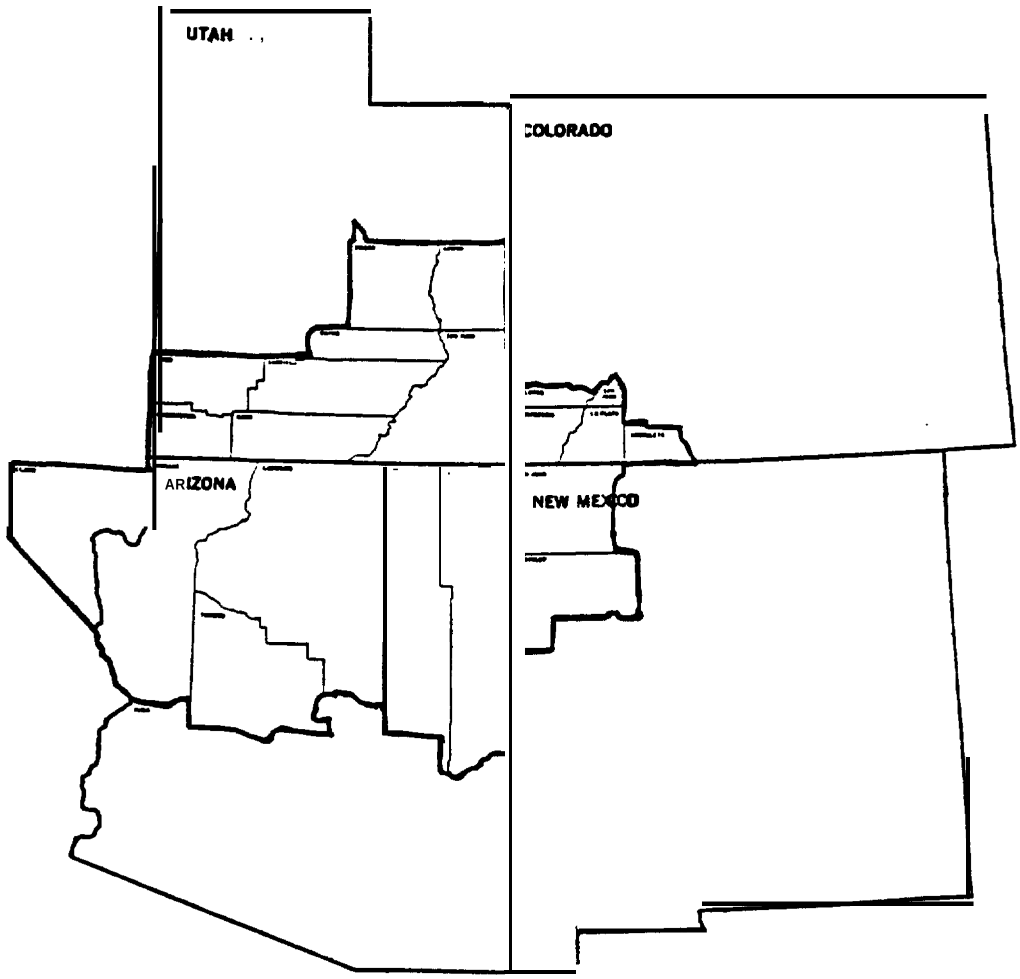
In order to develop a scenario based on a definite change in em'issions, the the smelter emissions contributing to the test region are assumed to remain constant.

In the test region the current major sources of SO_2 are listed in Table 4. All these sources are coal-fired power plants.

The size is given as a range where various sources of information differ.

Figure 4

Test Region



State	County
Arizona	Apache
	Coconino
	Mohave
	Navajo
	Yovapai
Colorado	Archuleta
	Dolores
	La Plata
	Montezuma
	San Juan
New Mexico	San Juan
	Rio Arriba
	McKinley
Utah	San Juan
	Kane
	Washington
	I ron
	Garfield
	Wayne
	Emery
	Grand

Table 4

Current Major SO_2 Emissions In Test Region

Name	Location	Unit	Power (mw)	Control (%)	Sulfur Dioxide Level lb SO_2 / 10^6BTU	Emissions Rate (tons per day) Controlled	Uncontrolled
Cholla	Joseph City, AZ	1	110-115	>90[1]		7[2]-13[3]	22-40
		2	250-270	>90[1]		7-13	22-40
Four Corners[3]	Kirtland, NM	1	190	65		8.5-20.5	35
		2	190	65		8.5-20.5	35
		3	245	0		10-24	40
		4	778	0		90-160	160
		5	778	0		90-160	160
Hunter (Emery)	Castle Dale, UT	1	400(N)-430(G)	80		7	26
		2	400(N)-430(G)	80		35	26
Huntington[2]	Huntington, UT	1	400	80		21.5	26
		2	415	80		21.5	26
Mohave	Bullhead City, AZ	1	820	0		40,46[3],50[2],64	40-64
		2	820	0		40,46, 50,64	40-64
Navajo	Page, AZ	1	770	0	.5216	46.7[3],55.7[4],81.3	46.7-81.3
		2	770	0	.5216	46.73,55.74,81.3	46.7-81.3
		3	770	0	.5216	46.73,55.7,81.3	46.7-81.3
Coronado	St. Johns, AZ	1	350(N)-395(G)	66*	.816	38	113
Reid Gardner[5]	Moapa, NV	1	110-130	80		16.7	83.3
		2	110-130	80		16.7	83.3
		3	110-130	80		16.7	83.3
San Juan[3]	Fruitland, NM	1	360	67	.55	22	67
		2	350	67.5	.53	21	65
		3	500	67	.55	35	106
TOTALS		23 units				692-1074	1398-1587

N = net rating = gross rating minus on site consumption of power

G = gross rating

* = .8 of total flow is controlled to 82 percent level

Sources:
(1) Roberts, Edwin, 1980, phone communication to Arizona Public Service Company, June 30; (2) Christian, John, 1980, personal communication to National Park Service, Air Quality Office, June 2; (3) Copeland, John O., 1979, EPA memo to Steve Eigsti, July 17; (4) Noon, Don, 1980, phone communication to Salt River Project, July 9; and (5) Syzedek, Laura, 1980, personal communication to Nevada Power Company, June 19.

The two sizes are sometimes the net and gross ratings, respectively. Some refer to maximum possible electrical output while others refer to the normal output. These differences are small enough to neglect for the purpose of this study. Each generating unit is listed separately because we must account for the great variation of size, control equipment and SO_2 emissions that sometimes exists between units of the same power plant.

The controlled emission rate of SO_2 is reasonably well known for these sources. A list of units proposed to operate by 1990 is presented in Table 5. The projected SO_2 emissions for these units are not so readily available. Each utility company was requested to provide emissions by phone or letter if there existed no report with the information.

Using the relations for $\frac{d\alpha_{fp}}{dE_{SO_2}}$ and $\frac{d\chi_{fp}}{dE_{SO_2}}$, the increase in controlled SO_2 emissions will cause the concentration of fine particulate to increase by

$$\Delta\chi_{fp} = 0.19\text{-}0.20\ \mu gm^{-3}$$

This change is small, but must be translated into the change in apparent contrast of specific targets in order to judge perceptibility. Perceptible changes are required in order to ask people questions about their economic willingness to pay to prevent such changes. Selected locations and targets are listed in Table 6 along with the information used to compute contrast change. Equation 4 is used in the form

$$C_r = C_o e^{-(k\chi_{fp}+\bar{\alpha}_R)r} .$$

The change in the apparent green contrast between columns 7 and 8 of Table 6 cannot be perceived (Maim, et al., 1980a). This finding suggests that the addition of 392-410 tons of SO_2 per day to this region would be insignificant to visibility. For comparison, the 1979 SO_2 emissions from copper smelters in southern Arizona were 2400 tons per day, almost 5 times as much (Billings, 1980). Another approach is to compute an artificially larger scenario that causes a perceptible change in contrast which could be used in a questionnaire.

<u>Scenario 2</u>

The current and proposed power plants for the test region will be supposed to emit SO_2 at the maximum possible uncontrolled rate. Direct particulate emissions will continue to be controlled. The uncontrolled SO_2 emissions are listed in Tables 4 and 5. The increased emissions would be 3692-4327 tons per day. These uncontrolled SO_2 emissions would cause $\Delta\chi_{fp} = 1.48\text{-}1.73 \mu gm^{-3}$ over the summer 1979 fine particulate concentrations listed in Table 6. The changes in apparent contrast shown in column 9 of Table 5 vary between .05 and .09, and are perceptible changes (Maim, et al., 1980a).

The actual photographs used in the summer 1980 perception/economic survey are listed in Table 3 with information on the target name, time of day, inherent

Table 5

Major SO_2 Sources Proposed for Test Region by 1990

Name	Unit	Power (MW)	Sulfur Dioxide Control Level %	Sulfur Dioxide Control Level (pounds SO_2 per 10^6 BTU)	SO_2 Emission Rate (tons per day) Controlled	SO_2 Emission Rate (tons per day) Uncontrolled
Harry Allen[1]	1 2 3 4	500 500 500 500	92 92 92 92	.17 .17 .17 .17	10 10 ID 10	129 129 129 129
Green River	·	1000	90	.2	25	250
Werner Valley[1]	1 2	250 250	92 92	.17 .17	5 5	65 65
Garfield	1	400	90	.2	10	100
Inter-Mountain	1 2 3 4	750 (N) -820 (G) 750 (N) -820 (G) 750 (N) -820 (G) 750 (N) -820 (G)	90 90 90 90	.2 .2 .2 .2	18-20 18-20 18-20 18-20	184-200 184-200 184-200 184-200
Hunter	3 4	400-430 400-430	90 90	.2 .2	10 10	100-106 100-106
Colorado	1	250	90	.2	6	61
Cholla	3 4 5	242-289 350-375 350-375	90 90 90	.06-.07 .07 .07	2 3[2] 3[2]	20 30 30
Coronado	2 3	350-395 350-395	66[a] 66	.8[3]-9 .8[3]-9	38[2,3]-43 38[2,3]-43	113-127 113-127
Springerville	1 2 3	350 350 350	60 60 84	.6 .6 .25	25[2,4] 25[2,4] 10[2,4]	62.5 62.5 61
Moon Lake		800	90	.2	20	200
San Juan	4	500	67	.55	35	106
Plains Electric	1	210	90	.2	5	50
New Mexico G.S.	1 2 3 4	500 500 500 500	80 80 80 80	.34 .34 .34 .34	21 21 21 21	105 105 105 105
Reid Gardner	4	250-295	85	.14-.16	10	67
Totals	33 units	12,704-13,480			481-499	3328-3432

[a]Only 80 percent of total flow is directed through wet scrubbers with 82 percent control

N = net

G = gross

Sources:
(1) Syzedek, Laura, 1980, personal communication to Nevada power Company, June 19; (2) Energy Impact Associates, 1979, Update Report; (3) Noon, Oon, 1980. phone communication to Salt Rive Project, July 9; and (4) Fleck, Lowell, 1980, phone communication to Tucson Electric Power Company, July II.

Table 6

Apparent Green Contrast Change to be Caused in Test Region by Proposed Sources of SO_2

			Median Fine Particulate Concentration (μgm^{-3})			Median Apparent Green Contrast		
				1990-1995			1990-1995	
Location	Target	Time of Day	Summer 1979	Scenario 1	Scenario 2	Summer 1979	Scenario 1	Scenario 2
Grand Canyon	Trumbull Mountain	9 a.m.	1.92	2.12	3.40-3.65	-.12	-.11	-.06,-.05
"	"	3 p.m.	1.37	1.57	2.85-3.10	-.17	-.15	-.08,-.07
"	Desert View	9 a.m.	2.60	2.80	4.08-4.33	-.45	-.44	-.36,-.35
Mesa Verde	Lukachukai #1	9 a.m.	1.86	2.06	3.34-3.59	-.10	-.09	-.05,-.04
Zion	Trumbull Mountain	9 a.m.	1.82	2.02	3.30-3.55	-.12	-.11	-.06,-.05

contrast, Rayleigh attenuation coefficient, distance between the observer and the target, archive number, apparent contrast measured with a teleradiometer on the slide image projected on a screen, and the associated fine particulate concentration.

The regional analysis of the change in visibility from the current (summer 1979) median to the 1990 uncontrolled SO_2 emissions used the slides listed in Table 7, whose specifications are listed in Table 3.

D. Conclusions

The photographs collected in a regular photographic monitoring program over a period of at least half a year are numerous and varied enough to provide sets for surveying purposes. The photographs can be presented as slide images on a screen (Maim, et al., 1980a) or as prints. The frequency of occurrence of each photograph can be computed roughly from the photograph collection (Walther and Carey, 1980) or from the set of teleradiometer measurements of the apparent green contrast of a target in the scene. The apparent green contrast of the target in each photograph differs from the adjacent photographs in its subset by .02 to .12. These differences are perceptible, but they are not uniform because the photographic monitoring period was not long enough to produce every desired apparent contrast with the constraints of blue sky and no snow on the target. Photographs with these constraints and with perceptibly different contrasts allowed people to be questioned about the economic value of different visual air quality.

The locations of the EPA/NPS regional visibility monitoring program cameras and teleradiometers constrained the region that could be chosen for the scenarios of future changes that may affect visibility. The test region represents an area where good visibility is probably necessary for the high social value people place on the region's many national parks and monuments. Coal-fired power plants are the most numerous future sources of air pollution proposed for this test region and they have been the most controversial air pollution sources in the past history of this region. Because fine particulate is the single most important kind of pollutant affecting visibility in this region (Waggoner, et al., 1981) and because SO_2 emissions are the most important contribution to fine particulate, (White and Roberts, 1977) visibility will here be directly related to SO_2 emissions. This relationship was developed by others on the basis of airport visibility observations and the SO_2 emission inventory history of the southwest (Marians and Trijonis, 1979). As such it is a rough model, but it is consistent with the roughness of the economic information obtained by asking people how much they would be willing to pay on their monthly power bills to protect visibility.

One scenario of the future suggests no deterioration of visibility because smelter SO_2 emissions near the test region may decrease more than the SO_2 emissions may Increase from proposed coal-fired power plants. This scenario provides no basis for the survey process. A second scenario based on the actual SO_2 emissions expected from the proposed power plants suggests there will be no perceptible deterioration of visibility, again providing no basis for a survey. The third scenario is hypothetical, based on the totally uncontrolled

Table 7

Slides in Regional Scenario of Uncontrolled SO_2 Emissions

Location	Target	Slides: Current Median	Slides: 1990 Scenario Uncontrolled SO_2
Zion	Trumbull Mt.	Z190	z16
Mesa Verde	Lukachukai 1	MV133	MV48
Grand Canyon	Desert View	GC94	GC501

release of all SO_2 that can be created from the sulfur in the coal for both existing and proposed power plants. The r,egression-based relationship of visibility and SO_2 emissions is combined with this hypothetical scenario to compute a perceptible deterioration of visibility from the middle photograph of each vista to the next worse photograph. This change allows comparison of the value of the visibility increment to the cost of air pollution equipment needed to reduce the uncontrolled emissions to the actually projected level of control.

All three scenarios of future SO_2 emissions in the test region should be recomputed with the use of a long range transport model, allowing for: 1) the transport of distant emissions into the region; 2) the chemistry of SO_2 conversion to sulfate fine particulate; 3) the removal by dry and wet deposition of pollutants affecting visibility; and 4) the inclusion of smelter and urban emissions.

CHAPTER 4

PERCEPTION OF VISIBILITY

A. Introduction

Valuing visibility in economic terms requires a clear understanding of how people perceive visual air quality. This chapter summarizes our current understanding of perception of visibility and presents some new results of a study utilizing photographs similar to the ones used in the economics portion of the study.

Visibility is commonly interpreted as visual range, which roughly speaking, is the distance an observer would have to back away from a target for it to disappear. Visual range cannot be measured directly, nor is it necessarily representative of what an observer "sees." More importantly, visibility involves human perception of color, form and texture of near and distant natural structures.

0. Summary of Perception Studies

Characterization of visibility involves a selection of physical variables that can be directly measured and correlated with human perception of changes in visual air quality. Previous field experiments have examined the relationships between physical parameters of visibility such as apparent target contrast, color contrast, sun angle, and human perception of changes in those parameters (see Maim, et al., 1980a,1980b). These studies also addressed human perception of changes in air quality as presented in different media, comparing observer judgments of color slides, color photographs, and the actual scene as viewed on-site.

The original study which examined these variables was conducted by the National Park Service (NPS) and Environmental Protection Agency (EPA) at Canyonlands National Park during the summer of 1979. Visitors to the Island in the Sky District of the park were asked to rate color slides representing variations in air quality, sun angle, meteorological conditions, ground cover, and landscape elements. It was assumed, a priori, that such variables would be important factors affecting human perception of visual air quality. Thus, these factors were specifically controlled so that the effect of changes in air pollution on perceived visual air quality could be explicitly studied. This approach may be contrasted to that of randomly sampling the joint occurrences of all of these variables and then, a posteriori, attempting to separate their effects by means of statistical regression procedures (Latimer, et al., 1980). Both approaches can make valid and valuable contributions to the understanding of visibility perception. Where a purely statistical approach may have problems in explicitly extracting the targeted relationships between per ception of air quality and electro-optical parameters, it may achieve greater generalization in predicting the effects of illumination and meteorological conditions.

The study slides, all of the same scene, were chosen from over 1000 slides taken throughout the previous year as a part of the NPS/EPA visibility monitoring program. At the time each slide was taken, teleradiometer readings of apparent target contrast, color contrast, and various meteorological measurements were made. Therefore, for each slide rated by visitors, the physical and optical parameters of air quality were known. After viewing 10 preview slides representing the full range of air quality conditions, visitors rated 48 evaluation slides on a 1 to 10 scale, with 1 representing very poor visual air quality and 10 representing very good visual air quality. Interspersed with the 48 evaluation slides were 15 control slides used to determine the precision with which each visitor used the rating scale. After rating the slides, visitors completed a demographic questionnaire and were administered a test for color-blindness. Finally, they entered a second room of the survey trailer where they could view the La Sal Mountains through a window, framed much like the slides. The visitors were then asked to rate the visual air quality on that day as viewed through the window on the same 1 to 10 scale used for rating the slides. A color slide and teleradiometer reading were taken to correspond with each on-site rating. Later in the survey period, these slides were shown to visitors, who again rated visual air quality on the 1 to 10 rating scale. Nearly 700 visitors completed the survey.

Studies similar to the Canyonlands study were conducted at Mesa Verde and Grand Canyon National Parks during the summer of 1980. The differences include:

- Where the Canyonlands study used only one scene, the 1980 studies utilized several vistas located in different national parks;

  where the first study allowed visitors to rate a three dimensional scene constrained by a window to mimic the identical scene as viewed in the slides, the 1980 studies allowed the visitor to rate physically unrestricted views of a vista in the same general direction as the slides were taken. These on-site ratings were then compared to ratings (by other observers) of color slides;

- where the Canyonlands study reported results for all visitors combined as a group, the later studies specifically investigated the effects of a number of social and demographic characteristics on judgments of perceived visual air quality;

  where the 1979 study focused primarily on a determination of a humanly perceptible amount of change in visual air quality, the 1980 studies also examined social and economic issues associated with changes in visual air quality;

and, where the first study compared only visitors' judgments of changes in air quality shown in color slides and the actual scene, the 1980 studies compared visitors' judgments of air quality represented in color slides, the actual scenes, and color prints.

C. Study Results

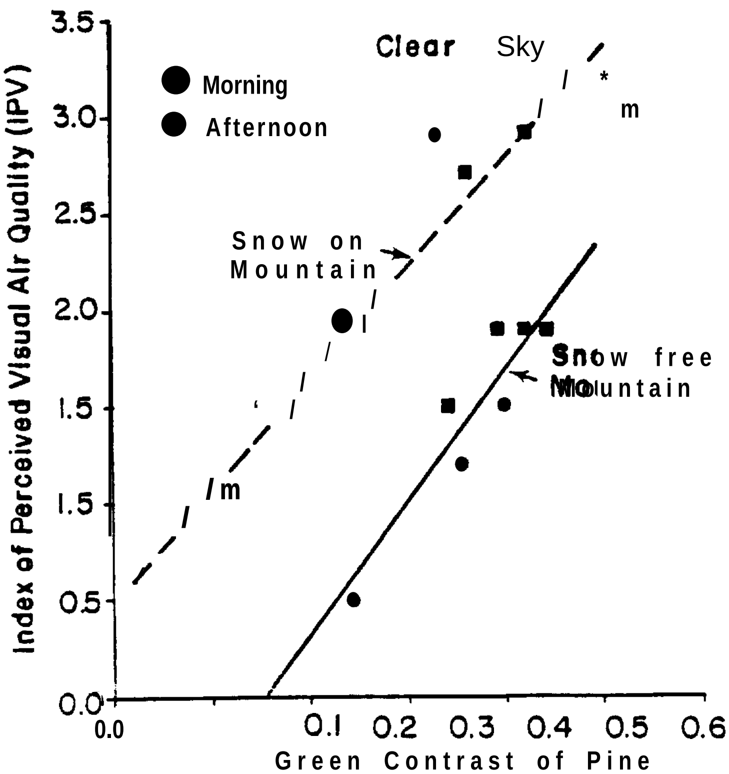
Visitors used the 1 to 10 rating scale with precision, as is evidenced by their ratings of the 15 control slides used in the Canyonlands study. The control slide mean rating (CSMR) for 50, 100, or 300 observers varied by less than .01 and the mean of their standard deviations varied by less than 0.4. Similar analysis of the evaluation slides shows almost identical results. Generally speaking, slides with extremely good or extremely poor visual air quality were universally rated the same by all observers. Slides which represented intermediate levels of visual air quality were more difficult to rate; control slide ratings indicated that some observers tended to be extremely precise and consistent in their ratings while others had more difficulty in using the rating scale. It is important to note, however, that the average rating given each slide by a series of observers did not change when those observers with a control slide standard deviation (CSSD) of greater than 1.0 were eliminated from the data set, nor did the introduction of more observers, beyond approximately 50, change the average rating given each slide.

There was, however, an ordering effect when a slide representing average visual air quality was preceded by a slide representing extremely good or poor visual air quality. This effect was minimized by reversing the order of the slides half-way through the study period. Thus, a slide that initially followed an extremely good or poor slide, would be evaluated first, normalizing the overall slide ratings.

There seemed to be little or no difference in the way observers with different demographic backgrounds used the rating scale. However, a Z-score analysis was carried out to minimize the effect of variations between individual observers. This Z-score analysis then allowed for calculation of Indexes of Perceived Visual Air Quality (IPV's).

Figure 5 is a plot of mean IPV's versus apparent target contrast, C_G, at 550nm (as measured by a multiwavelength teleradiometer) for clear sky days (99 percent confidence limits around the mean is $\pm$ 0.11). The broken and solid lines correspond to snow and tree covered scenes, respectively. It is evident that the functional relationship between Perceived Visual Air Quality (IPV) and contrast (C_G) is linear. The correlation coefficients, significant at the 99 percent confidence level, between IPV and C_G for the six meteorological and air quality conditions measured are presented in Table 8.

Figure 5



Graph of the index to Perceived Visual Air Quality (IPV) as a function of apparent target (tree covered portion of the La Sal Mountains) contrast for the clearsky condition. The dotted and solid line are for snow covered and snow free conditions, respectively while (●) AND (■) indicate slides that were taken in the morning and afternoon, respectively.

Table 8. Correlation Coefficients between IPV and C_G

	Clear Sky	Cumulus Clouds	Overcast Sky"
Snow covered mountain	0.93	0.93	0.94
Green mountain	0.90	0.98	0.93

This functional relationship can be expressed as follows:

$$IPV = mC_G + b$$

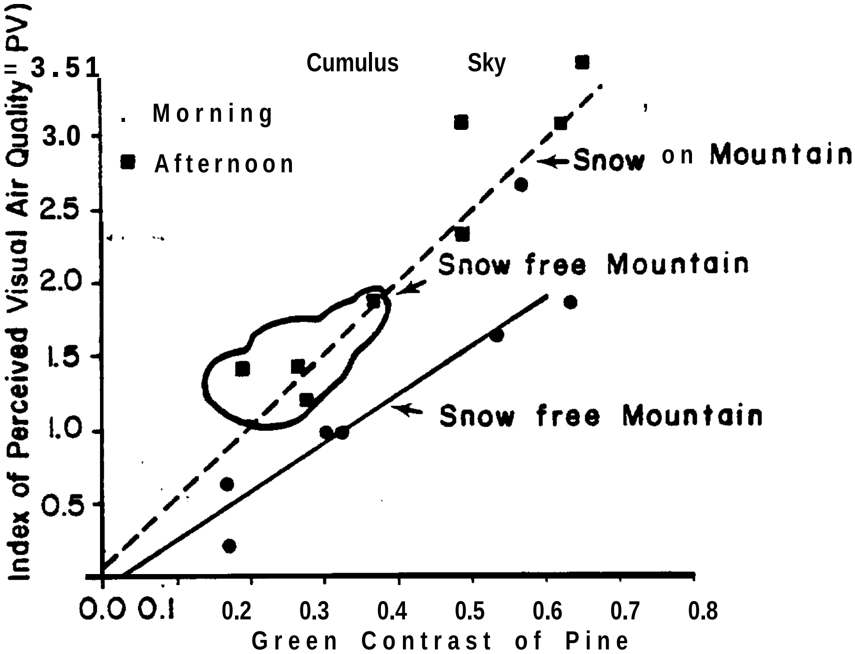
where IPV is the Index of Perceived Visual Air Quality, C_G is apparent target contrast (tree covered mountain in this case), b is the y-intercept, and m is an index indicating the sensitivity of a given vista to changes in air pollution. The sensitivity of a vista to the impact of air pollution, then, is the slope of the IPV vs. C_G curve; the steeper the slope, the more sensitive a vista is to incremental changes in air pollution. Upon comparison of the slopes of the curves shown in Figures 5, 6 and 7, it is clear that cumulus clouds and overcast cloud conditions cause m to decrease; with m being the lowest for the cumulus cloud condition. Clouds tend to obscure the effects which increased air pollution has on perceived visual air quality.

Perceived visual air quality of a vista under clear sky conditions seems to be most sensitive to changes in amounts of air pollution. In addition, snow in a vista appears to increase the observer's rating of visual air quality for all sky conditions. It should be noted that even though an observer's rating of visual air quality increases with a snow covered mountain (indicating greater scenic quality), the sensitivity of that vista to contrast change, and thus air pollution, remains approximately the same for different meteorological conditions.

It is important to understand that changes in apparent target contrast due to increased air pollution are dependent on the amount of pollutants in the existing atmosphere. In a clean atmosphere, a small increase in particulate concentration will cause a large decrease in contrast, while in a relatively dirty atmosphere that same increase in particulate concentration may not be perceptible. Figure 8 graphically shows the expected change in contrast resulting from additions of 2 micrograms per cubic meter ($\mu g/m^3$) fine particulate (0.1 µ - 1.0 µ diameter particles) to atmospheres containing approximately 0, 4, 8 and 18 $\mu g/m^3$ fine particulate as a function of vista distance. It has been assumed that an attenuation coefficient of 0.01 km^{-1} is equivalent to a fine particulate concentration of 2 $\mu g/m^3$. It is clear in all cases that the cleaner the existing atmosphere, the more sensitive it is to an incremental increase in particulate loading.

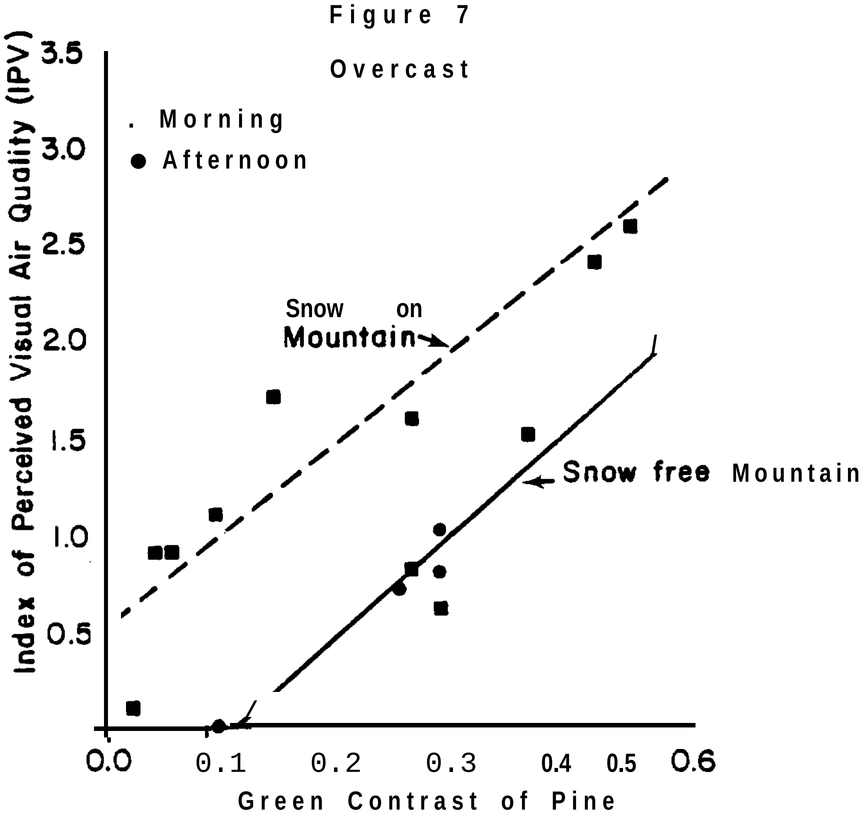
Also, as shown in Figure 8, the maximum sensitivity to incremental increases in air pollution occurs at a vista distance of about 60-100 kilometers in a clean atmosphere. In an atmosphere containing 18 $\mu g/m^3$ particulate this distance of maximum sensitivity decreases to 10 kilometers.

Figure 6



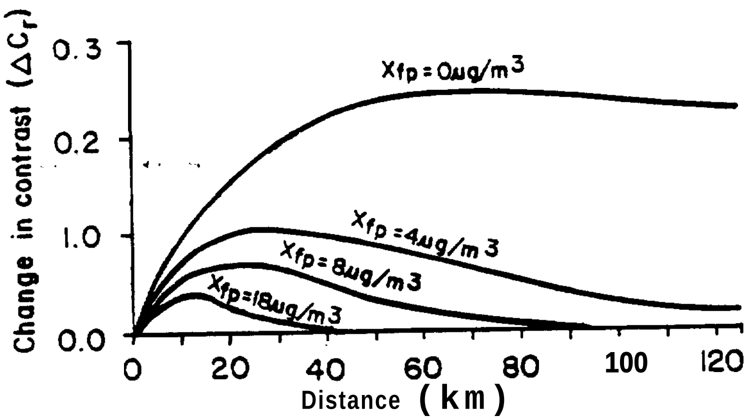
Same as Figure 5 but for cumulus cloud conditions.

Figure 7



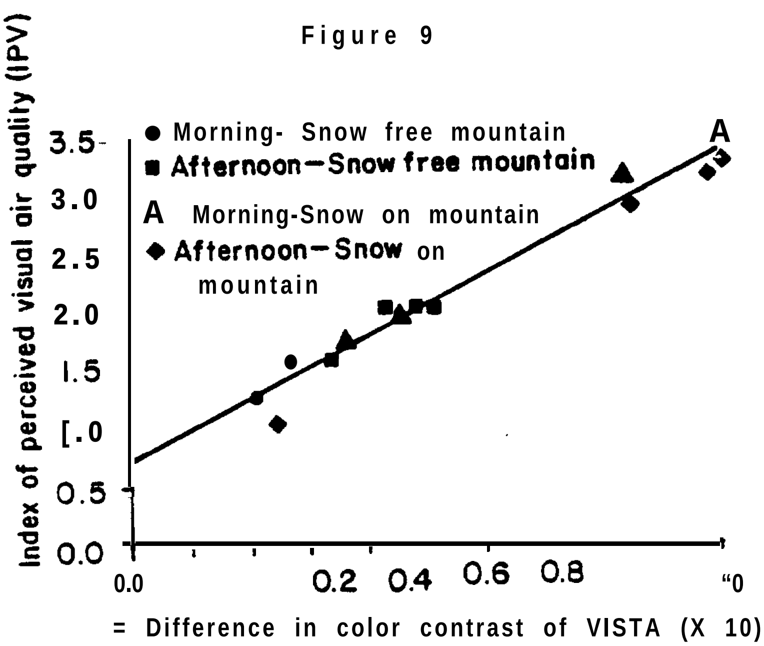
Same as Figure 5 but for overcast cloud conditions.

Figure 8



A plot of contrast change resulting from an increase in fine particulate concentration of 2 ug/m3 as a function of vista distance for initial loadings of 0.0, 4, 8 and 18 ug/m3.

Figure 9



Graph of I PV versus change in overall vista color. Indices of perceived visual qir quality presented in this graph, were derived from visitor's ratings of the morning and afternoon, snow, and no snow, clear sky conditions.

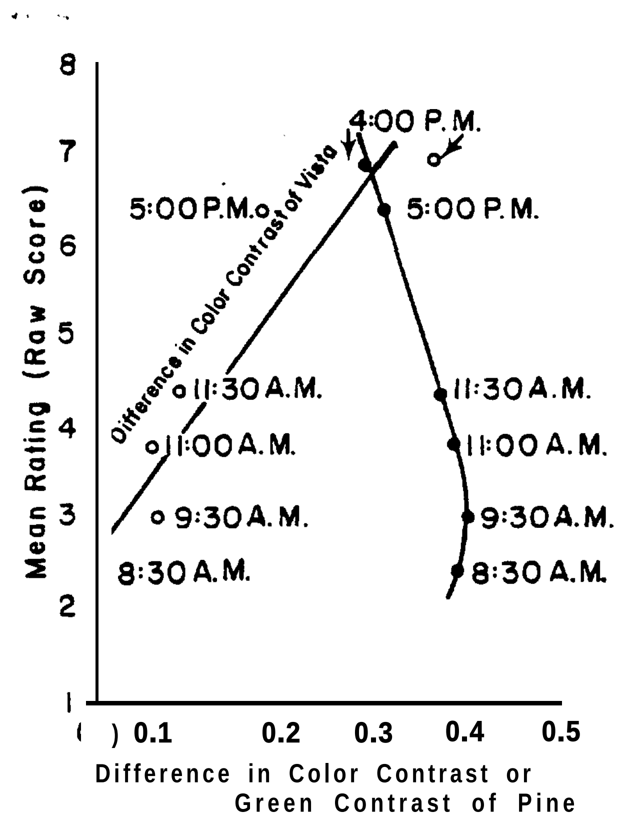
Results of the Canyonlands study also indicate that any increase in color of the total vista results in increases in the IPV. The change in overall color contrast, ΔC_T, for each slide was plotted against the IPV, indicating the linear relationship shown in Figure 9. The observer rated the visual air quality of a scene in direct proportion to the amount of color present.

Sun angle plays an important role in vista color and observer's judgments of visual air quality. Visitors were asked to rate a series of slides of the La Sal Mountains which were taken starting at 8:00 a.m. and continuing until 4:00 p.m. The air pollution as measured by a teleradiometer and an integrating nephelometer remained unchanged throughout the day. The canyon walls in the mid-foreground of the scene were in complete shadow at 8:00 a.m. The color of the canyon walls continually increased as the day progressed and the sun angle changed. As more color appeared in the scene, observers gave it a higher rating of visual air quality. Figure 10 shows this relationship, plotting the mean slide rating (raw score) for 50 observers as a function of color contrast for the green portion of the La Sal Mountains. Time of day is indicated next to each data point. During the course of the day, the contrast at 550nm actually decreased because of a decrease in inherent contrast, while the mean rating of the slides increased. However, the relationship between change in color contrast and perceived visual air quality remains linear. The correlation coefficient between these two variables is greater than 0.9, significant at the 99 percent confidence level. This relationship also appears to be independent of the demographic characteristics of the observers.

Once these physical and perceptual relationships are established, it is important to analyze the relationships between human perception of changes in visual air qual ity as represented in different media. Do observers perceive changes in visual air quality in an actual on-site situation with the same precision as they would perceive the same amount of change as shown on a color slide? In order to examine this question, visitors in the Canyonlands study rated 40 slides that had been taken during on-site ratings earlier in the study period. The optical and meteorological data for the approximately 400 on-site ratings were inspected to locate cases representing sun angle, meteorological and air pollution conditions as near as possible to those in each of the 40 slides. For some slides, several corresponding on-site ratings were found. A student t-test was used to determine whether the slide ratings were statistically different from on-site ratings. Since the test was applied to the null hypothesis that the two samples being compared were drawn from the same population, calculations were made to determine the probability of the difference between means of on-site and slide ratings having a value as large as, or greater than observed. The null hypothesis being examined assumed that the two samples belong to the same population, consequently, the two variance estimates must not be significantly different. This hypothesis was examined by means of the F-test.

Results of the comparisons are summarized in Table 9 while a scattergram of the on-site and slide ratings is shown in Figure 11. The first column of Table 9 gives the time that the slide was taken; it is also the time, ± 30 minutes, that the on-site ratings were made. Column two is a meteorological code indicating the cloud cover present at the time the photograph was taken;

Figure 10



Mean rating (raw scene) of a series of six slides that were taken of the La Sal Mountains, starting at 8:00 A.M. and continuing until 5 P. M., as a function of color contrast change of the vista (o) or apparent target green contrast of pine covered portion of the vista (●).

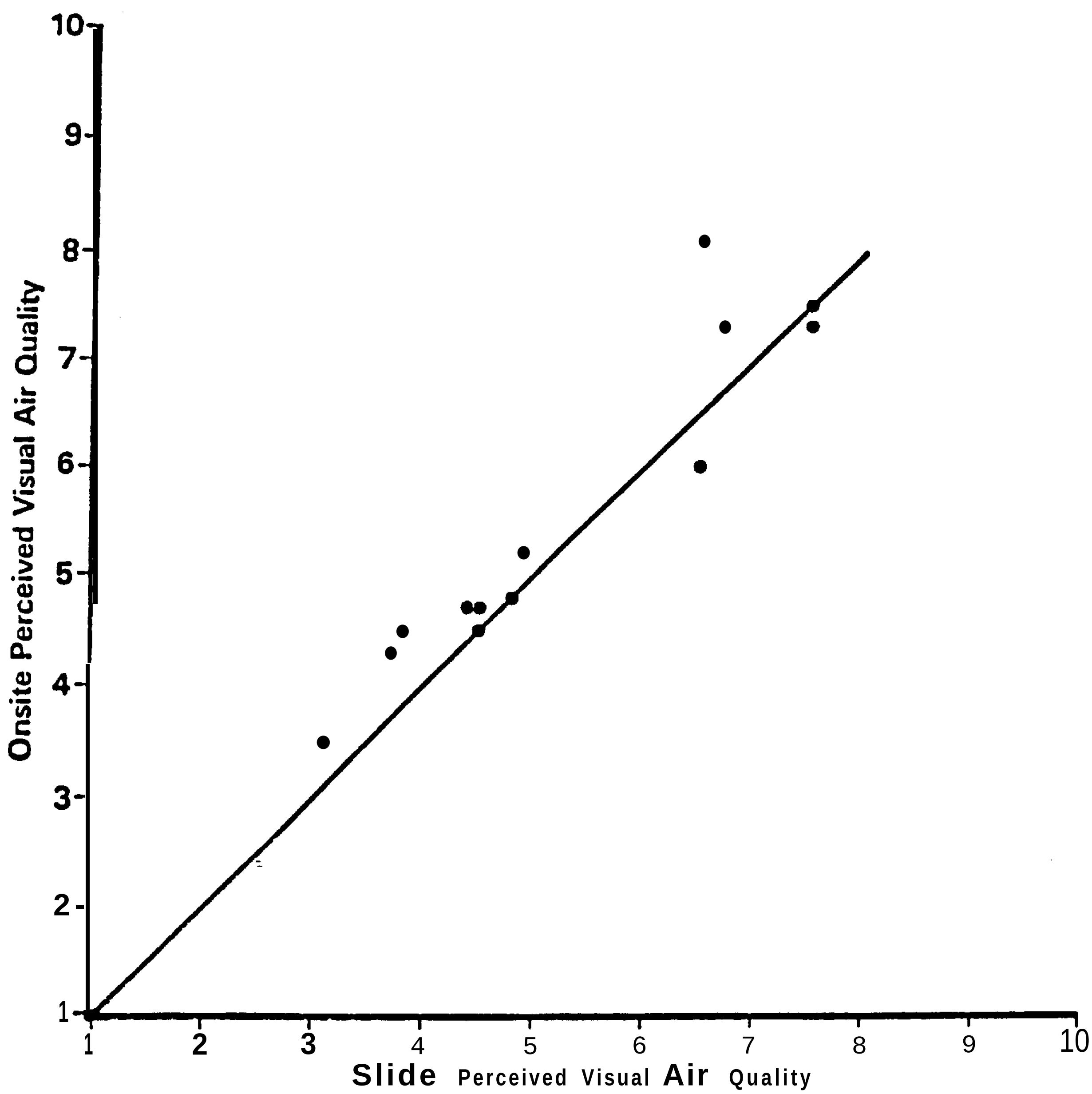
Table 9

Statistical Analysis of On Site and Slide Ratings

Time	Sky Code	Green Cont.	Slides				On Site				Tests			
			Nobs	Mean	SD	95%-CL	Nobs	Mean	SD	95%-CL	T	T(Crit)	F	F(Crit)
1000	2	.34	22	3.1	1.6	.66	8	3.5	1.9	1.36	.574	2.05	1.451	2.4
1030	1	.40	208	4.5	1.7	.24	13	4.5	1.5	.84	.080	1.96	1.274	2.1
1100	0	.38	45	3.8	1.2	.37	10	4.5	1.4	.86	1.631	2.00	1.273	2.8
1100	2	.33	22	4.5	1.7	.71	17	4.7	1.9	.94	.354	2.00	1.287	3.0
1130	1	.36	45	4.4	1.2	.37	21	4.7	1.4	.60	.944	1.96	1.329	2.4
1130	2	.34	22	4.9	1.4	.59	18	5.2	1.8	.86	.523	2.00	1.696	2.8
1130	5	.34	22	4.8	1.3	.57	9	4.8	1.6	1.04	“.041	2.05	1.446	3.35
1130	4	.19	22	3.7	1.1	.48	9	4.3	1.1	.75	1.449	2.05	1.033	3.35
1330	2	.30	208	6.5	1.8	.25	15	6.0	2.1	1.07	1.029	1.96	1.323	2.04
1330	2	.33	208	7.5	1.8	.25	23	7.5	1.1	.45	.057	1.96	2.769	1.79
1400	0	.36	45	6.5	1.4	.42	13	8.1	1.0	.53	3.802	2.00	2.153	2.66
1400	0	.35	160	7.5	1.6	.26	8	7.3	-9	.63	.438	}.96	3.258	2.51
1400	0	.35	160	6.7	1.7	.27	8	7.3	.9	.63	.907	1.96	3.678	2.51

Figure 11

Average perceived visual air quality ratings of 13 different three-dimensional scenes are plotted against corresponding ratings of slides that represented those same scenes.



0 = cloudless skies; 1 = no clouds in the plane of the observer, sun, and vista; 2 = O to 1/3 cloud cover; 3 = 1/3 to 2/3 cloud cover; 4 = 2/3 to full cloud cover; and 5 = overcast. Column three is the apparent target contrast at 550nm of a forested section of the La Sal Mountains on the day when the slide was taken; it is also the apparent target contrast +0.01 of that same portion of the vista on the days that the three dimensional-on-site ratings were made. Columns four to seven are the number of observations, arithmetic mean, standard deviation, and 95 percent confidence interval of the slide ratings, and columns eight to eleven give the same statistics for the on-site ratings. Columns twelve and fourteen are the t and F statistic while columns thirteen and fifteen are the associated "critical" values which the t and F number should not exceed for a 5 to 1 percent level of significance respectively. These calculations were carried out only if there were at least 8 on-site ratings.

An examination of the F-test shows that of 13 populations that were compared, the F value exceeds its critical value 3 times. For the remaining 10 populations the difference between the variances is not significant at the one percent level. If the calculated t value is greater than the tabulated critical value (5 percent level of significance), the null hypothesis is rejected and the conclusion is that the difference between the on-site and slide rating is significant. Or conversely, if the value of t is less than the critical value it is concluded that there is no statistically significant difference between on-site and slide ratings. In only one case is the calculated t value greater than its associated critical value. Thus, there are 9 comparisons of on-site versus slide ratings that show no significant difference between their means.

The previous statistical tests do not prove that the means of on-site and slide ratings are the same, only that they are not statistically different. However, the analysis in conjunction with a fairly high correlation of 0.94 between the on-site and slide ratings and the close proximity of the data points to the line that shows where they would fall if there were a one-to-one correspondence, seems to indicate that when the actual scene is confined to the same form as that of the slides, slides are good substitutes for the actual three dimensional scenes.

For research design purposes, it is also important to know if observers perceive changes in visual air quality as shown in color prints with the same precision as they perceive changes shown on color slides. In the 1980 Grand Canyon study, groups of observers were asked to rate sets of 30 randomly ordered 8 X 10 inch color prints on a 1 to 10 scale. Two sets of photographs were rated; one set contained Mt. Trumbull scenes under differing ground cover, meteorological and air quality conditions, while the other photographic set contained Desert View scenes under varying meteorological and air quality conditions (the Desert View data set did not contain any scenes with snow on the ground). Groups of observers rated the sets of 30 color slides from which the photographs were made. Mean ratings for all slides in each set were then compared to the mean ratings for each color photograph for groups of at least 50 observers. Comparisons were made by regressing the slide-based ratings (mean ratings on the 1 to 10 scale) on the ratings of the corresponding color photographs. Again, the relationship is a positive one, as indicated by a simple correlation coefficient of .96, significant at the 99 percent confidence level, between the slides and corresponding photographs used in the economic analysis.

D. Conclusion

These positive relationships of human perception of changes in visual air quality, whether viewed in a color slide, color print or on-site, allow for different research methods. It appears that it may no longer be necessary to conduct air quality perception research only in on-site situations. This finding enables researchers to conduct air quality perception studies in other environments throughout the country, with substantially' reduced costs, but more importantly, allows for a statistically random sample of observers which is not possible in on-site studies. It is important that researchers continue to examine these relationships in order to develop a valid model for the prediction of air pollution and scenic quality effects on perceptions of visual air quality.

CHAPTER 5

MEASURING THE ECONOMIC VALUE OF VISIBILITY

A. Introduction

Visibility is a pure public good as described by Samuelson (1954). The goal of Congress in passing the prevention of significant deterioration (PSD) amendments to the Clean Air Act was, in great part, provision of visibility in the National Parklands. However, utilities and other industries have claimed, quite correctly, that preservation of visibility (air quality) is costly. Do the benefits of preservation justify these costs? The purpose of this chapter is to provide a methodology for assessing the benefits of preserving visibility so that the question posed above can, in part, be answered.

Economists have used a number of techniques for valuing public goods. These include, first, direct costing wherein, for example, benefits of air pollution control could partly be measured as the reduced economic damage to material (e.g., paint), vegetation (including agriculture) and health (e.g., inure productive workers). A second technique called the hedonic approach uses an indirect method to value public goods by trying to associate changes in market prices with changes in public goods across locations. Thus, urban property value studies are typically utilized in areas of heavier air pollution. One can get an indication of how people value clean air by looking at the premium paid for homes in clean air areas. Both of these methods are described in detail by Freeman (1979) and Mäler (1974) but are not applicable to valuing visibility in rural recreation areas such as the National Parklands of the Southwest.

To develop value in such a situation, economists have turned to survey methods . A large literature has developed around the use of survey techniques in valuing visibility which includes, in part, early work by Randall, et al. (1974) and Brookshire, et al. (1976), and more recently work by Rowe, et al. (1980) and Brookshire, et al. (1980). This literature has been summarized in Schulze, et al. (1981) so we will not go into great detail here. However, it has been shown that-survey techniques do provide willingness to pay measures for air quality in an urban setting (Los Angeles) consistent with results of a hedonic property value analysis, lending support to the survey approach (see Brookshire, et al. [1982]). This last study is included as Appendix B.

Additionally, survey work with consumers has failed to show any evidence of strategic bias (Schulze, et al. [1981]) in valuing public goods. This result is in agreement with the work of Grether and Plott (1979) and Smith (1978) which also failed to find evidence of strategic economic behavior in experimental settings. A number of other biases which have long been recognized in the survey literature have been identified, but standard techniques developed in the political science, psychology and sociology survey literature have been employed to cope with them (see description of the survey procedure in the next section).

B. The Theoretical Basis - The Economics of Preservation

The goal of the PSD regulations is preservation of the natural environment. An integral part of the environment of the national parklands of the southwest is visibility, the ability to see both color and detail clearly over long distances. It has been shown that human perception of visual air quality is associated with the apparent color contrast of distant visual targets. As contrast is reduced, a scene "washes out" both in terms of color and in the ability to see distant detail. Chapter 3 has related decreases in apparent color contrast to air pollution, noting, of course, that only part of the regional air quality situation is attributable to identifiable man-made air pollution. Chapter 4 has quantified perception of visual air quality. We now attempt to specify how people value preservation of perceived visual air quality.

The existing literature in environmental economics suggests that preservation value has two possible components.

First, a scenic resource such as the Grand Canyon attracts large numbers of recreators. The quality of the experience of these recreators depends in great part on air quality, in that scenic vistas are an integral part of the Grand Canyon "experience". Thus, air quality at the Grand Canyon is valuable to recreators. We might call this economic value, or willingness to pay for air quality at the Grand Canyon that enhances the qual ity of the recreation experience, user value. Thus, recreators in the National Parklands of the Southwest should be willing to pay some amount to preserve air quality for each day of their own use if their recreation experience is improved by good air quality. Total annual user value is then, simply, the total number of annual users times the average number of days spent in the parklands by each user per year times the average value to users of preserving visibility per day. One hypothetical market for collecting user value is an increase in entrance fees to be used to finance preservation of air quality, i.e., purchase of air pollution control equipment. Survey questionnaires can be designed to estimate user value based on such a hypothetical market.

The second component of preservation value is termed existence value. Individuals and households which may never visit the Grand Canyon may still value visibility there simply because they wish to preserve a national treasure. Visitors also may wish to know that the Grand Canyon retains relatively pristine air quality even on days when they are not visiting the park. Concern over preserving the Grand Canyon may be just as intense in New York or Chicago as it is in nearby states and communities.

Thus, preservation value has two additive components, user value and existence value. However, it is difficult to construct even a hypothetical market to capture pure existence value. Rather one could imagine a lump sum fee added., for example, to electric power bills to preserve air quality in the Grand Canyon and the surrounding parklands. Such a hypothetical fee could capture total preservation value, the sum of existence plus user value, if used as the basis of a survey questionnaire. In fact, the survey described in the next chapter asked approximately one-third of the respondents a pure user value question (how much would they be willing to pay in higher entrance fees per day for visibility at the Grand Canyon or other parks) and the other two-thirds of the respondents how much would they be willing to pay as a higher monthly power bill to preserve visibility in the parklands, a total preservation value question. Clearly, if total preservation value is much larger than total user value, then existence values must be large.

From an economic-theoretical perspective, consumer preferences can be modeled as follows:

Let C^u = color contrast (visibility) during a visit to the site by a user household;

$\bar{C}$ = average color contrast over the year at the site;

V = number of visits per year by the household to the site;

D = distance of the household from the site;

m = cost per mile of travel;

Y = household income;

X = composite commodity;

q = quality of the visit, a function $q(C^u)$ of visibility during the visit;

R = q " V = quantity of recreation obtained at the site;

E = entrance fee per visit;

B = total lump sum preservation bid for visibility;

U = household utility, a quasi-concave increasing function $U(\bar{C},R,X,)$ of average yearly visibility, $\bar{C}$, recreation at the site, R, and consumption of the composite commodity, X.

In general, a household will wish to maximize utility,

$$U(\bar{C},R,X),$$

subject to the amount of retreat ion attained by visiting the site

$$R = q(C^u)V$$

which we assume is the product of the quality of the visit, a function of visibility during the visit, C^u, and the number of visits, V. Additionally where we take the price of the composite commodity as unity, the availability of the composite commodity is

$$X = Y - B - (E + 2mD)V$$

or income minus any lump sum bid for visibility, B, minus any expenditures for visiting the site which are the sum of entrance fees, E, and travel costs, 2mD, for each visit, V. Note, any costs other than travel costs could conceptually be lumped with E. We take V, X, R, B, and E to be non-negative as well.

To get at user value, we will first take B to be identically equal to zero. The first order condition for use, V, where we substitute the constraints into the utility function is then:

$$U_R q - U_x(E + 2mD) < 0 \quad .$$

Note that, with the terms rearranged, if

$$\frac{U_R}{U_x} < \frac{E + 2mD}{q}$$

then V = O. In other words, if the sum of entrance fees plus travel costs divided by quality (the r.h.s. above) exceeds the marginal rate of substitution between recreation and the composite commodity (the value of recreation which is the l.h.s. above), then visitation is zero for the household. Note then, that, where distance from the site, D, is large, V may well be zero, a corner solution. Thus, someone from New York may never visit the Grand Canyon and consequently have a zero user value as well. To show that user value is zero if visitation is zero let us assume that the entrance fee, E, is a function of visibility, C^u, so we have $E(C^u)$. The consumer can then have a first order condition over choice of C^u by paying $E(C^u)$. This condition is

$$V \cdot (U_R q' - U_x E') = 0.$$

If V > 0, the user will then have

$$\frac{U_R}{U_x} q' = E'.$$

So E' is a measure of marginal user value of visibility per visit. However, if V = O, the first order condition for C^u is satisfied without equality of $U_R q'$ and $U_x E'$, so E' measures nothing, i.e., is of no relevance to the consumer. Thus, logically, a change in entrance fees will measure marginal willingness to pay for visibility in use only for users.

To get at total preservation value, let us fix entrance fees at E" and allow households to make a lump sum bid, B, for visibility at the site where we also assume that $C^u = \bar{C}$. In other words, households assume that the expected visibility level for their visit, C", is the average visibility level, $\bar{C}$. Since we have made the household utility function purely dependent on visibility at the site, the marginal bid for better visibility (derived by holding the utility level constant and totally differentiating the utility function) takes the form

$$\frac{dB}{d\bar{C}} = \underbrace{\left(\frac{U_{\bar{C}}}{U_x}\right)}_{\text{"a"}} + \underbrace{\left(\frac{U_{Rq'}}{U_x}\right) V}_{\text{"b"}}$$

where the term in brackets "a" is the pure marginal existence value and the term in brackets "b" is marginal user value per visit (shown to be E' above for users if an entrance fee is collected for visibility). Thus, the lump sum bid, B, "collects" both existence value and user value from the household. B is then a measure of preservation value. The survey questionnaire presented in the next chapter attempts to estimate both $E(\bar{C}^{U})$ and B(C) as defined above and thus provides measures of user and total preservation value.

The model developed in the paragraphs above focuses on the difference between pure user value and pure existence value. The notion of pure existence value was put forward by Krutilla (1967) as an outgrowth of the notion of option value developed by Weisbrod (1964). In particular, Weisbrod argued that a potential user who might never actually visit a particular national park in his lifetime might well be willing to pay to preserve the <u>option</u> of use over that lifetime. This notion simply adjusts the concept of user value (as developed in the model above) for uncertainty. In other words, a potential user who might never make the trip to the Grand Canyon might be willing to pay a kind of insurance premium to retain the option of future use. The notion of pure existence value is, however, totally different from user or option value, in that, knowledge of the continued existence of a pristine national park in and of itself provides satisfaction. Thus, although option value might accrue to individuals who might never visit the Grand Canyon, that value is still based on potential use. Alternatively, existence value has no basis in actual or potential use, rather only on knowledge of the continued preservation of a unique resource such as the Grand Canyon.

REFERENCES

1. This approach does not account for uncertainty over visibility conditions, but will suffice for our purposes here. A model incorporating uncertainty would replace the user value notion with an option value measure.

CHAPTER 6

SURVEY DESIGN

. . . .

A. Introduction

The survey instrument addressed a multiple set of issues in the problem of valuing visibility in the national parklands. First, the parklands are unique national treasures and part of the national heritage. Thus, the parklands and their characteristics (i.e., visibility) might be valued by all citizens, whether or not they have or ever will visit the area. The survey instrument elicited valuations for actual users--in the national parklands. Second, new and current industrial facilities in the southwest impact not only specific parks but potentially could contribute to a regional deterioration of visibility. The survey instrument as a result of this local versus regional deterioration problem addressed the valuation of visibility in the Grand Canyon as well as in a regional scenic setting which included Mesa Verde and Zion National Parks. Figure 12 depicts a regional map showing the relative location of the three national parks, and their proximity to a partial list of existing and proposed industrial facilities in the southwest.

The following subsection will consider general aspects of the overall questionnaire design. Later subsections will address the actual mechanics of the valuation questions. Appendix C includes the complete survey instrument.

B. Survey Instrument Structure

The survey instrument follows, in general, the design that is set forth by Randall et al. (1974) and Brookshireet al. (1976). A hypothetical market is established around a well defined nonmarketed good for the respondent and a bidding vehicle is utilized. However, rather than a suggested initiation point for the bidding process, a set of columns representing varying amounts are given to the respondent enabling him to check the appropriate bid. This alleviates the potential for starting point bias as described in Brookshire et al. (1976) and empirically observed in Rowe et al. (1980). No specific mechanisms were incorporated into the questionnaire for other bias checks. In general, biases have not been found to be a systematic problem in bidding games. For a summary and analysis of bidding games in general and those exploring bias problems see Schulze et al. (1981).

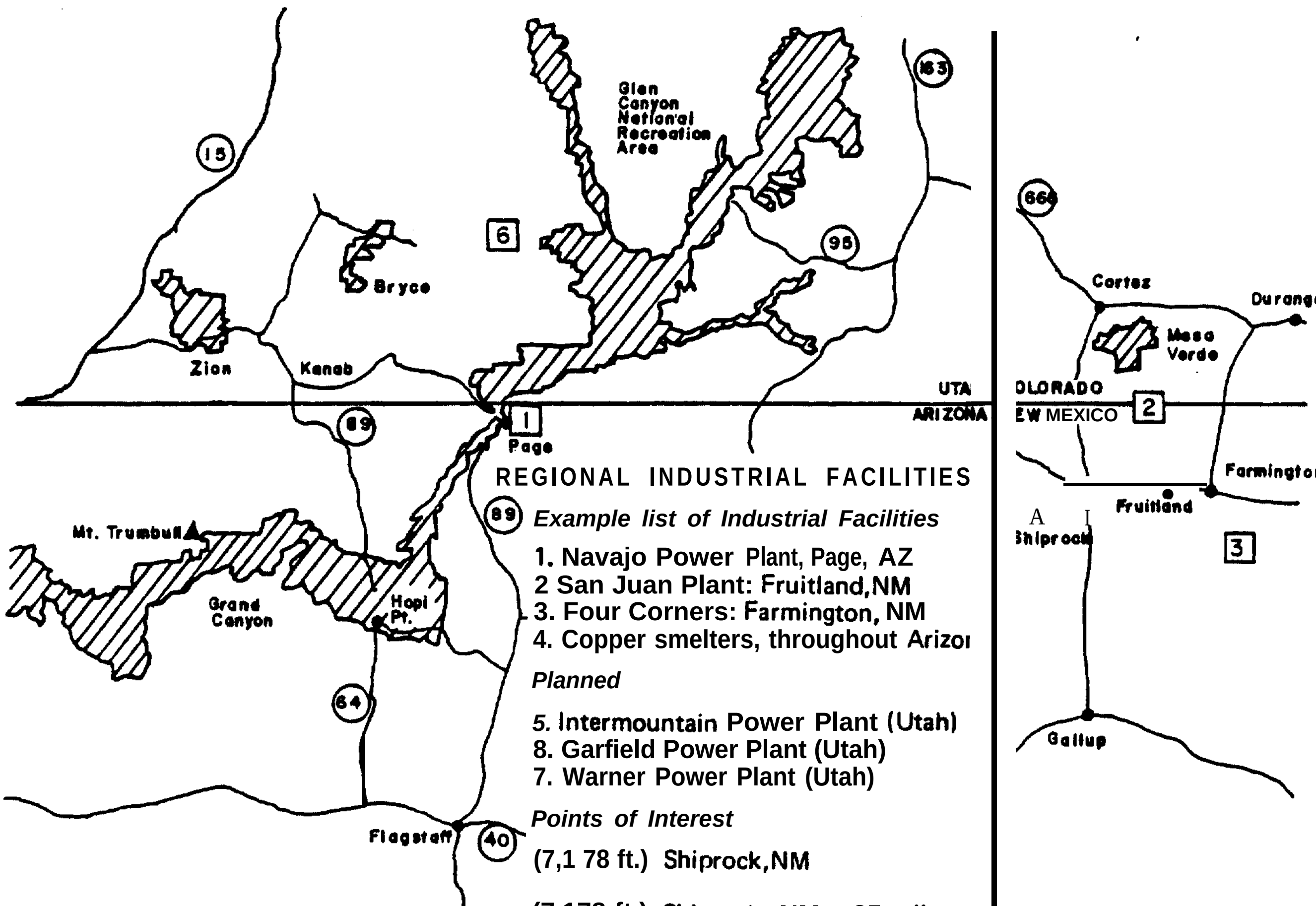
Figure 13 presents the basic flow of information gathered by the survey instrument. A brief introduction explaining the causes of poor visibility and an explanation of the photographs of the Grand Canyon was presented to each household. (See Chapter 2 for a complete discussion of the photographs.) After the introduction, past and proposed future use by the household for the Grand Canyon, Zion, Mesa Verde, Bryce, and Canyonlands National Parks was

5

Figure 12

REGIONAL MAP

7



REGIONAL INDUSTRIAL FACILITIES

Example list of Industrial Facilities

1. Navajo Power Plant, Page, AZ
2 San Juan Plant: Fruitland,NM
3. Four Corners: Farmington, NM
4. Copper smelters, throughout Arizo

Planned

5. Intermountain Power Plant (Utah)
8. Garfield Power Plant (Utah)
7. Warner Power Plant (Utah)

Points of Interest

(7,1 78 ft.) Shiprock,NM

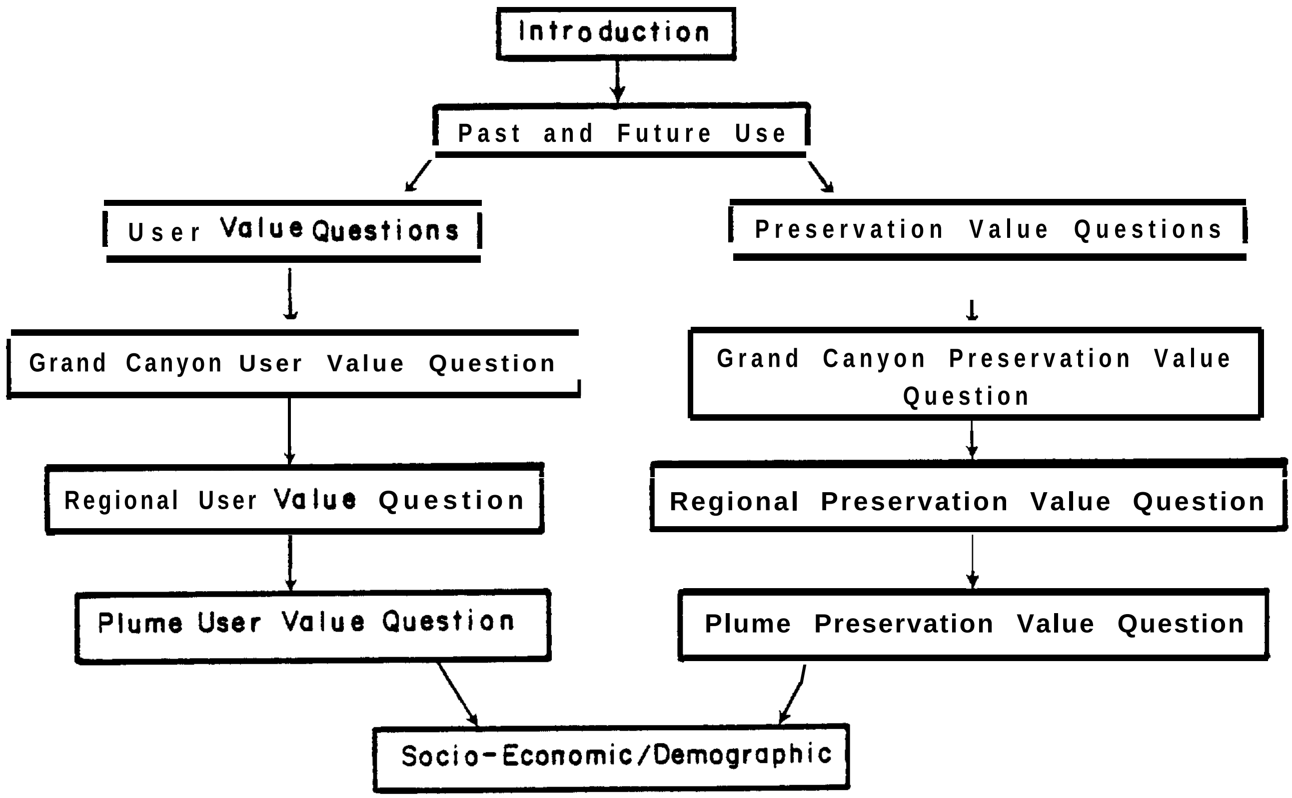
(7,178 ft.) Shiprock, NM - 35 miles from Mesa Verde

(8,029 ft.) Trumbull Mountain, AZ - 50 miles from Zion and 1 mile from Grand Canyon

4

Figure 13

QUESTIONNAIRE STRUCTURE



determined. Households were asked how many days in the last ten years they visited and how many days in the next ten Years they anticipate visiting the above listed National Parks. Two-thirds of the respondents were given the preservation value questions (i.e., user plus existence values), while one-third were given the user value sequence of questions. Every respondent was asked at the conclusion of the valuation questions a set of demographic/economic questions: home zip code, education, age group, sex, size of household, whether the respondent was primary income earner and income group.

The photograph sets utilized were presented to the respondents in a folding display. All respondents were shown identical displays but the valuation process was divided between user and preservation questions. In explaining the photographs the following types of information were given to the respondent:

> The Grand Canyon picture set displays a total of five levels of visibility represented by Columns A through E and three vistas from Hopi Point represented in the rows. Column A represents poor visibility, B below average, C average visibility, D above average and E good visibility. The rows in the picture display represent morning and afternoon views from Hopi Point in the Grand Canyon. The first row represents the different visibility and air quality conditions looking east in the morning from Hopi Point. The second row represents morning conditions looking west from Hopi Point. The third row represents the view from Hopi Point in the afternoon looking west.

> The regional picture set display represents five different levels of air quality from poor visibility, Column A, to good visibility, Column E. The rows represent morning conditions for the Grand Canyon, Mesa Verde and Zion National Parks. Row 1 looks out from Hopi Point towards the east in the morning at the Grand Canyon. Row 2 represents the vista from Mesa Verde at Far View Overlook towards the south in the morning. Finally, Row 3 is at Lava Point in Zion National Park looking southeast in the morning.

The Grand Canyon and regional picture set displays were utilized for user and preservation value questions.

> The plume analysis picture display represents two situations. In Picture A no plume can be seen looking west from Hopi Point in the Grand Canyon. Picture B is identical except that a plume is visible.

Again both user and preservation value respondents utilized the same plume picture display.

Three other general characteristics of the questionnaire are worth mentioning. First, after all user and preservation value Grand Canyon and regional bids were obtained, the respondent, if having bid zero, was asked the reason: 1) the air quality improvements represented in the columns were not significant, 2) the source of air pollution should be required to pay the costs of improving the air quality and 3) other (specify). Second, if the respondent stated confusion as to the sources and causes of air pollution or to the veracity of the photographs, a special verbal explanation was given to the respondent explaining the sources and causes of air pollution in more technical detail. This is presented as a supplement to the questionnaire in Appendix B. It was noted on the respondent's questionnaire if this information was requested. Finally, all respondents were shown the map in Figure 12. This was to supplement the picture sets and verbal description in describing the regional nature of the visibility problem.

The areas sampled by the survey teams were chosen in a semi-random fashion in that income class and racial composition were important factors in determining the sampled areas. Approximately one-third of the surveys were to be taken from each of the following income classes; low, medium, and high. Also, it was deemed desirable to obtain an appropriate mix of races representing the average composition across America. Relying primarily on 1970 census tract data it was determined that several areas satisfied the income and race considerations. Thus the actual areas sampled were chosen essentially at random. The out-dated nature of the 1970 data made on-site inspection of the selected areas necessary, but we found the redistribution over the last decade to be minimal. Tables 10, 11 and 12 describe in detail the areas sampled and provide some relevant census tract data. Actual data of the sampled population is given elsewhere.

Before the interviewing commenced, a pre-test of the questionnaire was carried out in Laramie, Wyoming. This served to identify problems in the questionnaire and train the interviewing teams. Due to the size of the picture displays and possible reluctance of some respondents to be interviewed by males, male - female teams administered the surveys.

In any interviewing procedure, care must be taken that the process of sampling and interviewing does not introduce biases into the responses. Thus log sheets were kept by each interviewing team detailing whether a household contacted was: 1) not at home, 2) wished to be interviewed later or 3) refused to be interviewed. This allows the final survey results to be checked for non-respondent bias and a type of sampling bias.

Let us turn now to a more detailed look at the content and sequence of user and preservation value questions focusing on specific information given the respondent and the mechanisms utilized for eliciting a response.

C. User Value Questions

The user value questions asked respondents' willingness to pay to improve visibility in the Grand Canyon, willingness to pay to prevent a deterioration of visibility from the current average for the Southwest region and willingness to pay to prevent plume blight over the Grand Canyon.

The payment vehicle for the Grand Canyon user analysis was increments in additional daily entrance fees. Respondents were told that all visitors would end up paying the same total daily fee and further that all monies collected would be used to finance the air quality improvements represented in the

Table 10

Description of the areas sampled for the National Park Survey Los Angeles County

Name of community or area	Boundaries of the area sampled	Census tract number[a]	Mean income[b]	Percent Black[c]	Percent other races[d]
Santa Monica	West: Lincoln Blvd. North: Pico Blvd. South: Ashland East: 20th Street	7022	11,924	1.6	5.2
Venice District	west: Washington Blvd. North: Rose Ave. South: Brooks Ave. East: 6th Ave.	2733	7913	38.9	2.1
Venice District	west: Main Street North: California Ave. South: Venice Blvd. East: Lincoln Blvd.	2736	9864	2.2	3.0
Inglewood	west: Rosewood Ave. North: Arborvitae St. South: Century Blvd. East: La Brea Ave.	6012.02	11,353	.2	2.4
Inglewood	West: Wooster Ave. North: Slauson Ave. South: 62nd Street East: Charlton Ave.	7030	25,876	1.1	1.8
San Marino	West: Los Rabies Ave. North: Monterey Road South: Huntington Dr. East: Oak Knoll Ave.	4641	34,992	.2	.6
Monrovia	West: Myrtle Ave. North: Greystone Ave. South: Lima Ave. East: Shamrock Ave.	4303	13,513	.2	.7

a. As defined in the maps of Block Statistics: Los Angeles - Long Beach, California, Urbanized Area: 1970 Census of Housing, U.S. Department of Commerce Bureau of the Census Publication HC(3)-18.

b. From Table P-4 "Income Characteristics of the Population: 1970" in Census Tracts: Los Angeles Long Beach, California Standard Metropolitan Statistical Area: 1970 Census of Population and Housing, U.S. Department of Commerce Publication PHC(1)-117.

c. From Table P-1 General Characteristics of the Population: 1970, ibid.

d. Calculated from Table P-1, ibid.

Table 11

Description of the areas sampled for the National Park Survey: Albuquerque Metropolitan area.

Name of community or area	Boundaries of the area sampled	Census tract number[a]	Mean income[b]	Percent Black[c]	Percent other races[d]
Albuquerque	West: William Street North: Stadium Blvd. South: Woodward Road East: i-25	13	4968	11.2	2.9
Albuquerque	West: Rio Grande River North: Montano Road South: Candelaria Road East: San Isidro St. and Guadalupe T.	31	10,312	.4	2.3
Albuquerque	West: State Hwy. 448 North: Interstate-40 South: Bridge Blvd. East: Coors Blvd., Central Ave., and Rio Grande River	24	7860	3.2	2.4
Albuquerque	West: 8th St. and 5th St. North: interstate-40 South: Lomas Blvd. East: Broadway N.E.	28	5919	7.9	4.7
Albuquerque	West: interstate-25 North: Grand Ave. South: Hazeldive Ave. East: University Blvd.	16	7161	2.0	5.0
Albuquerque	West: Carlisle Blvd. North: Lomas Blvd. South: Zuni Road East: San Pedro Dr.	5	10,833	.3	2.2
Albuquerque	West: Carlisle Blvd. North: Montgomery Blvd. South: Candelaria Road East: Louisiana Blvd.	2.01	12,254	1.1	1.2
Albuquerque	West: San Pedro Or. North: interstate-40 South: Lomas Blvd. East: interstate-40	6.01	15,613	2.1	.7
Albuquerque	West: Eubank Blvd. North: Candelaria Road South: Indian School Road East: Chelwood Park Blvd.	1.02	12,432	1.5	1.2

a. As defined in the maps of Block Statistics: Albuquerque, New Mexico, Urbanized Area: 1970 Census of Housing, U.S. Department of Commerce Bureau of the Census Publication PHC(1)-5.

b. From Table P-4 " Income Characteristics of the Population of 1970" in Census Tracts: Albuquerque, New Mexico Standard Metropolitan Statistical Area: 1970 Census of Population and Housing, U.S. Department of Commerce Publication PHC (I) - 5.

c. From Table P-1 General Characteristics of the Population: 1970, ibid.

d. Calculated from Table P-1, ibid.

Table 12

Description of the areas sampled for the
National Park Survey: The Denver Metropolitan area.

Name of community or area	Boundaries of the area sampled	Census tract number[a]	Mean income[b]	Percent Black[c]	Percent other races[d]
Denver	East: York Blvd. South: 23rd Street North: 32nd Street West: Downing Ave.	23	6582	83.1	1.7
Denver	East: Platte River South: 19th Street North: Speer Blvd. West: Federal Ave.	6	6547	.3	2.7
Denver	East: (I-25) Valley South: Hampden North: Yale West: Colorado Blvd.	40.03	12,365	.3	.7
Denver	East: Colorado Blvd. South: Mississippi Blvd. North: Alameda Blvd. West: University Blvd.	39.01	25,892	.1	.4

a. As defined in the maps of, Census Tracts Denver, Colorado Standard Metropolitan Statistical Area: 1970 Census of Population and Housing, U.S. Department of Commerce Bureau of the Census Publication PHC(1)-56.

b. From Table P-4 "Income Characteristics of the Population: 1970," ibid.

c. From Table P-1 "General Characteristics of the Population: 1970," ibid.

d. Calculated from Table P-1, ibid.

pictures. After explaining the air quality problem in the Southwest region (verbally and via pictures), the payment vehicle, and stating the mean payment criteria, the respondent was asked to bid always comparing the proposed improved air quality (i.e., Columns B or C or D or E) with the lowest air quality conditions as represented in Column A on the picture display. Further, the respondent was asked to assume, when bidding, that each photograph represented the visibility on a day that he would be visiting the Grand Canyon National Park. An example portion of the question presented to the respondent is:

> This is Column A, representing very poor air quality and visibility. Please indicate on your answer sheet how much of an increase above the total daily park fees of $2.00 per car load you would be willing to pay for your household to improve the visibility to that shown in Column B. Put a B next to the highest dollar amount you would pay per day if you were visiting in question E5 on your answer sheet.

While the bidding for Column B versus Column A was being conducted, all other columns were covered up. The process continued for Column A versus Column C etc., again the remaining unused columns were covered.

The regional user value questions varied only slightly from that of the user value questions for the Grand Canyon. First, the picture set was described earlier; second, entrance fees would be raised not just in the Grand Canyon but throughout the national parklands in the Southwest. Finally, the following additional information was provided:

> If current emission standards are maintained, the average conditions will be as seen in Column C. If, however, current emission standards on existing and proposed industrial facilities are relaxed or not enforced, then average air quality and visibility in the region will be represented as in Column B. As shown in Column B a deterioration in visibility would occur in the Grand Canyon, Zion and Mesa Verde National Parks. As a result, conditions as presented in Columns C, D, and E will occur less frequently. Conditions in Columns A and B would occur more frequently. We would like to know how much the maintenance of average regional air quality and visibility is worth to you.

The bidding question presented to the respondents was then for preventing a deterioration from the conditions represented in Column C to conditions in Column B and thus shifting the frequency of occurence of all conditions to a generally poorer level of visibility in the region. The valuation question was as follows:

> How much would you be willing to pay per day in addition to existing park entrance fees for your household at the Grand Canyon, Mesa Verde, or Zion National Parks to prevent a deterioration in visibility in the region as represented

> in moving from Column C to Column B. [SHOW photographs AND POINT TO COLUMNS C AND B FOR GRAND CANYON, MESA VERDE AND ZION]. Assume that entrance fees would be raised throughout the National Parks in the Southwest. Please put an R next to the dollar amount closest to the highest increase in daily entrance fees you would be willing to pay for your household for a region-wide preservation in visibility for question E6.
>
> . . .

Finally, the plume analysis addressed visibility problems other than regional haze. The pictures utilized were discussed earlier. Again the bid was in terms of daily entrance fees for the prevention of plume blight while visiting the Grand Canyon.

D. Preservation Value Analysis

The preservation value analysis varied only slightly from the user analysis. First, the vehicle was an increase in monthly electric utility bills. As in the user regional analysis the focus was on the possibility of a shift in the frequency of occurrence of the various visibility conditions represented by Columns A through E. In particular the following information set the background for the bid:

> Again, let us look at the photographs representing visual air quality ranging from very poor in Column A to very good in Column E for east and west views in the morning and afternoon from Hopi Point. If current emission standards are maintained the average conditions will be as seen in Column C. If, however, the current emission standards for sulfur oxide are not enforced, then average air quality and visibility in the region will become like Column B. As a result, conditions as represented in Columns C, D and E will occur less frequently. Conditions in Columns A and B would occur more frequently in the Grand Canyon. Such emission controls will likely make electricity more expensive.

The specific bidding question given to the respondents was as follows:

> We would like to know if you would be willing to pay higher electric utility bills if the extra money collected would be used for additional air pollution controls to preserve cu-rrent air quality and visibility levels at the Grand Canyon. How much extra would you be willing to pay at most, per month as an increase in your electric utility bill to preserve current average visibility as represented in Column C rather than have the average deteriorate to that shown in Column B? Please put an X next to the highest amount you would be willing to pay per month for your household on your answer sheet for question E8.

The regional preservation value question also used electric utility bills as the bidding vehicle, focused on a shift in the frequency of occurrence from the current average in Column C to that in Column B and utilized the regional picture set board discussed earlier.

A difference, however, between the structure of the regional user and preservation value questions does exist. Recall that the regional user question was a separate bid from that for preserving visibility just in the Grand Canyon. The preservation regional question was a willingness to pay question that asked how much more above and beyond the amount the respondent stated when only bidding for visibility in the Grand Canyon.

Finally, the preservation value plume blight question mirrored that of the user question except that the vehicle was increases in electric utility bills. Again, this was for preserving, thus preventing plume blight over the Grand Canyon.

CHAPTER 7

SURVEY RESULTS

A. Introduction

In this chapter the results of the survey efforts described in Chapter 6 are presented and analyzed. Two groups of responses are analyzed. Survey participants who answered questions concerning their willingness to pay an entrance fee to the Grand Canyon National Park are called "user value respondents." Those who were asked questions concerning their willingness to pay higher electric utility bills to preserve or improve air quality in the Grand Canyon National Park and the surrounding region are referred to as "preservation value respondents."

Section B contains a discussion of various socio-economic and demographic characteristics of the survey respondents. Section C presents a detailed report of the findings of the user value component of the survey. The preservation value findings are then presented in Section D.

B. Socio-economic and Demographic Characteristics of the Sample

There exists in each of the survey subsamples a substantial similarity in gross demographic measures. These are presented in Tables 13a and 13b. In both cases the Los Angeles and Denver groups are quite close in mean years of formal education, age and income while the Albuquerque group was on average younger, less well educated and received substantially lower incomes. The Chicago group consisted exclusively of preservation value respondents and within this category occupied intermediate positions in education and income. The Chicago respondents' mean age was slightly higher than that of any other city.

Within each city, the user value respondents tended to be younger, better educated and the recipients of higher incomes than the preservation value respondents. Visitation experience and plans of these respondents is reported in Figure 14. An exception to this tendency is that in Denver user value respondents reported a mean income slightly less than did existence value respondents. The difference, though, is sufficiently small that it warrants little discussion given the broad similarities observed.

All these measures, then, bear relationships to one another which enhance their prima facie plausibility as the results of a representative survey of United States citizens. The household size and electricity bills reported similarly tend to confirm that an appropriate sample was selected.

Table 13a

Socioeconomic characteristics of existence value respondents by city (mean and standard deviation)

	Number of Respondents	Education (years)	Age (years)	Household size (number of members)	Income (x $1000)	Elect. Bill (dollars/month)
Albuquerque	115	13.60 (2.57)	38.60 (14.47)	3.23 (1.79)	19.02 (11.61)	36.78 (22.99)
Los Angeles	127	14.52 (2.21)	41.05 (14.89)	2.72 (1.70)	28.06 (20.40)	36.27 (25.79)
Denver	110	14.76 (2.34)	40.84 (14.61)	2.54 (1.41)	30.57 (20.64)	58.41 (39.79)
Chicago	98	13.91 (2.39)	42.66 (14.62)	3.80 (1.97)	25.93 (18.25)	55.64 (40.65)

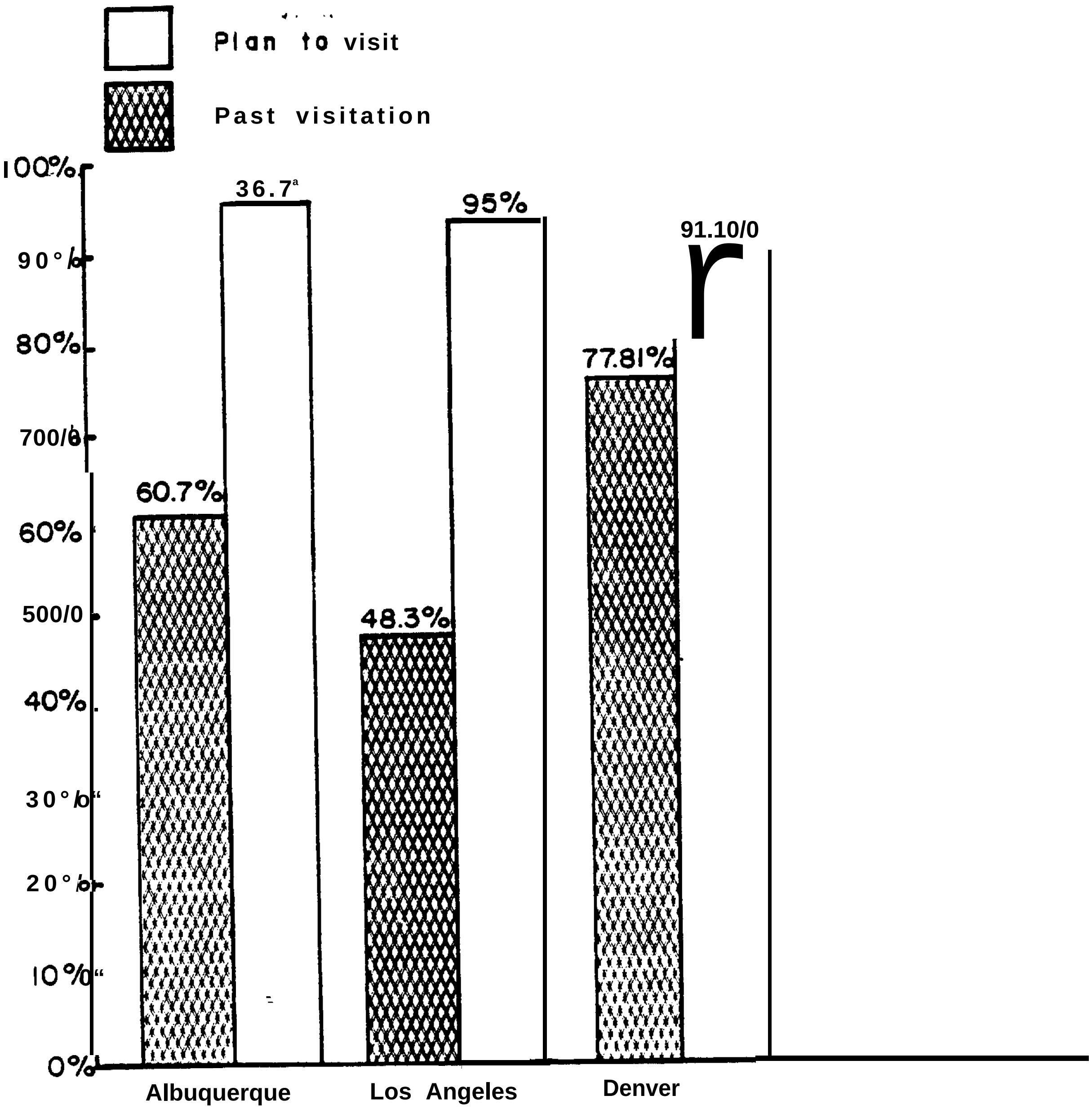
Table 13b

Socioeconomic characteristics of user value respondent by city (mean and standard deviation)

	Number of Respondents	Education (years)	Age (years)	Household size (number of members)	Income (x $1000)	Elect. Bill (dollars/month)
Albuquerque	61	14.26 (2.29)	35.31 (14.15)	2.88 (1.52)	25.29 (15.90)	36.02 (17.24)
Los Angeles	60	14.90 (2.37)	36.60 (13.06)	2.98 (1.35)	30.77 (20.59)	42.53 (32.68)
Denver	45	15.02 (2.47)	37.11 (15.36)	3.09 (1.67)	30.14 (15.89)	47.67 (26.32)

Figure 14
Grand Canyon Visitation

Experience and Expectations of User
Value Respondents, by city.



c. Value in Use to Visitors

The user value survey participants were asked to reveal the maximum additional amount over the current $2.00 daily fee they would be willing to pay for daily admission to Grand Canyon National Park if this fee would be used to maintain specified degrees of air quality. The question was phrased as to ask the maximum total daily fee to maintain each of conditions B, C, D and E over condition A, a situation with severely impaired visibility.

The mean and standard deviation of responses in each city are presented in Figures 15a, 15b and 15c. A notable feature of these results is the uniform display of what might be called increasing returns to scale in air quality. In all three cities nearly half of the total bid for very high visibility was an increase over only slightly diminished clarity. This seems to contradict the conventional assertion that incremental improvements in air quality would yield ever smaller benefits to viewers.

Instead, more serious thought must be given to what has been called the Dubos Hypothesis.[2] This argument holds that for "natural wonders" it is in fact the pristine state that is valued, and that once any degradation has taken place additional damage matters relatively little. The bids for air quality preservation at the Grand Canyon certainly appear to be consistent with this hypothesis, as does the decline in zero bids for greater improvements in air quality. (Tables 14a and 14b present this information.) Were "not significant" not the most frequently given reason for zero bids for the visibility change one would regard this as unremarkable, but the fact that the initial improvements are regarded as insignificant by most zero bidders is in itself noteworthy.

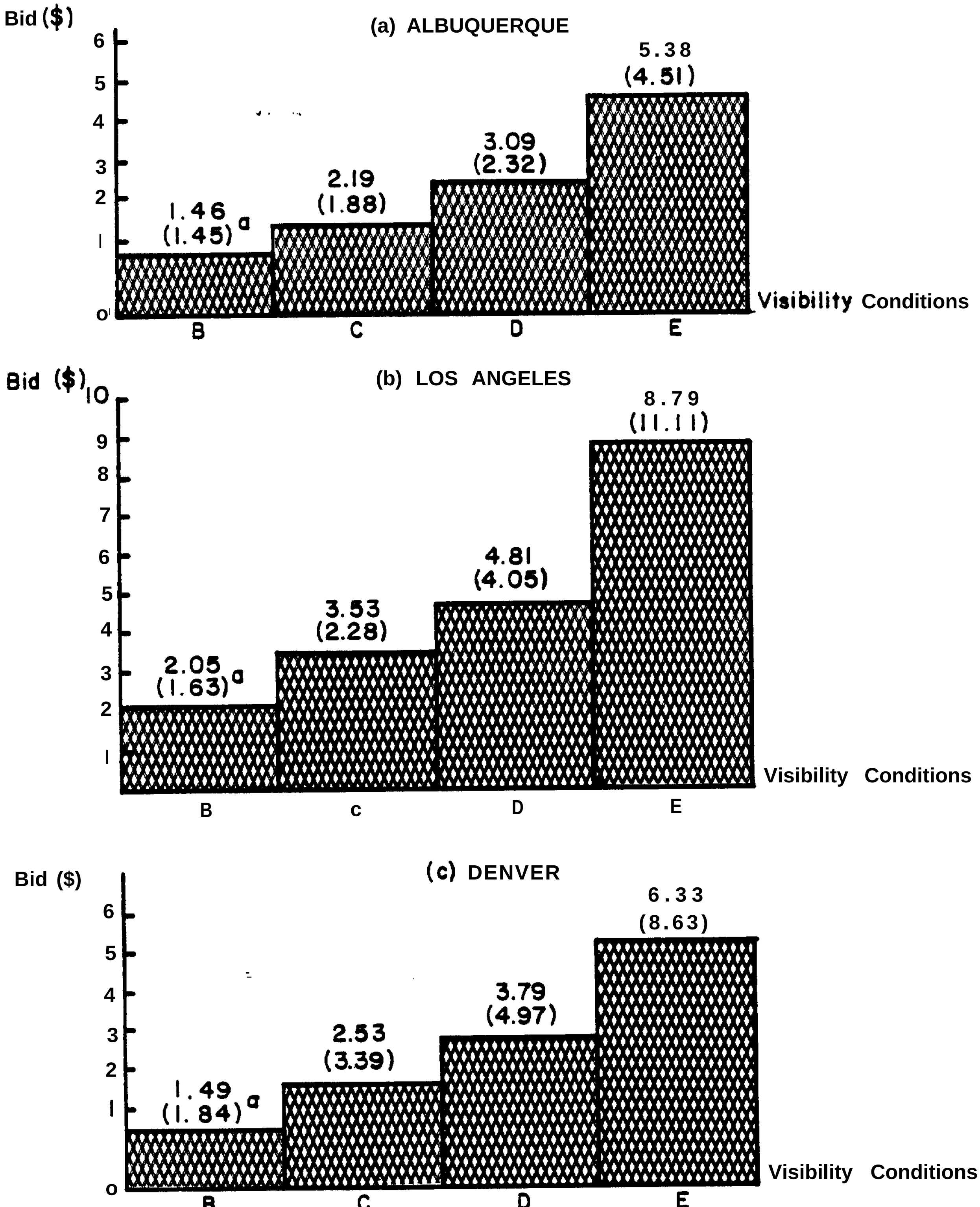
The visitation experience of user value respondents for the Grand Canyon is consistent across income groups and city of residence. Tables 15a and 15b present mean visitation during the previous ten years by city and income class respectively. One intcresting aspect is that less than one day per ten years separates the Los Angeles group (with the highest mean visitation) from Denver (with the lowest) as is the similarity of visitation experience among low, middle and high income groups.

As might be expected, use of other National Parks in the region varies considerably among cities and income as well as among the parks themselves. One suspects that a visit to Grand Canyon National Park is the central feature of most parklands tours with trips to other parks and national monuments reflecting any number of family characteristics such as length of vacation, later destinations and knowledge of the region.

Visual quality in these other areas is apparently less valuable to users than at the Grand Canyon. Figure 16a presents the mean bid of respondents to avoid a regional decrease in average air quality from C to B. The mean regional bid in Albuquerque was $.99 more than the comparable Grand Canyon bid, while in Los Angeles and Denver the increases were $1.24 and $2.40 respectively. Only among Denver respondents did the surrounding region rival the Grand Canyon as a source of viewing pleasure. This might be a result of Denver residents' relatively heavy use of other parklands parks as presented in Table 15a.

Figure 15

Mean Bid for Specified Visibility Conditions
at Grand Canyon of User Value Respondents,
by City (with standard deviation).



[a] standard deviation in parentheses

Sample size (number of households) for Albuquerque,
Los Angeles and Denver is respectively, 61, 60 and 45.

Table 14a

Zero bids by user value respondents for specified visibility improvements, by city (number of zero bids)

	A→B	A→C	A→D	A→E
Albuquerque	10	6	4	2
Los Angeles	2	1	I	1
Denver	12	8	6	4

Table 14b

Zero bids by reason among user val w respondents

	not significant	source shou Id pay	other	total
Albuquerque	9	2	I	12
Los Ange les	1	0	2	3
Denver	3	2	2	7

Table 15a

Southwest Nat ional Park use patterns (by city) for user value respondents. (Number of days at parks during previous ten years; mean and standard deviation.)

	Grand Canyon	Zion	Mesa Verde	Bryce	Others
A I buquerque	2.69 (3.60)	.47 (1. 06)	1.73 (3.67)	.52 (1.35)	2.08 (3.91)
Los Angeles	3.28 (5.67)	1.77 (4.05)	1.35 (4.21)	1.65 (4. 30)	3.20 (5.99)
Denver	2.51 (2.82)	.80 (1.44)	2.24 (3.66)	1.29 (2.36)	6.27 (7.78)

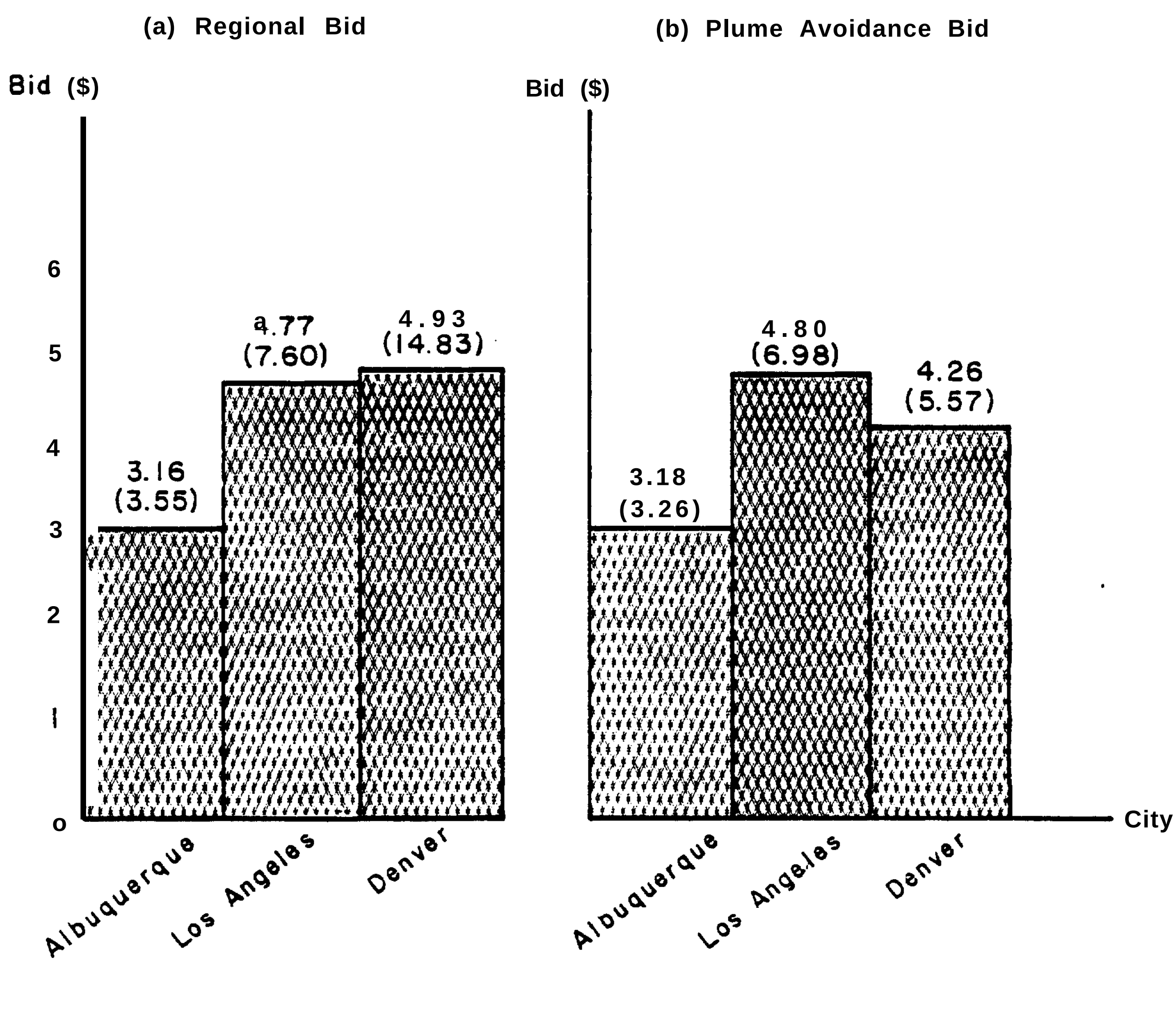
Table 15b

Use patterns among user value respondents by income c I asses (Mean days in previous ten years)

	G raod Can yon	Zion	Br yce	Mesa Verde
Low I ncome (14,999 or less)	2.85	.78	.68	2.05
Middle Income (15,000 - 19,999)	2.98	1.26	1.47	1.33
High Income (20,000 or more)	2.73	.97	1.11	1.92

Figure 16

Mean regional and plume avoidance bid
by user value respondents, by city



Denver user value respondents were also exceptional in their valuation of plume blight. When asked to reveal the highest daily use fee they would pay to avoid the presence of conspicuous Plume on the horizon, Albuquerque and Los Angeles respondents offered a bid that averaged very close to the bid for the maintenance of slight haze (situation D). In Denver the mean plume avoidance bid was substantially higher than the bid for situation D. The plume avoidance bids are depicted in Figure 16b.

D. Preservation Value .,

Preservation value respondents in each of the four cities were asked how much they would be willing to pay as an increase in electric utility bills to prevent average visibility declining from situation C to B.

While preservation value respondents were asked their visitation plans and experience, no use was made of this information in the survey except that respondents who had neither visited nor planned to visit the Grand Canyon were forced into the preservation value group. Even so, a substantial portion of the preservation value respondents in each city had visited the Grand Canyon and a majority planned to visit. Figure 17 presents visitation experience and plans for preservation value respondents in each city.

In Table 16 the mean number of days spent at various southwestern national parks can be seen. No data is offered for the Chicago respondents since they were asked simply whether they had visited Grand Canyon and whether they planned such a trip. Among the respondents in the other cities the pattern is much the same as for user value respondents except that the numbers are smaller, as would be expected. Mean days of visitation at the Grand Canyon is approximately the same in each city and Denver respondents had used “other” parks in the region much more than did residents of Albuquerque and Los Angeles.

The bids of preservation value respondents, it must be remembered, include both a user value and a pure existence value and thus would be expected to exceed a comparable user value bid. The bids used in the user and preservation value variants of the survey described here are sufficiently distinct that some discussion seems appropriate.

The user value bids, it will be recalled, are formulated as daily increases in entrance fees during a visit that is anticipated. The preservation value bids are to be paid whether or not the respondent actually uses the Grand Canyon or surrounding parklands region. A user value bid comparable to preservation value bids reported would be, then, the product of the daily bid and average number of days per month the fee will be paid. Whether one uses actual visitations in the past or declared intentions, the user value will be insignificant compared to the preservation value bids reported in Table 17. The Grand Canyon bids in this table are for the maintenance of situation C as the average visibility condition. If the same relationships held among preservation values for visibility as among user values, an increase in visibility to situation E would more than double these bids. One hesitates to assert that such is the case, but the consistency with which the Dubos Effect was observed among user value bids requires at least a mention of this possibility.

Figure 17

Grand Canyon visitation experience and expections of preservation value respondents.

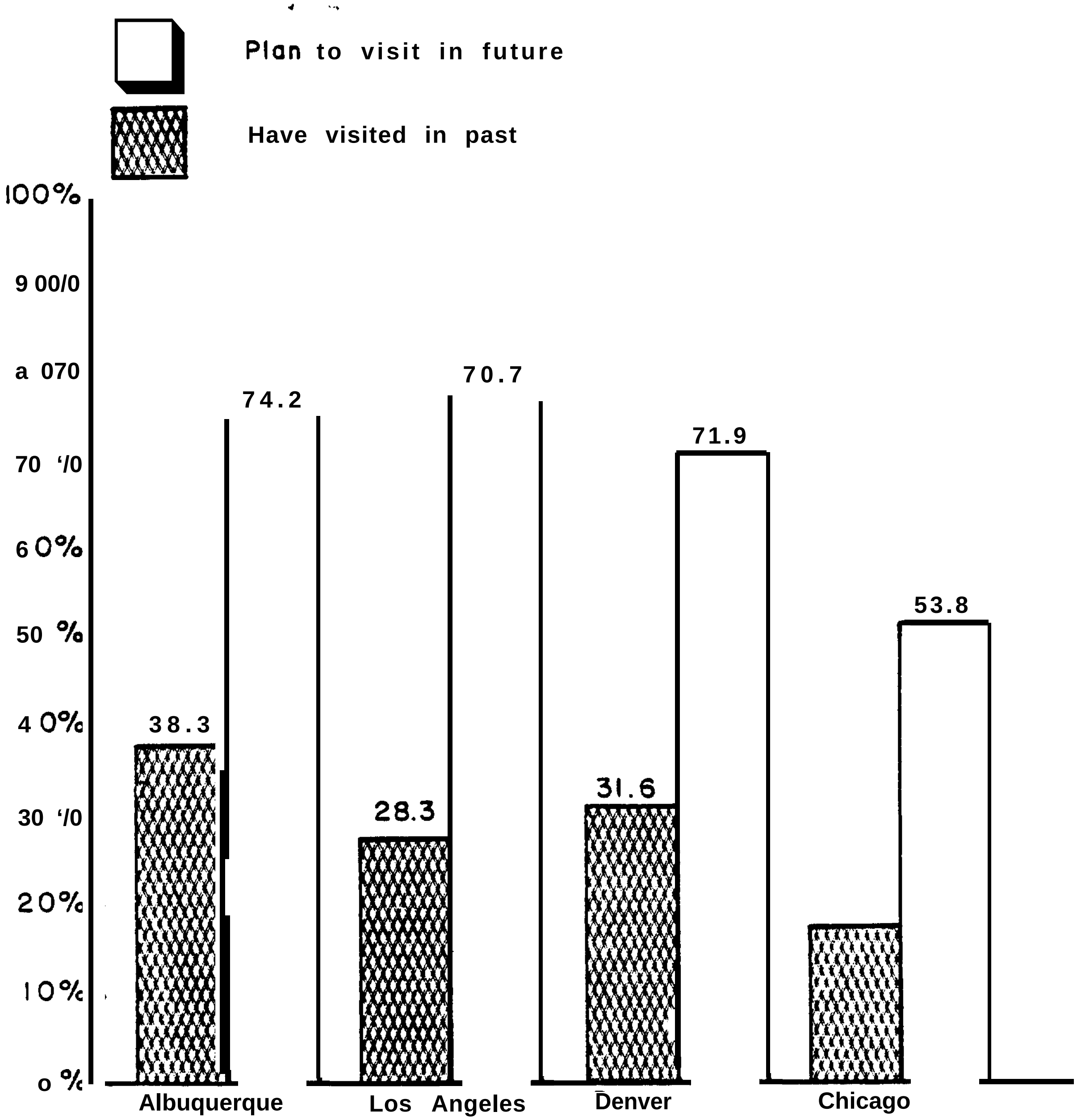


Table 16
Southwest National Park use patterns (by city) for preservation value respondents. (Number of days at parks during previous ten years; mean and standard deviation.)

	Grand Canyon	Zion	Mesa Verde	Bryce	Others
Albuquerque	1.38 (3.25)	.35 (1.93)	.67 (1.58)'	.28 (1.15)	1.79 (4.72)
Los Angeles	1.17 (3.06)	.83 (1.90)	.45 (1.58)	.68 (1.72)	1.65 (4.40)
Denver	1.11 (2.62)	.26 (.69)	1.50 (2.47)	.21 (.54)	4.25 (6.40)

Table 17
Preservation value bids by city; mean and standard deviation ($)

	Grand Canyon	Additional for Region	Plume Avoidance
Albuquerque	4.09 (11.68)	4.14 (14.41)	4.25 (13.42)
Los Angeles	5.14 (10.79)	4.50 (10.32)	2.84 (4.53)
Denver	3.72 (5.31)	2.89 (4.12)	2.89 (4.54)
Chicago	9.06 (30.49)	7.10 (24.80)	4.32 (13.77)

The preservation value of clean air in the region appears to be substantial to residents of all four cities surveyed, as does the avoidance of plumes. The regional bids presented in Table 17 are bids in addition to the Grand Canyon bid. In an important sense, the plume avoidance bid is also an additional bid since it addresses a separate issue.

The magnitude of these bids when compared to user value bids, especially given the large portion of the respondents who reported an intention to visit the Parklands region, might cause some concern regarding the true apportionment of user option value and pure existence value.

In Figures 18-20 mean bids are presented for respondents by city and by visitation experience and plans. These partitions of the sample suggest that visitation plans are not an overwhelming factor in determining bids and that knowledge acquired through past visits is also of relatively little importance.

Among Albuquerque participants previous or planned travel to the Grand Canyon is associated with larger bid differences than for any of the other cities. This may be a result of Albuquerque's proximity to the Grand Canyon. That is, those who find such things attractive intend to visit the Grand Canyon. The 25.8% of the Albuquerque sample that has no plans to visit the Grand Canyon has the lowest average bid in every classification. A Grand Canyon experience makes much less difference in the mean bid.

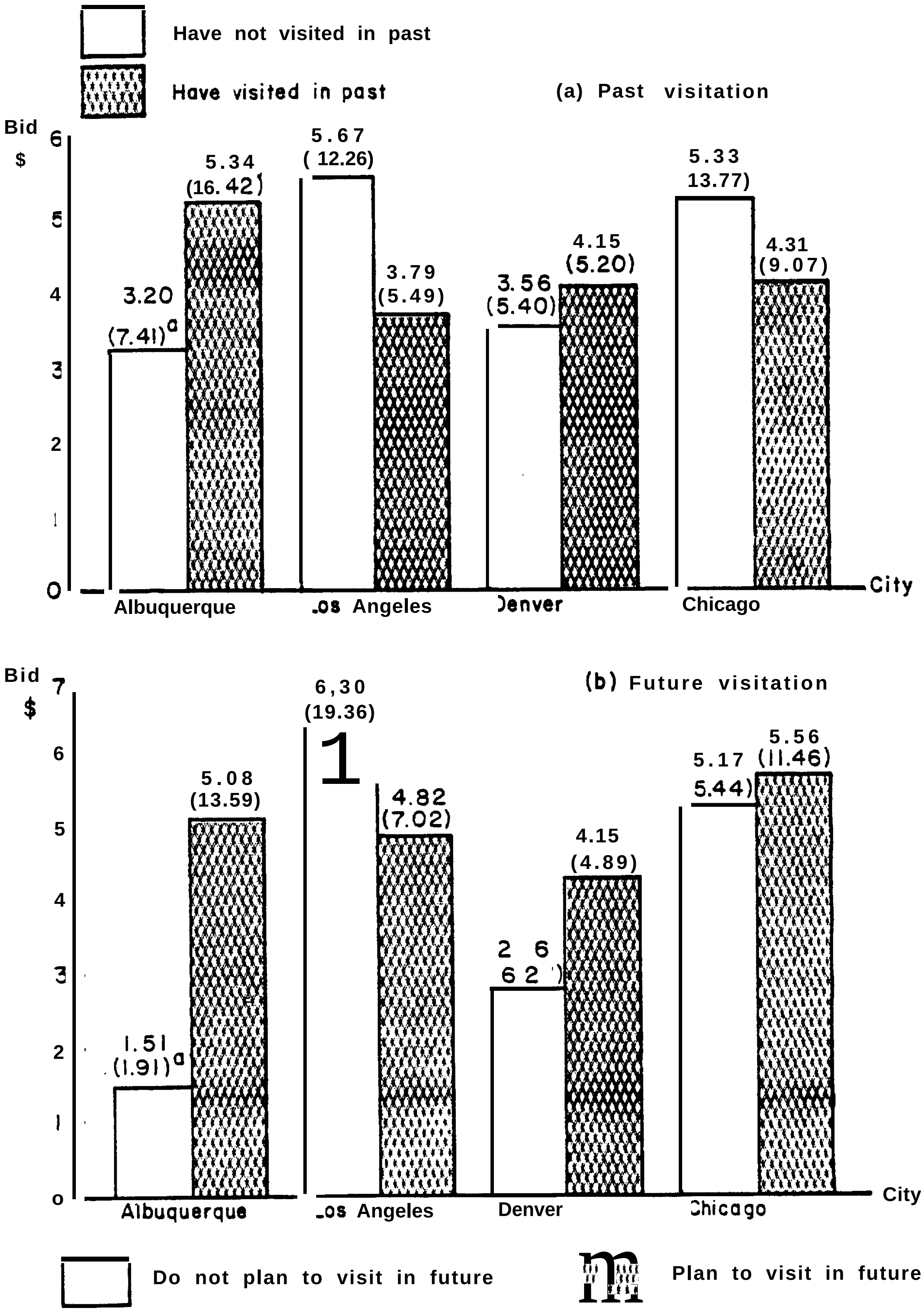
For both Grand Canyon and Parklands total bids the mean bid among Los Angeles respondents was higher without experience or intention to see the Grand Canyon, while visitation plans resulted in higher plume avoidance bids and visitation experience in lower bids. This would seem to suggest a substantial pure existence value.

Past exposure to the Grand Canyon made very little difference in mean Grand Canyon or regional bids in the Denver sample, while anticipated Grand Canyon travel made a large difference in both these measures. The same was true of plume avoidance bids, with travel plans being associated with substantially higher bids.

The Chicago group had the highest mean bid in every category and with only one exception past or planned visits to the Grand Canyon resulted in a lower mean bid., The exception is the Grand Canyon specific bid in which respondents planning a visit made average bids slightly higher than did those not planning a trip to the Grand Canyon.

One would have expected bids to decline with distance, and the substantial margin by which the Chicago bids were higher remains a topic of interest. In the next chapter it will be seen that even when adjustments are made for the income and age of respondents, distance has little discernible effect on bids to preserve air quality in the Grand Canyon.

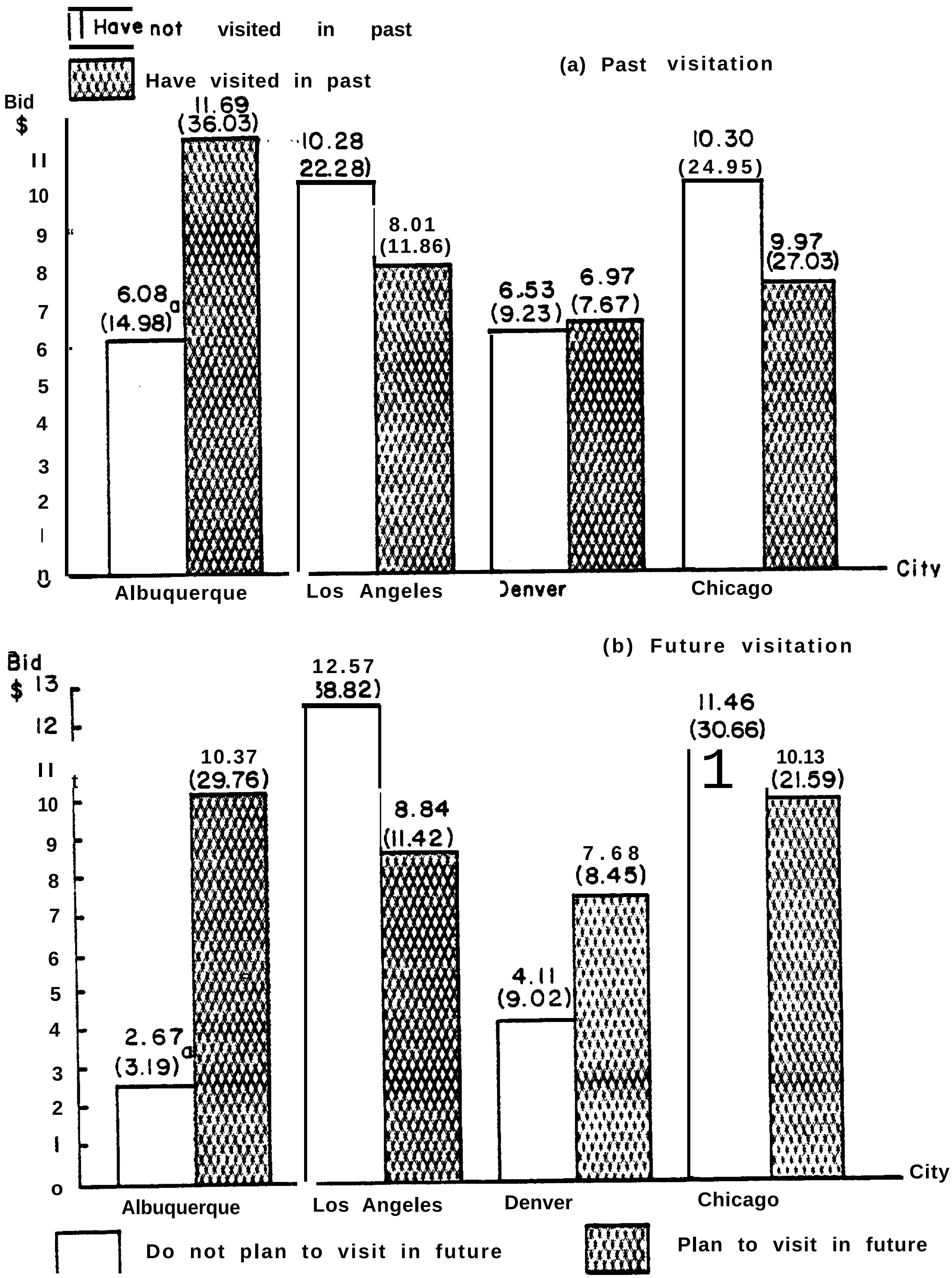
Figure 18
Mean Grand Canyon Bids of preservation value respondents, by city and past and future visitation



[a] standard deviation in parentheses

Figure 19

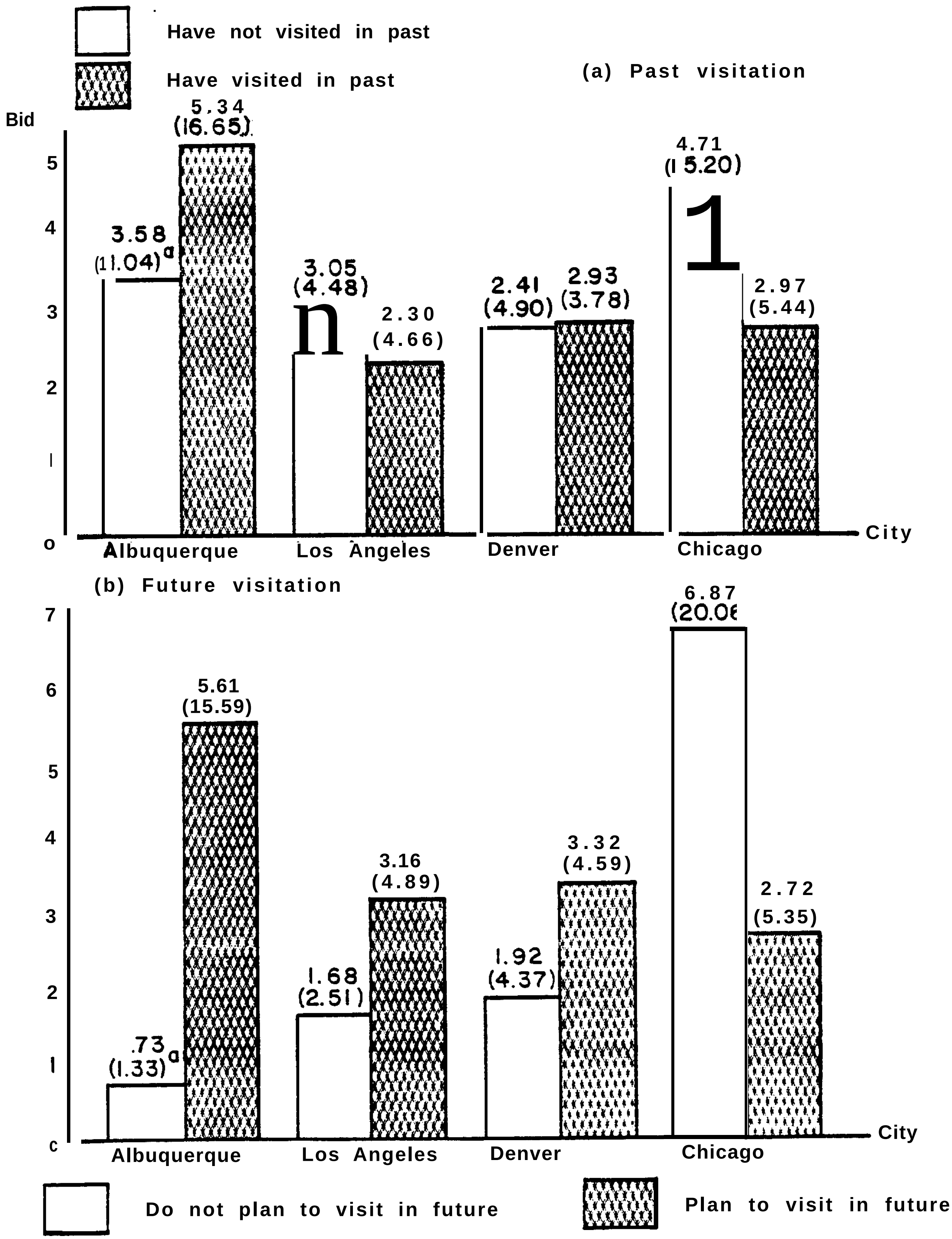
Mean total regional bids of preservation value respondents, by city and past and future visitation



'standard deviations in parentheses

Figure 20

Mean plume avoidance bids of preservation value respondents, by city and past and future visitation



[a] standard deviations in parentheses

REFERENCES

1. See Chapter 6 for a discussion of the survey procedures used and the modifications adopted for the Chicago sample.

2. The name is taken from Rene Dubos who proposed that as the environment deteriorates people care less and less about further deterioration. In other words, people put a special value on pristine environmental conditions.

CHAPTER 8

AGGREGATE BENEFITS OF PRESERVING VISIBILITY

A. Introduction

This chapter will present aggregate benefit estimates for preserving visibility in the Grand Canyon and the southwest region as a whole. As discussed, the survey enabled revelation of the household's willingness to pay for preserving and/or improving visibility in specific parks of the Grand Canyon Region. Recall the bids stated by respondents in the preservation value section of the survey encompass both pure existence value and user's valuation of preserving visibility. Therefore, to estimate the visibility preservation benefits, it suffices to concentrate on and work with the preservation value section of the survey.

The benefits in question can be estimated by applying statistical techniques to the results of the survey conducted for this study. It can be hypothesized that the amount of the bids offered by interviewees to preserve and/or improve visibility in the areas where the survey focused is a function of certain relevant independent variables such as income, age, race and distance from a national park. Utilizing such a relationship we can estimate the benefits to residents of the southwest region as well as the entire nation resulting from the preservation of visibility in the Grand Canyon National Park and Parklands Region."

B. Estimating the Benefit Function for the Southwest

In estimating an individual mean dollar benefit function, certain characteristics of the sample population should be considered in that the cities of Los Angeles, Albuquerque, Denver and Chicago are not homogeneous. That is, in order to aggregate across all populations the demographic and economic profile of each city must be considered. Thus we hypothesize that a household bid is a function of family income, age of the family head, race, the household's distance from a national park and an error term.

To estimate the benefits to residents of the Southwestern U.S. (consisting of the following states: California, Colorado, Arizona, Utah, Nevada, and New Mexico) of preserving visibility in national parks three benefit functions have been estimated utilizing the Albuquerque, Denver, and Los Angeles data. Table 18 summarizes the estimated benefit functions. A brief analysis of the results follows.

Table 18

Benefit Functions Estimated from Albuquerque, Denver, and Los Angeles Data

Bid for Preserving Visibility ($)	Constant	Income [$1000)	Age (years)	Race (white = 1) (nonwhite - 0)	Distance (miles)	R^2	Number of Observations
Grand Canyon	9.19 (4.23)[a]	.05 (1.79)	-.14 (-4.01)	2.03 (1.69)	-.0037 (-1.2)	.06	352
Region (Grand Canyon, Mesa Verde and Zion)	18.11 (4.11)	.103 (1.79)	-.26 (-3.7)	3.69 (1.52)	-.0088 (-1.46)	.05	352
Plums Blight over the Grand Canyon	8.67 (4.54)	.0014 (.06)	-.12 (-4.02)	1.03 (.97)	-.0021 (-.81)	.05	352

[a]t-statistics in parentheses

As Table 18 indicates, the relationship between income, age, race, distance and the amount of bid-offered is as expected. Higher levels of income should, normally, raise the amount of bid offered. Age contributes in a negative manner in all bid equations implying the young are seemingly more concerned with air quality problems in" the area. Since "whites," on average, fall in the "higher brackets" of income and education distribution in the United States compared to "nonwhites," it is reasonable to expect higher bids from whites than nonwhites. In addition, it is likely that "race" captures other social and cultural characteristics which are not easily observable. The relatively low t-statistic possibly reflects a substantial diversity within each of the "white" and "nonwhite" groups. The negative relationship between distance and the amount of bid offered indicates that the greater the distance from the national parks, the less their overall bid, However, the relationship between distance and the amount of bid offered is not strongly significant. Furthermore, as it will be seen shortly this result does not appear consistently in all of the analysis. Note also that the coefficient of determination (R^2) in all three benefit equations reported in Table 18 is extremely low. This indicates that there may be other important independent variables that affect the bidding behavior of the households, but which have not been accounted for in this study.

Nevertheless, it is possible to estimate the aggregate benefits accruing to the Southwest region of the United States from preserving visibility in the Grand Canyon National Park area. Let us first consider the benefit equation for the Grand Canyon (Row 1, Table 18). This equation indicates that if the average family income, average age of the head of households, ratio of white and nonwhites and the distance to the Grand Canyon from a particular state, say Arizona, is substituted in the equation, then the amount of bid an average household in Arizona would offer to preserve the visibility in the Grand Canyon would be estimated. Then if the benefit measure so estimated is multiplied by the number of households in the state of Arizona, the total amount of money that the entire population of Arizona would be willing to pay to preserve visibility in the Grand Canyon National Park is estimated. Following a similar procedure, it is possible to estimate the aggregate benefits for the remaining five states in the Southwest region, and hence, the aggregate benefits to the Southwest region is estimated.

As Table 19 indicates, the aggregate benefits for the Southwestern region from preserving visibility in the Grand Canyon National Park, the encompassing region (Grand Canyon, Mesa Verde, and Zion) and for avoiding plume blight over the Grand Canyon is respectively $466 million, $889 million, and $373 million.

Table 19

Annual Aggregate Benefits for the Southwest Region

Benefits for Preserving Visibility in the:	TOTAL ($ Millions)
Grand Canyon	466
The Region[a] - Grand Canyon, Mesa Verde and Zion National Parks	889
Avoidance of Plume Blight	373

[a]Benefits for the region include benefits for the Grand Canyon

c. Estimating Benefit Functions for the Nation

To estimate the aggregate national benefits from preserving visibility in the Grand Canyon National Park, surrounding region and for avoidance of plume blight, benefit functions in Table 20 are re-estimated, utilizing the interview data from Albuquerque, Denver, Los Angeles, and Chicago. Thus the principal difference will be the influence of the bids obtained from respondents in Chicago. Table 20 summarizes the re-estimated benefit functions which will be used to estimate the aggregate national benefits of preserving visibility.

Table 20

Benefit Functions Estimated from Albuquerque Denver, Los Angeles, and Chicago Data

Bid for Preserving Visibility ($)	Constant	Income ($1000)	Age (years)	Race (white = 1) (nonwhite = 0)	Distance (miles)	R^2	Number of Observations
Grand Canyon	8.36 (4.76)	.047 (1.76)	-.15 (-4.59)	1.14 (1.02)	.0004 (.39)	.05	450
Region (Grand Canyon, Mesa Verde and Zion)	15.46 (4.41)	.11 (2.12)	-.29 (-4.44)	2.29 (1.04)	.0004 (.19)	.05	450
Avoidance of Plume Blight over the Grand Canyon	8.6 (5.22)	-.003 (-1.78)	-.15 (-4.6)	1.14 (1.02)	-.00014 (-.16)	.05	450

[a] t-statistics in parentheses

The benefit functions reported in Table 20 are for the most part similar to, and consistent with, the benefit equations obtained from the sub-sample of the Albuquerque, Denver, Los Angeles interviews reported in Table 18. Examination of Tables 18 and 20 reveal that the degree of significance of income is consistent in both sets of equations. Note that the significance of income in the “plume” benefit equation is lower than the other two equations in both Tables. Age remains strongly significant and consistent in the two sets of equations. The behavior of the variable “white/nonwhite” is very similar to that of the income. The direction of the relationship is consistent; so is the degree of significance among the benefit equations of each table as well as between the two tables. The only major difference is the relationship between distance and the amount of bid offered when the Chicago interviews are not included (Table 18) and included (Table 20). The direction of the relationship reverses itself from negative to positive when the Chicago data is added to the sample (except for the “plume” equation). Furthermore, significance level for the distance variable fails to be consistent. Without the Chicago data, distance is relatively more significant (except in the “plume’s” benefit equation); after the Chicago data is added, the direction of relationship of this variable changes and it also fails to be significantly related to the amount of bid. Nevertheless, it is convincing to note that other than for the distance variable, when the sample size is increased by some 21%, (as Chicago data is added to the sample), the relationships remain consistent and stable.

The aggregate national benefit estimation procedure is identical with the procedure employed in the previous pages to estimate the benefits to the Southwest region. Aggregate benefits to all states (except Alaska and Hawaii, but with the addition of the District of Columbia) have been summed to arrive at the national aggregate benefits from preserving visibility. Table 21 summarizes the aggregate national benefits.

The benefits of preserving visibility for the Southwest and the Nation can be related to emissions by noting the following. Projected emissions with currently planned levels of SO_2 controls would not produce a perceivable decline in visibility in 1990 according to the calculations from Chapter 3. However, complete decontrol of projected regional power plant emissions of SO_2 in 1990 would decrease visibility by approximately the same amount as shown in the photographs which form the basis of these benefit estimates. Thus, one can interpret the aggregate bids to preserve regional visibility as the projected benefits of power plant SO_2 controls in 1990.

The annual figures presented in Tables 19 and 21 represent benefits to the Southwest and the nation for preservation of visibility in 1980. In order to obtain benefit estimates for 1990 power plant controls two modifications are required. First, the benefit figures are adjusted by the expected population growth over the next decade. Bureau of Census estimates “ tion growth of approximately one percent per year is expected. ~nd~~~~~d, the present value of future benefits must be calculated. Assuming a thirty year life span for power generating plants and real rates of discount of 3, 6, and 9 percent, Table 22 summarizes the present discounted value of future benefits in constant 1980 dollars to the Southwest region and the entire nation from preserving visibility in the Grand Canyon National Park and the Parklands region.

Table 21

Annual Aggregate National Benefits from Preserving Visibility in the Grand Canyon National Park

Benefits from	TOTAL ($ Millions)
The Grand Canyon	3,370
The Region - Grand Canyon, Mesa Verde, and Zion	5,760
Avoidance of Plume over the Grand Canyon	2,040

The nine percent real discount rate case corresponds to a ten percent discount rate and a continued one percent growth in population. This case is therefore consistent with the Office of Management and Budget discount rate guidelines (10 percent) for assessment of future benefits. Thus, the nine percent case seems the most apropos for comparison to the associated pollution control costs.

The comparison between benefits and costs can either be completed in present value or annual terms. Using the latter method requires annualization of the present value figures reported in Table 22. Focusing on the nine percent discount rate case and using a capital recovery factor based on a ten percent rate of interest the relevant annualized benefits for preservation of regional visibility are $1.173 billion and $7.6 billion for the southwest and nation, respectively.[3]

Clearly, preserving visibility in the Grand Canyon National Park region also entails certain costs. These include capital expenditures for SO_2 removal equipment, recurring annual expenditures and the cost of the regulatory system. The capital expenditures associated with SO_2 removal for all current and proposed power plants in the region (see Tables 4 and 5 for listing) are estimated to be approximately $5.3 billion or between 270 and 560 million dollars per year for real interest rates of three and ten percent and a thirty year life.[4] In addition, the recurring annual expenditures are estimated to be 2 billion dollars per year. Finally, the regulatory system cost is approximately .534 billion dollars per year.[5] Therefore, total costs of currently planned SO_2 controls for the region are between 2.8 and 3.1 billion dollars annually (1980 dollars). Therefore, national benefits ($7.6 billion annually) exceed the total control costs and these approximate values indicate that the currently proposed level of control on SO_2 emissions are not without some economic justification.

Table 22
Present value of future benefits
assuming thirty year life span for power
generating plants (in $ Million)

Benefits to" the Southwest from preserving visibility in	Discount Rate		
	3%	6%	9%
The Region - Grand Canyon, Mesa Verde and' Zion National Parks	20,209	14,484	11,060
Benefits to the Nation from preserving visibility in	**Discount Rate**		
	3%	6%	9%
The Region - Grand Canyon, Mesa Verde and Zion National Parks	130,957	93,860	71,667

D. Summary

There are three especially noteworthy observations which emerge from the above analysis in Chapters 7 and 8: 1) contrary to conventional thinking, survey respondents "placed a much higher value on higher levels of visual clarity than on comparable subsequent decreases; 2) neither past nor anticipated journeys to the Grand Canyon seemed to be important determinants of preservation value; and 3) distance from the Grand Canyon had little statistical significance in explaining the magnitude of household bids.

Because the Grand Canyon is the dominant feature in a region with many visitor attractions, one must be especially cautious in extending these findings to other recreational attractions. It seems likely that there are only a very few natural phenomena in the United States about which Americans have such strong feelings. Obvious candidates for this short list would be Old Faithful (in Yellowstone National Park), and Niagara Falls.

The magnitude of the annual benefits for the region when aggregated across households is impressive: $889 million in the Southwest and $5.76 billion in the nation. The present value of these benefits streams over thirty years, discounted at a 3 percent real rate, would be $20.2 billion and $131 billion, respectively.

In sum, the survey results revealed that Americans place great value on the preservation of air quality in the Parklands Region and that this valuation is not localized to residents in the Southwest. Further, it was found that pure existence value overwhelms a substantial user value for the national parks in the region.

Two qualifications are important in interpreting these results.

First, the accuracy of the survey techniques used in this study to estimate the benefits of preserving visibility in the Grand Canyon Region can be judged by comparison to other methodologies. Such comparisons suggest that all available techniques including survey methods, property value, wage and travel cost studies, are subject to errors of about plus or minus 50 percent (see Appendix B). It is inherently difficult to quantify environmental values in dollar terms, but available evidence indicates that the several techniques available all yield the same order of magnitude of benefits estimates when applied to the same problem.

Second, the principal benefits of preserving visibility in the Grand Canyon Region as estimated in this study, derive from the apparent desire of Americans to preserve a national treasure, whether or not they intend to visit or use the region themselves. Economists have termed this type of value "existence value." To our knowledge, this is the first study attempting to estimate existence values per se. Thus, the methodology used in this study should be viewed as experimental.

REFERENCES

1. sources for the state data are:

   Number of Households: Statistical Abstract of the United States, 1978, U.S. Department of Commerce.

   Incomes: Survey of Current Business, April, 1979, Vol. 59 #4, "County and Metropolitan Area Personal Income."

   Average Age and Race: Current Population Reports, Population Estimates and Projections.

2. See Illustrative Projections of State Populations by Age, Race and Sex: 1975 to 2000, March 1979, U.S. Department of Commerce, Bureau of the Census.

3. The capital recovery factor is the rate which transforms an initial capital amount (present value) into a series of equivalent annual amounts, including both interest and capital.

4. See "Cost Analysis of Lime Based Flue Gas Desulferization Systems for New 500 Megawatt Utility Boilers," EPA document EPA-450/5-79-003 (January 1979), prepared by PEDCO Environmental, Inc.

5. Annual regulatory system costs are taken to be equal to the entire 1980 Environmental Protection Agency budget outlays for all air quality programs plus an equal amount for private sector costs. This is an obvious over-estimate of the costs of power plant SO_2 control but more refined data were not avilable. See the Department of Housing and Urban Development and Certain Independent Agencies Appropriations for Fiscal Year 1980, Part I-Justifications, hearings before a subcommittee on appropriations, U.S. Senate, Washington, D.C., 1980.

APPENDIX A

Theory of Visibility

This discussion is limited to those aspects of visibility addressed in this study. More complete treatments can be found in Middleton (1952) and McCartney (1976). The discussion covers the optics of visibility, and the contributing role of specific gaseous and aerosol pollutants and the modeling of visibility.

1) Optics of Visibility

A person sees by the light reaching his eyes from objects. Light is electromagnetic radiation with wavelengths capable of stimulating the receptors in human eyes, covering the range of approximately 0.38 to 0.77 μm. The amount of light energy per unit time received per unit area of detector, per unit solid angle field of view of the detector and per unit wavelength interval at a specific wavelength (see Figure Al) is called spectral radiance, N. This spectral radiance is called inherent radiance, N_o, if the detector is located at distance, r, from the object. The contrast of a target against its background, usually the sky. As with radiance, contrast can be described as inherent or apparent, depending on the distance between the observer and the target. Inherent spectral contrast Co, is defined as:

$$C_o = \frac{{}_tN_o - {}_sN_o}{{}_sN_o} \quad \text{(Al)}$$

and apparent spectral contrast, C_r, is defined as:

$$C_r = \frac{{}_tN_r - {}_sN_r}{{}_sN_r} \quad \text{(A2)}$$

where tNo = inherent spectral radiance of the target at zero distance (watt/m^2 steradian μm)

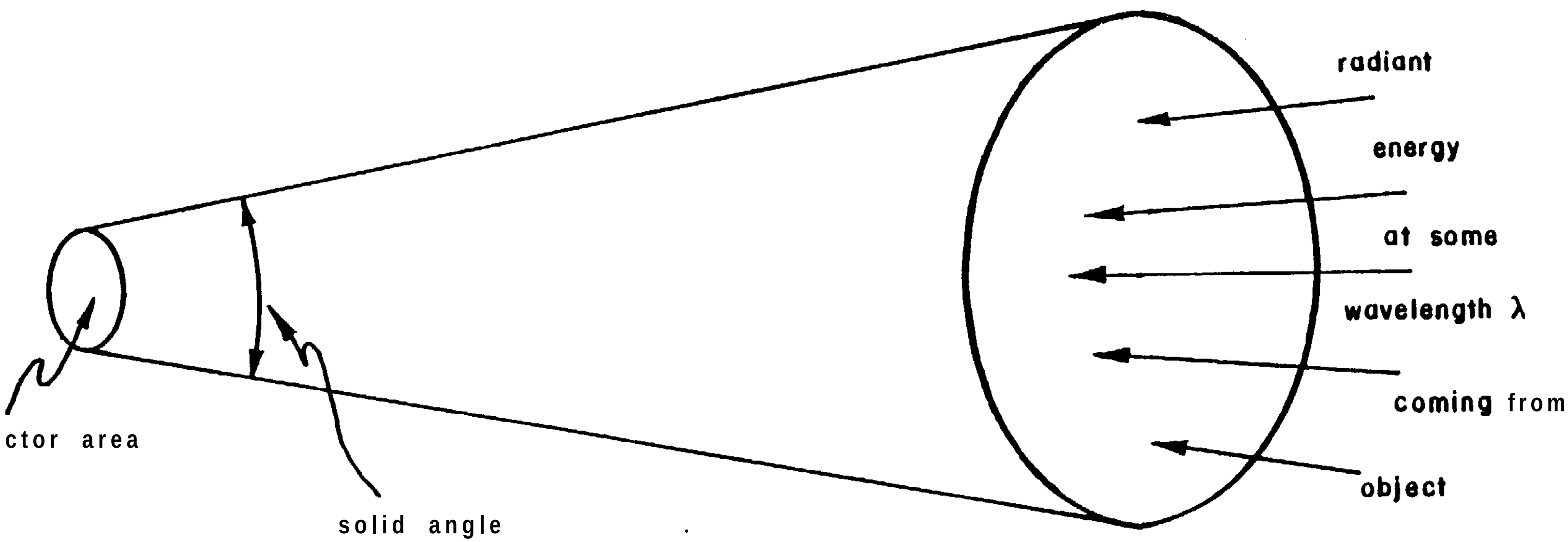
${}_sN_o$ = inherent spectral radiance of the sky at the target (watt/m^2 steradian μm)

tNr = apparent spectral radiance of the target at distance r, and (watt/m^2 steradian μm)

${}_sN_r$ = apparent spectral radiance of the sky at distance r from the target (watt/m^2 steradian pm)

Figure Al

Spectral Radiance



Contrast is dimensionless because it is a ratio of radiances. The light coming from a target is attenuated by scattering and absorption (see Figure A2 and A3). Gas molecules and particulate matter scatter some of the inherent radiance out of the sight path and absorb another portion. Skylight and light reflected from the ground is scattered by particulate and gas molecules into the sight path towards the observer (see Figure A4). The result of these processes is illustrated in Figure A5. A bright object loses radiance as the distance between it and the observer increases, approaching the limiting value of the adjacent horizon sky radiance. A perfectly black object has no inherent radiance. It acquires radiance as the path between it and the observer increases, again approaching the horizon sky radiance as the limiting value. A dark object is an intermediate case. The apparent radiance reaching the observer from a target has two parts, the attenuated inherent radiance and the path radiance added by scattering from the surrounding air. In equation form,

$$ {}_tN_r = {}_tN_o T_r + N_r^* \qquad \text{(A3)} $$

where T_r = transmittance of light from the target to the observer at distance r (dimensionless)

N_r^* = spectral path radiance over distance r(watt/m^2 steradian µm).

Similarly, for the apparent background sky radiance,

$$ {}_sN_r = {}_sN_o T_r + N^*_r \qquad \text{(A4)} $$

If Equation A4 is subtracted from Equation A3, then

$$ {}_tN_r - {}_sN_r = ({}_tN_o - {}_sN_o) T_r \qquad \text{(A5)} $$

Equation AS expresses the fact that the difference in radiance between the target and sky is transmitted to the observer with the same attenuation as each image-forming ray of light. If we divide both sides of Equation A5 by the background sky apparent radiance and multiply the right side of the equation by ${}_sN_o / {}_sN_o$, then

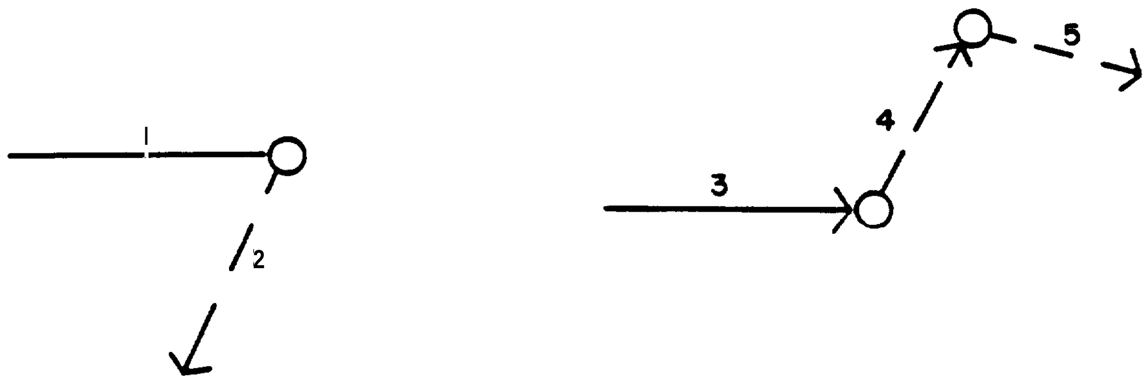
$$ \frac{{}_tN_r - {}_sN_r}{{}_sN_r} = \frac{({}_tN_o - {}_sN_o)}{{}_sN_o} \, \frac{{}_sN_o}{{}_sN_r} \, T_r \qquad \text{(A6)} $$

Combining Equations Al, A2, and A6, we get the following relation for the apparent contrast of a target:

$$ C_r = C_o \frac{{}_sN_o}{{}_sN_r} T_r \qquad \text{(A7)} $$

Apparent contrast depends on the inherent contrast of the target, which depends on the type and amount of vegetation on the target, the illumination of the

Figure A2



Scattering

Scattering: Photon on path I is backscattered along path 2. Photon on path 3 is forward scattering along paths 4 and 5.

Figure A3

Absorption

Absorption: Photon on path 1 is absorbed by the gas molecule or particle.

Figure A4

Sc representation of vision through the

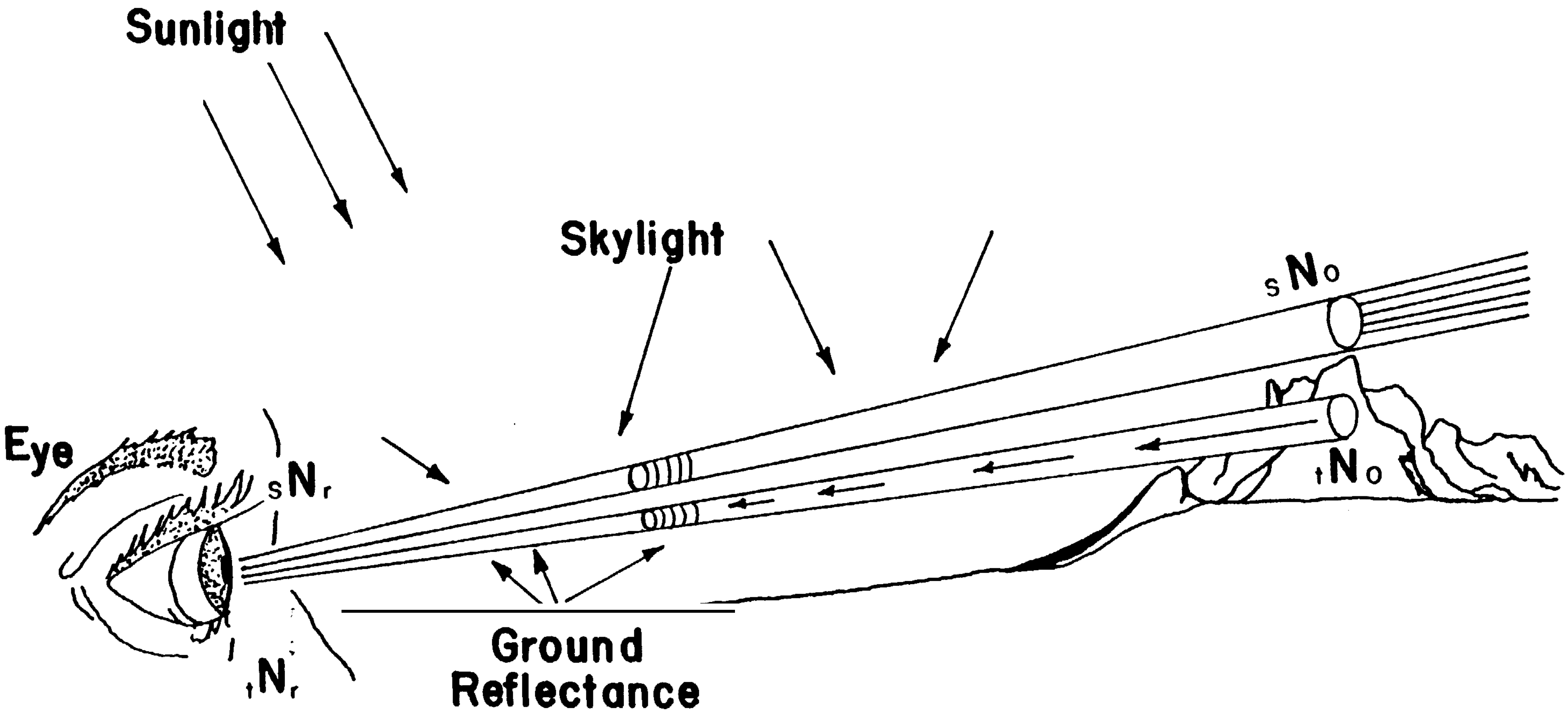
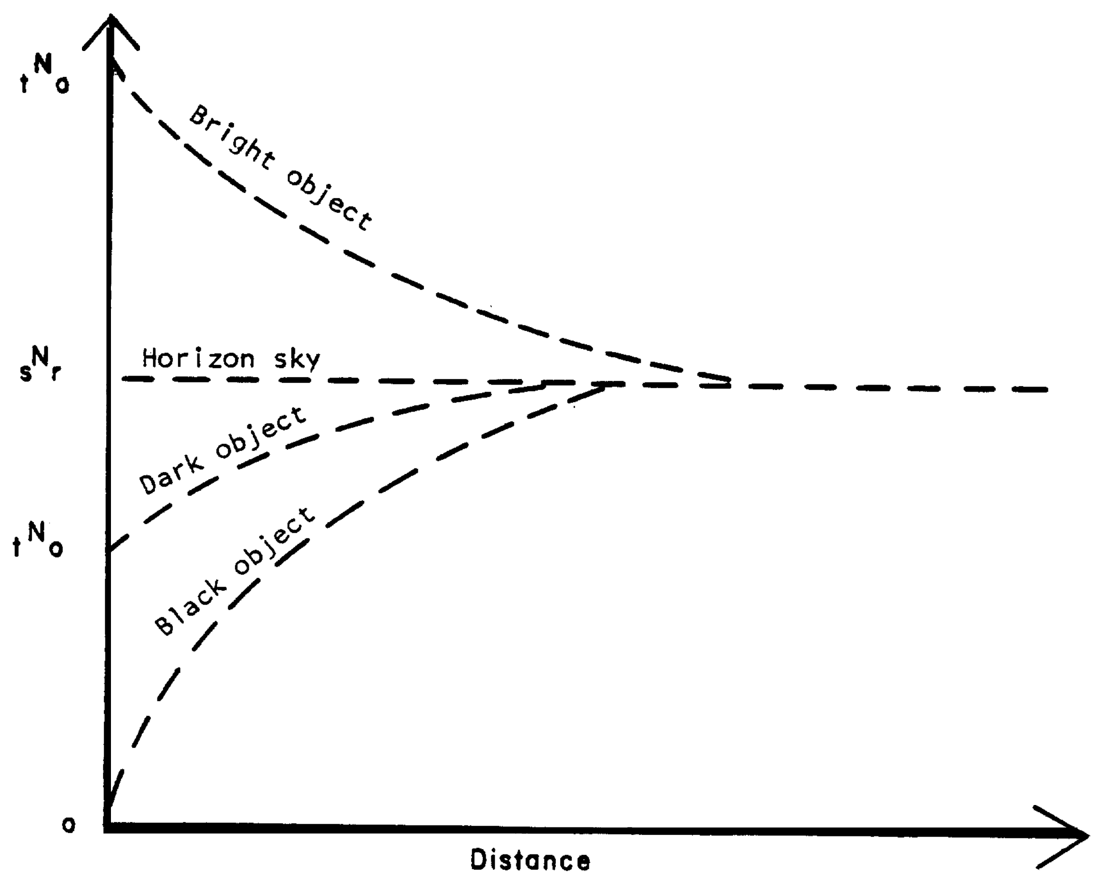


Figure A5

The Dependence of Target Radiance on Distance



target as a function of time of day, latitude, longitude, azimuth of the sight path, azimuth of the normal to the face of the target, and the slope angle of the target. The ratio of sky radiances at the target and at the observer is equal to unity for the theoretical assumption of a uniform atmosphere and a horizontal sight path.

If the atmosphere is homogeneous in composition along the entire sight path, then the transmission, T_r, can be expressed as a function of the extinction coefficient, b_{ext}:

$$T_r = e^{-b_{ext} r} \qquad \text{(A8)}$$

Combining Equations A7 and A8:

$$C_r = C_o e^{-b_{ext} r} ({}_sN_o/{}_sN_r) \qquad \text{(A9)}$$

If C_r and Co are measured with a teleradiometer and r is known, then Equation A9 can be solved for the average extinction coefficient:

$$\bar{b}_{ext} = \frac{1}{r} \ln \left(\frac{C_o}{C_r} \frac{{}_sN_o}{{}_sN_r}\right)$$

The ratio ${}_sN_o/{}_sN_r$ is unity for a horizontal sight path through homogeneous air under uniform illumination on a flat earth.

Under these same conditions visual range is defined as the distance at which the apparent contrast of a black target is reduced to 2 percent ($C_r = -.02$). Equation A9 can then be solved for visual range, VR:

$$VR = \frac{3.912}{\bar{b}_{ext}} = \frac{3.912}{\frac{1}{r}\ln\frac{C_o}{C_r}} \qquad \text{(A10)}$$

The choice of 2 percent as the threshold contrast is easily adjusted to values as high as 5 percent. Middleton (1952) discusses the experiments conducted by others to derive the threshold contrast. It is important to not interpret visual range too literally as the distance at which large black targets disappear. Hence the choice of threshold contrast is not critical but needs to be consistent for comparing different data sets.

This definition of visual range attempts to account for different distances between the observer and targets, and different inherent contrasts. It does not account for targets viewed at different altitudes, for which the atmosphere has a different clean air (Rayleigh) extinction coefficient. Measurements of the apparent contrast of targets at different altitudes are standardized by correcting the total extinction for the Rayleigh component. This correction is made by subtracting the average Rayleigh extinction coefficient of the actual sight path from the measured total extinction and coefficient and then adding back the reference Rayleigh extinction coefficient. This reference is set at .01 km^{-1} corresponding to an altitude of 1550m (Elterman, 1968). Hence standard visual range SVR, is defined by:

$$SVR = \frac{3.912}{\frac{1}{r}\ln\frac{C_o}{C_r} - \bar{b}_{ext,R} + .01} \qquad (A11)$$

where $\bar{b}_{ext,R}$ = average extinction coefficient of the sight path.

The variables discussed so far describe visibility without reference to what it would be in a Rayleigh atmosphere, completely unpolluted by natural or anthropogenic sources. The change in the apparent contrast of a target from its best possible value in a Rayleigh atmosphere is called delta contrast, ΔC, and is defined by:

$$\Delta C = C_r - C_o e^{-\bar{b}_{ext,R}(z_m)r}$$

where $z_m = \frac{z_o + z_t}{2}$

z_m = altitude of sight path midpoint (m).

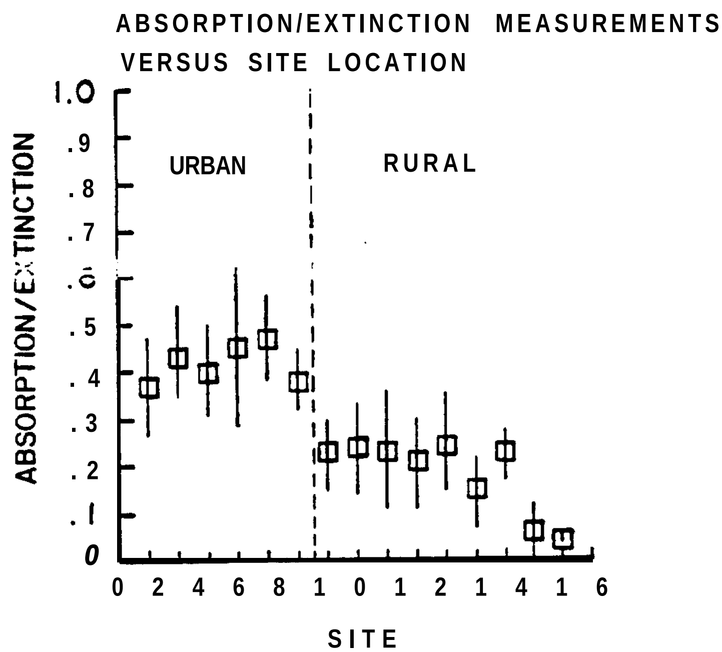
The second term is the apparent contrast of the target computed as if it were viewed through a Rayleigh atmosphere.

Now that several variables describing visibility have been covered, we are ready to discuss the physical processes by which particles and gas molecules affect the transfer of light through the atmosphere.

2) Relating Optics to Pollutants

Particulate and gaseous pollutants attenuate light by scattering and absorption as a function of the gaseous molecular structure, the size and composition of the particles, and the wavelength of light. Most absorption is caused by NO_2 and carbon particles, while most scattering is caused by particles. Any changes in source emissions and meteorology that cause higher concentrations of light scattering or absorbing pollutants will result in increased visibility impairment. Scattering usually dominates absorption, especially in clean air, where 78-95% of the total attenuation is caused by scattering. Scattering is closer to 55-63% of the total attenuation in highly polluted urban areas (Weiss, et al., 1979). The proportional contribution of absorption to total extinction (attenuation) can be seen in Fig. A6.

Figure A6



1. Industrial Seattle, WA.
2. Downtown Portland, OR.
3. Industrial St. Louis, MO.
4. Denver, CO. (fairgrounds)
5. Denver, CO. (trout farm)
6. Central Phoenix, AZ.
7. Residential Seattle, WA.
8; Residential St. Louis, MO.
9. Tyson, MO. (1973)
10, Tyson, MO. (1975)
11, Milford, MI.
12. Hall Mt. AR.
13. Puget Island, WA.
14. Flagstaff, AZ
15. Mauna Loa Observatory, HI

(After Weiss, et al, 1979)

2-1) Gaseous Scattering

Scattering of gases is treated separately from scattering by particles because of important differences. Gaseous scattering has an inverse fourth power dependence on wavelength, which accounts for the blue color of skylight. In Rayleigh unpolluted air, scattering is the dominant process because the nitrogen, oxygen, and other gases absorb a negligible amount of visible light. The Rayleigh scattering by gases depends somewhat on the direction of observation as shown in Fig. A7. Maximum forward and backward scattering is at observation angles of O and 180, and minimum scattering is at 90°.

More detail on the scattering by an individual gas molecule can be found in McCartney (1976). If the scattering by air molecules in a specific direction is summed over all possible directions, the total scattering can be found. Expressing total scattering as a coefficient, the effect of air with a molecular density appropriate to sea level is about 10^{-2} km^{-1}.. Hence, Rayleigh scattering removes about 1% of the incident light per kilometer of horizontal path. Using Eq. AlO, this Rayleigh scattering coefficient translates into a visual range of 391 km, assuming no abosrption nor particulate scattering. Do not expect to see real objects over such distances. Mountains are not black objects and they are not tall enough to be seen at such distances.

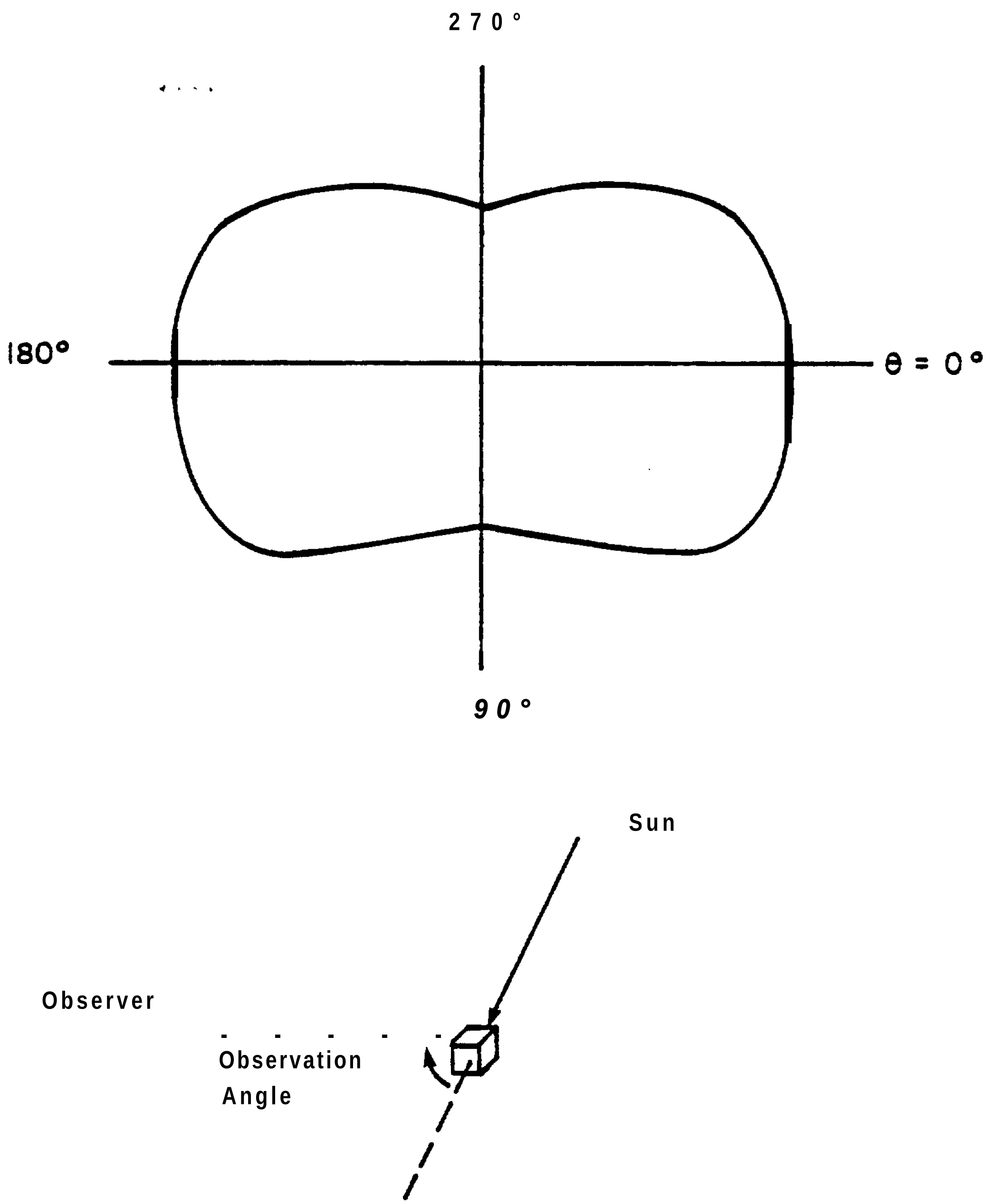
2-2) Particulate Scattering

Scattering by particles is more complex in its angular dependence, which itself depends on the size of the particle. Particulate scattering is often called Mie scattering, after the scientist who developed the first successful theory (Mie, 1980). As particle size decreases, the Mie theory of scattering approaches the Rayleigh theory, appropriate to particles or gas molecules smaller than 1/10 the wavelength of light (McCartney, 1976).

The Mie theory was developed for spherical particles of uniform composition and hence, uniform index of refraction. Ambient aerosol, though, comprises spherical, irregular, plate-like, and rod-like particles. In order to utilize the Mie theory for nonspherical particles, a compromise is made. Size distributions are measured by some instruments in terms of the aerodynamic behavior of the particles, from which an equivalent spherical diameter is computed. This diameter is then used in the Mie theory to predict the approximate scattering of complex shaped aerosol. The angular dependence favors the forward direction, as shown in Fig. A8, with greater complexity as the particle size increases.

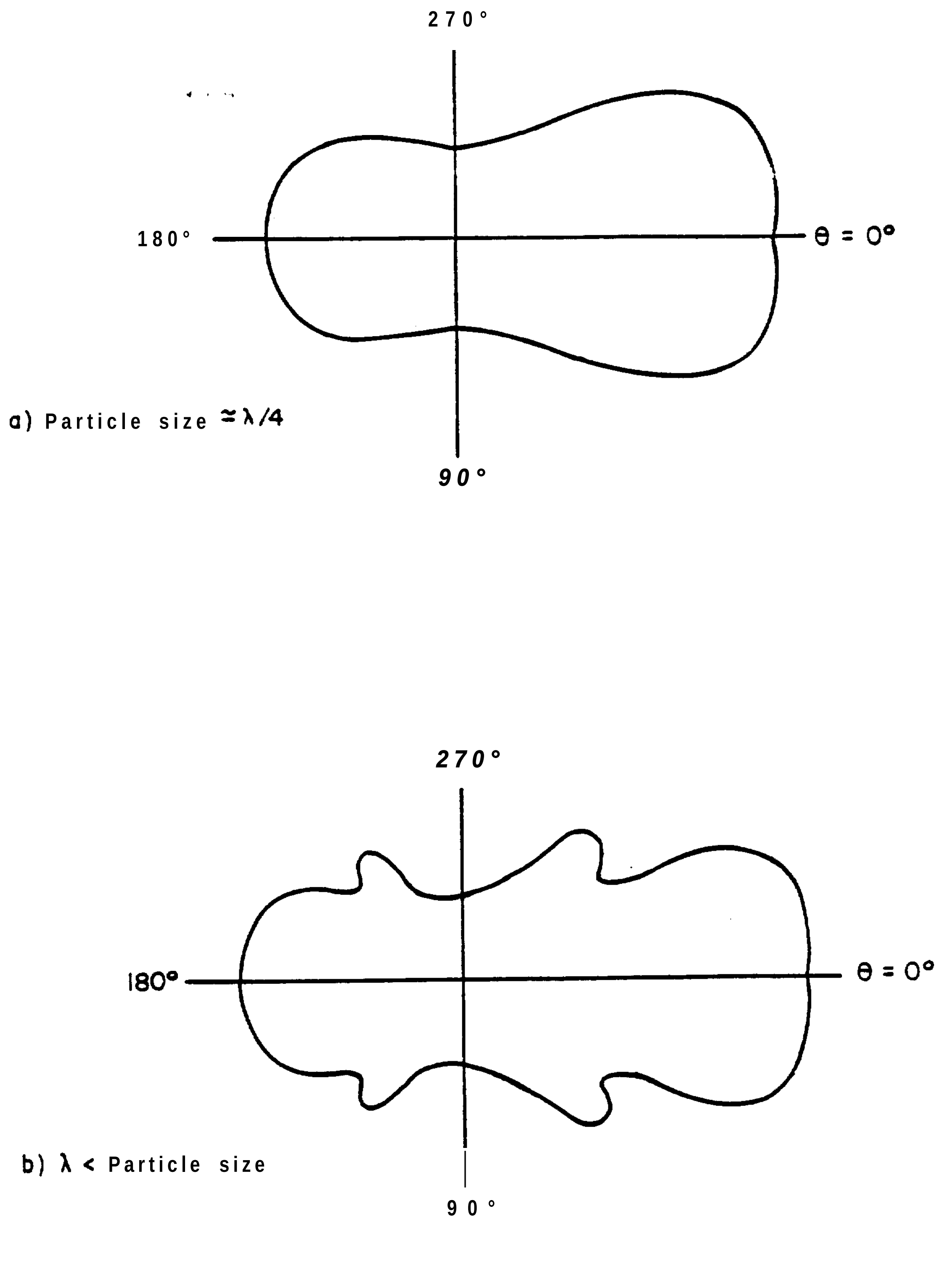
An important aspect of scattering is the efficiency with which particles of different size scatter incident light in all directions. The scattering efficiency factor is defined as the ratio of the total scattering cross-section and the geometric cross-section. For a spherical particle, the geometric cross-section is πr^2, where r is the radius of the particle. The total scattering cross-section is “that cross-section of an incident wave, acted on by the particle, having an area such that the power flowing across it is equal to the total power scattered in all directions” (McCartney, 1976). The dependence of the scattering efficiency factor on the size parameter, $\alpha = 2\pi/\lambda$, is shown in Fig. A9. The relative size of the particle with respect to the

Figure A7



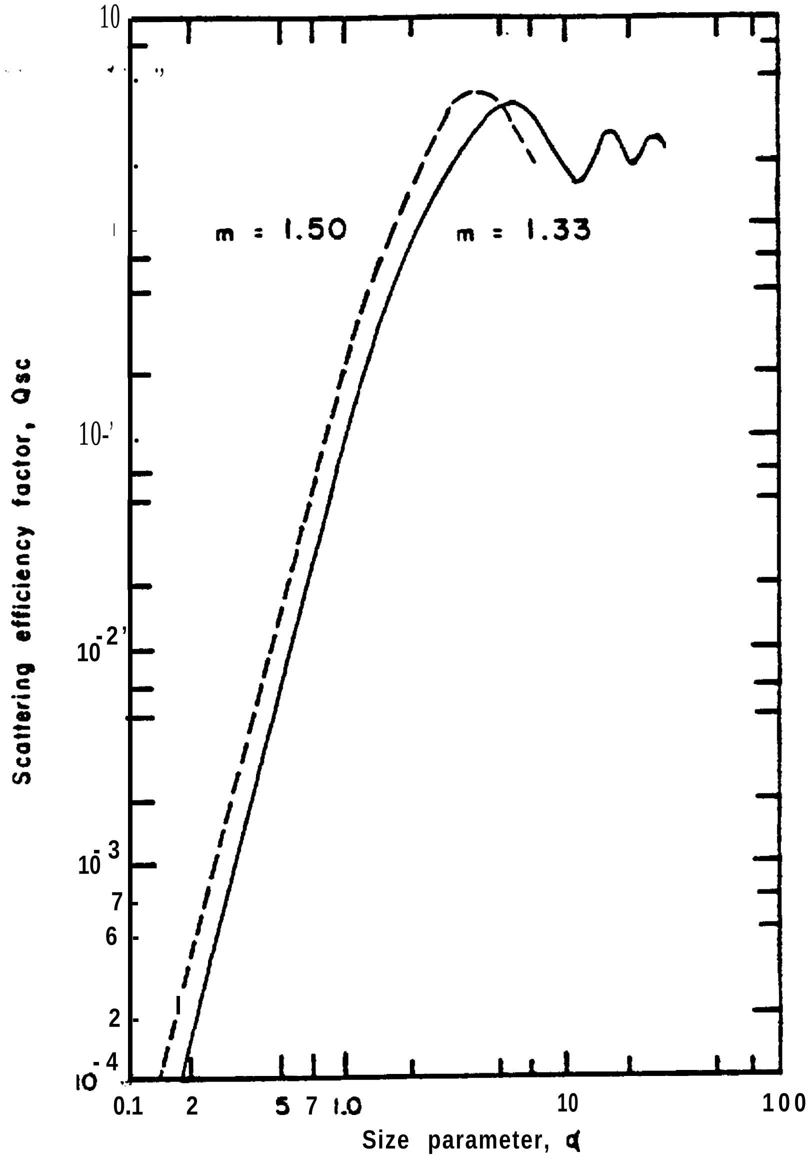
Rayleigh Scattering Dependence on Observation Angle

Figure A8



Observation Angle Scattering Dependence for Particles
(Adapted from McCartney, 1976)

Figure A9



Scattering Efficiency Factor as a function of Size Parameter, a, and Refractive Index. m (After McCartney. 1976) wavelength of incident light, not its absolute size, is the important independent variable, as implied by the use of the size parameter, a. The curve with index of refraction m = 1.33 represents particles of water, while the m = 1.5 curve approximates silica or ammonium sulfate, two critical components related to soil and coal combustion sources respectively. In Fig. A9 the scattering efficiency factor oscillates less and less around a value of 2 as relative size becomes very large. At this value a particle refracts, reflects and diffracts twice the radiant power incident on the geometric cross-section (McCartney, 1976). White and Roberts (1977) found that sulfates and nitrates in the Los Angeles air basin scattered light more efficiently per unit mass concentration than other chemical fractions of the ambient aerosol. The high scattering efficiency of sulfates and the large stationary source emissions of sulfates led these authors to suggest that this source was comparable with the automobile in reducing visibility there.

The size of particles and the resulting light scattering is sensitive to the relative humidity of the air. When the relative humidity rises above 70% water condenses on particles and makes them bigger (Charlson, Waggoner and Thielke, *1978).* The composition of the particle affects the threshold relative humidity, above which water vapor condenses on the particle. The ratio of scattering coefficient at any relative humidity to that at *30%* is plotted in Fig. A10.

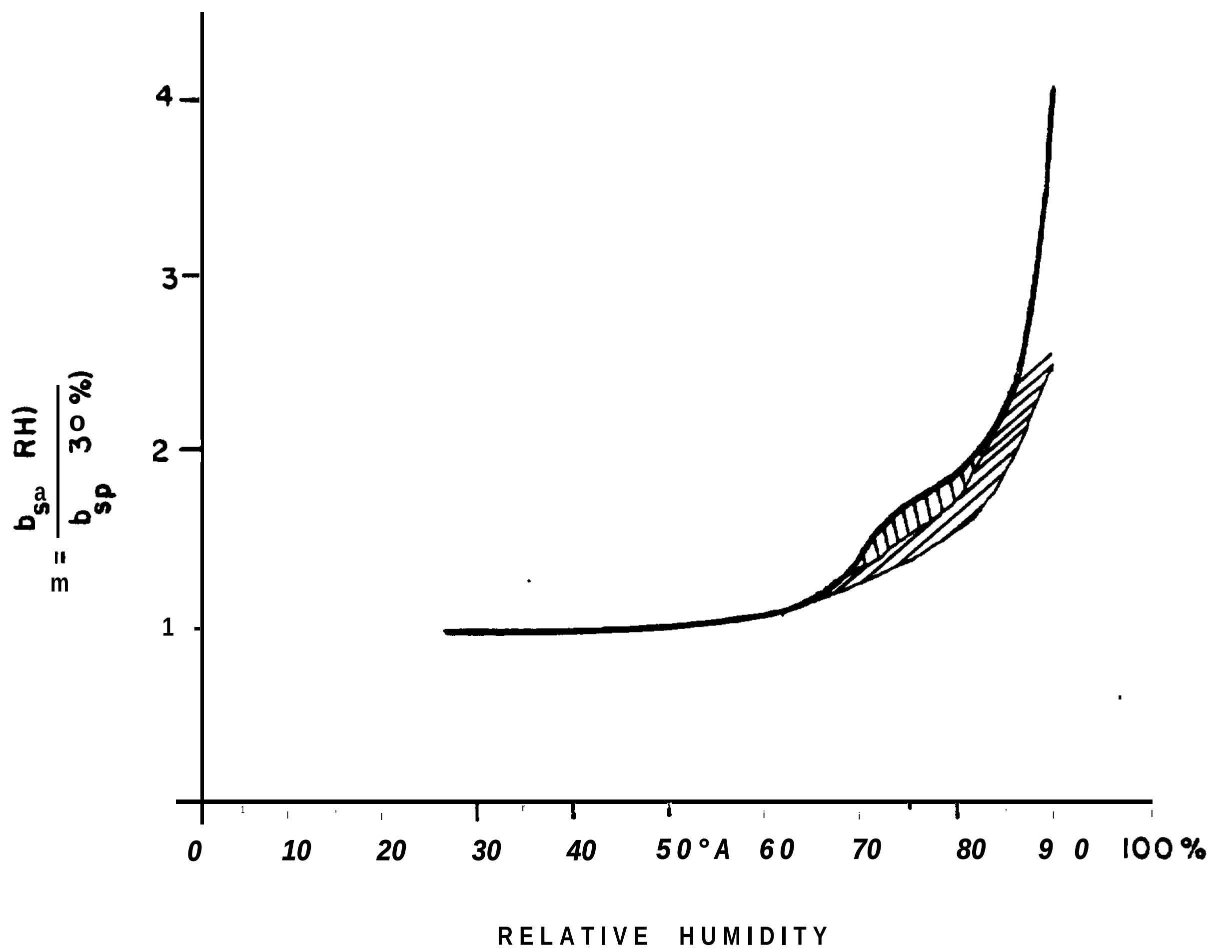
2-3) Absorption

Absorption of light is the process by which the incident light at specific wavelengths is converted to internal energy of molecules (rotation, vibration, and electronic arrangement). A quantum of energy is absorbed for each discrete change in any of these forms of internal energy. The energy of a quantum is inversely proportional to the wavelength of the light or other electromagnetic radiation.

The only absorption of enough consequence in the gaseous air pollutants from power production is that of nitrogen dioxide, NO_2. The absorptivity is the relative loss of incident light per unit length of absorbing path per unit concentration of pollutant. The absorptivity of NO_2 as a function of wavelength is shown in Fig. A11 taken from Hall and Blacet (1952). The absorptivity is strongest in the blue. Also, there are many detailed absorption peaks in the overall curve, whose wavelengths correlate with specific changes in the internal energy of the NO_2 molecule. The strong NO_2 absorption of blue light causes plumes and urban hazes to appear brown. Simultaneous scattering of all wavelengths by particles and scattering of blue by air leads to a variety of brown, gray, and white colors, depending on the relative contribution of these processes.

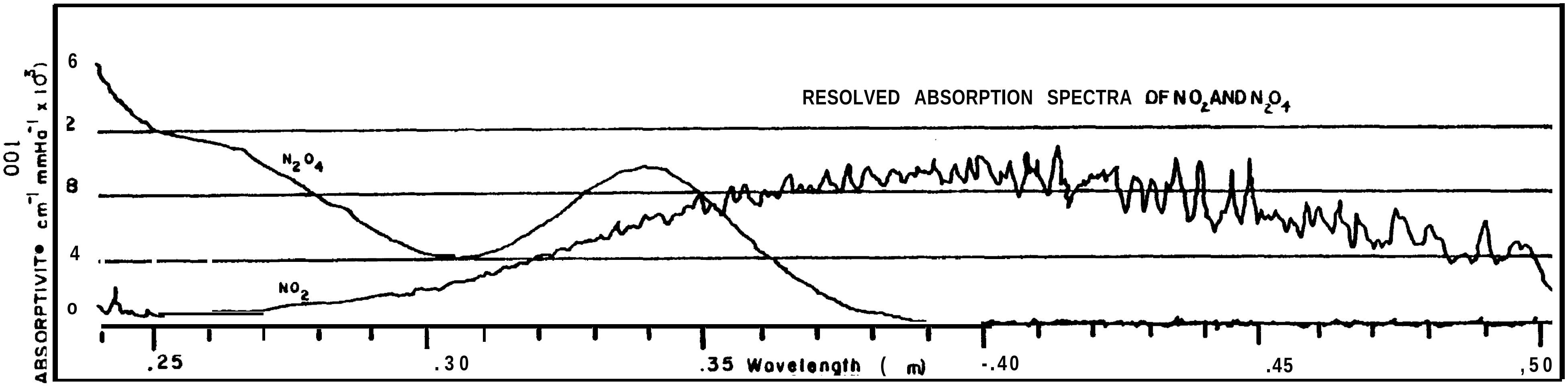
Absorption of light by particles is attributed to their graphitic "soot" content (Rosen, et al., 1979; Weiss, et al., 1979). Faxvog and Roessler (1978) found that carbon particles were most effective in reducing visibility if their diameters were 15-50% of the wavelength of light. Roessler and Faxvog (1980) found that 85% of the acetylene smoke particle attenuation of 514 nm light was caused by absorption and 15% caused by scattering. Roessler and Faxvog *(1981)* found that absorbing aerosols increase the visual range com-

Figure AIO



Range of variability in Humidogram data averaged by site; vertically hatched area includes strongly deliquescent aerosol at Pr. Reyes and Tyson. (Adapted from Charlson, Waggoner and Thielke, 1980)

Figure All



Absorptivity of NO_2 and N_2O_4 vs. wavelength measure at 25°C

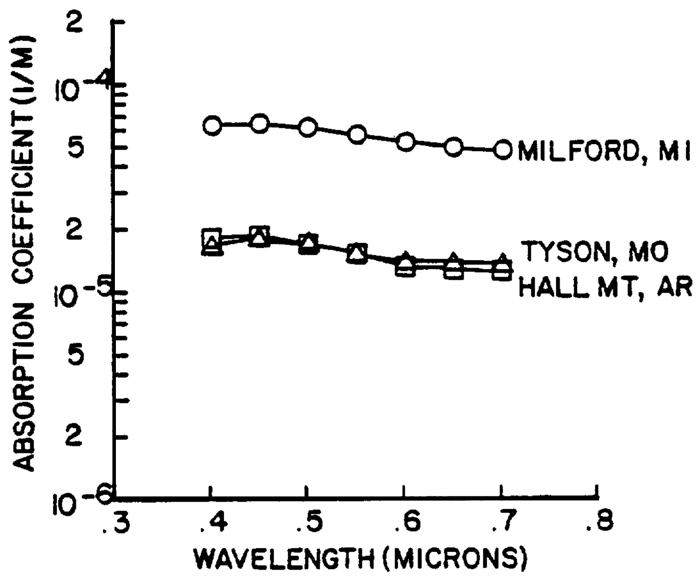
Absorptivity of NO_2 as a function of Wavelength of Incident Light
(After Hall and Blacet, 1952)

puted for light objects viewed against the horizon sky. The dependence of absorption on the wavelength of incident visible light is quite weak as shown by the curves in Fig. All (Weiss, et al., 1979). The effect of absorption in optical computations can be expressed in terms of an absorption coefficient, as plotted in Fig. A12.

The processes by which light is attenuated as it moves through air have been described to help understand the physical measurement of visibility variables. The discussion now moves on to the way we construct complete models of visibility as a function of air pollution.

Figure A12

CHARACTERISTIC ABSORPTION WAVELENGTH DEPENDENCE MEASUREMENTS



Absorption wavelength dependence measurements.

(After Weiss et al, 1979)

APPENDIX B

VALUING PUBLIC GOODS: A COMPARISON OF SURVEY AND HEDONIC APPROACHES'

INTRODUCTION

Although the theory of public goods has progressed rapidly since Samuelson's seminal article (1954), the empirical measurement of the value of (demand for) public goods only recently has received increased attention. Perhaps the best known and most widely accepted empirical approach has been the use of hedonic prices wherein, for example, it is assumed that either wages or housing values reflect spatial variation in public good characteristics of different communities. This indirect approach, based on theoretical work of Tiebout (1956), Lancaster (1966), Rosen (1974) and others has proven quite successful. Among public goods or bads which have been valued using the hedonic approach are climate [Hoch (1974)], air pollution [Anderson and Crocker (1971) and Harrison and Rubinfeld (1978)], social infrastructure [Cummings, et al. (1978)] and other community characteristics such as noise level [Nelson (1979)] and ethnic composition [Schnare (1976)].

An alternative approach is to directly ask households or individuals to state their willingness to pay for public goods using survey techniques. Despite arguments that strategic bias will invalidate survey results, there exists the need for an alternative to the hedonic approach. As an example, consider the case of a remote and unique scenic vista, valuable to recreators, which is threatened by air pollution from a proposed coal fired plant--a typical situation in the Western United States. Although it is possible, in principle, to impute the value of clean air and visibility from the relative decline in local visitation which might follow construction of a power plant, information on the value of visibility at the site is needed prior to construction for socially optimal decisionmaking on plant location and pollution control equipment. The hedonic approach is unavailable both because the scarcity of local population--as opposed to recreators--makes use of wage or property value data impossible and because scenic vistas may themselves be unique. For these 'reasons, Randall et al. (1974) first applied survey methods for valuing visibility and other environmental effects of large coal fired power plants in the Four Corners region of New Mexico. Since this initial application, the survey approach has been widely used to value environmental commodities where market data for hedonic analysis is difficult to acquire [see, for example, Brookshire, Ives and Schulze (1976), Rowe, et al. (1980), and Brookshire, et al. ([1980]). Other early attempts to value public goods using the survey approach include Davis (1963), Bohm (1972) and Hammack and Brown (1974).

Although results of using the survey approach for estimating the value of public goods appear to be internally consistent, replicable and consistent with demand theory [see Schulze et al. (forthcoming)], no external validation has been reported (i.e., a comparative analysis using another approach independent of the survey has not been conducted). Thus, the purpose of this paper is to report on an experiment designed to validate the survey approach by direct comparison to a hedonic property value study.

The Los Angeles 'metropolitan area was chosen for the experiment because of the well defined air pollution problem and because of the existence of detailed property value data. Twelve census tracts were chosen for sampling wherein 290 household interviews were conducted during March, 1978. Respondents were asked to provide their willingness to pay for an improvement in air quality at their current location. Air quality was defined as poor, fair, or good based both on maps of the region (the pollution gradient across the Los Angeles Metropolitan Area is both well defined and well understood by local residents) and on photographs of a distant vista representative of the differing air quality levels. Households in poor air quality areas were asked to value an improvement to fair air quality while those in fair areas were asked to value an improvement to good air quality. Households in good air quality areas were asked their willingness to pay for a region-wide improvement in air quality. The region-wide responses are reported elsewhere [Brookshire, et al. (1980)].

For comparison to the survey responses, data was obtained on 634 single family home sales which occurred between January, 1977 and March, 1978 exclusively in the twelve communities used for the survey analysis. As we show in the next section, households, in theory, will choose to locate along a pollution-rent gradient, paying more for homes in clean air areas based on income and tastes. However, <u>ceteris paribus,</u> we show that the annualized cost difference between homes in two different air quality areas (the rent differential for pollution) will in theory exceed the annual willingness to pay for an equivalent improvement in air quality for a household in the lower air quality area. Thus, the rent differential associated with air quality improvement from hedonic analysis of the property value data must exceed estimates of household willingness to pay for the survey responses, if the survey responses are a valid measure of the value of air quality improvements. Section 3 describes the data analysis and experimental design in more detail.

We also conjecture that the willingness to pay for air quality improvements is greater than zero for residents in our sample communities based on statewide political' support for air quality regulation. The State of California, principally in response to the air pollution problem in the Los Angeles Metropolitan area, has led the nation in imposing automobile emissions standards. The automobile industry, under pressure from the California Legislature, installed the first pollution control devises on California cars in 1961. This initial step was followed nationally in 1963. Again, California imposed the first exhaust-emission control regulations in 1966, leading the nation by two years. Over the decade of the 1970's, California has had more stringent automotive emission standards than Federal levels, resulting in higher initial costs and sacrifices in both performance and fuel economy.

In spite of these difficulties, political support, as reflected both in the State Legislature and in several administrations, has remained strong for auto emission controls.

In Section 4 the results of the hypotheses tests are presented. As Table 2 illustrates, results of the experiment can be summarized as follows: In the nine census tracts where air quality improvements are possible (poor and fair communities), we cannot reject our dual hypotheses that, in each census tract, household willingness to pay for air quality improvements, as estimated by surveying households, falls below equivalent property value rent differentials and lies above zero. We view these results as a qualified verification of the survey approach for estimating the value of public goods. Further interpretation of the results is contained in the concluding remarks offered in Section 5.

A THEORETICAL BASIS

The property value and the survey approaches for valuing public goods have received considerable theoretical scrutiny. Property value studies are conceptually based on hedonic price theory as developed by Rosen (1974) and recently summarized by Freeman (1979). The survey approach has been modeled using standard concepts of consumer surplus by Randall et al. (1974), Bohm (1972), and Brookshireet al. (1976) where the latter two analyses also focus on the possibility of strategic behavior. The considerable empirical evidence now available suggests that strategic bias may be of little consequence both in survey work [See Brookshire et al. (1980) and Rowe et al. (1980)] and in experimental economics [See Grether and Plott (1979), Scherr and Babb (1975) and Smith (1977)]. However, other types of bias may still invalidate a survey approach for valuing public goods. It has even been suggested that the survey approach produces "noise" since responses are purely hypothetical and have no necessary connection to actual budgetary decisions.

In this section, a simple theoretical model is developed for comparison of survey responses to a property value study for valuing air quality improvements in the Los Angeles region in order to determine if valid public good measures can be obtained from survey data.

We use the following notation:

Let P = the level of air pollution

X = consumption of a composite commodity excluding housing

c = unit cost or price of the composite commodity X

R = rent or periodic cost of housing

Y = household income

and U(P,X) = household utility, a decreasing function of pollution $U_P < 0$
an increasing function of consumption $U_X < 0$.[2]

Each household maximizes utility, $U(P,X)$, subject to the budget constraint:

$$Y - CX - R(P) = 0$$

where we assume the existence of a continuous differentiable rent gradient R(P). [See Rosen (1974)] for a complete discussion of the generation and existence of rent gradients. Our model is a simple adaptation of Rosen's, so we will not elaborate here.) Two distinct choices are modeled: consumption of the composite commodity, X, and that of housing location by pollution level, P. Presumably, lower rents will be paid for homes in more polluted areas, so $R'(P)<0$.[3] The first order conditions for choice of P and X imply that

$$c\frac{U_P}{U_X} = R'(P)$$

or that the marginal rate of substitution between pollution, P, and the composite commodity, X, valued at the cost of the composite commodity, C, equals the slope of the rent gradient R' (P) at equilibrium location and consumption levels.

Figure 1 illustrates the solution graphically and allows us to structure hypotheses for testing the validity of survey results in comparison to the property value approach. The vertical axis measures the quantity of the composite commodity, X, where we assume that the cost, C, of the composite commodity is unity; i.e., the vertical axis measures dollars as well. Pollution is on the horizontal axis. Given household income Y^o, the budget constraint, shown as Y^o - R(P) in Figure 1, is obtained by vertically subtracting the rent gradient, R(P). Thus, household A with preferences shown by indifference curve I^o_A would maximize utility at point "a", choosing to locate at pollution level P^o, consume X^o and pay rent R^o. If household A's income were to increase to Y^1, the budget constraint would shift vertically to Y^1 - R(P) and the same household would relocate, choosing point "b", at a lower pollution level P^1 with higher consumption, X^1, given tastes as represented by indifference curve I^1_A. Alternatively, another household, B, with, income Y^o, but tastes as shown by I^3_B would choose point "d", locating at P as well, but choosing lower consumption X^3. Thus, both tastes and income enter location decisions over pollution levels.

The survey approach used in the Los Angeles metropolitan area to obtain an estimate of the value of air quality asked households how much, at most, they would be willing to pay for an improvement in air quality at the site where they presently live. Thus, the household in equilibrium at point "a" in Figure 1 was asked how much X it would forego to experience P^1 rather than PO while maintaining the same utility level. Presumably, household A would be indifferent between points "a" and "c" and be willing to pay W^A dollars (or units of X) to achieve a reduction in air pollution of ΔP. Unfortunately, as is illustrated in Figure 1, the budget constraint, Y^o - R(p), obtainable by estimating the rent gradient function, R(p), does not provide information on the bid for improved air quality, W^A. Rather, the change in rent between locations with air quality levels P^o and P', ΔR in Figure 1, must, for any household located at "a", equal or exceed the bid W^A, if the second order conditions for the household optimization problem are generally satisfied. Thus, we can establish an upper bound on the willingness to pay for air quality improvement by examining the rent gradient. For example, if household B had a lower income, Y, it would locate at point "e". Even though household B is now located at pollution level P^o like household A, its bid for an air quality improvement ΔP would be W^B, smaller than W^A yet still less than ΔR. Thus, if survey bids are a valid measure of willingness to pay for air quality improvements then $\Delta R > W$.

This hypothesis holds for each household even if we consider the case of multiple housing attributes. Including other attributes such as square footage of the home, bathrooms, fireplaces, neighborhood characteristics, etc., denoted by the vector $\vec{Z}$, the model is revised as follows:

$$\text{Max } U(\vec{Z}, P, x)$$

$$\text{St. } Y - Cx - R(\vec{Z}, P) = 0$$

with first order conditions [4]

$$c\frac{U_P}{U_x} = R_P(\vec{Z},P)$$

and

$$C\frac{U_{\vec{Z}}}{U_x} = R_{\vec{Z}}(\vec{Z},P).$$

These first order conditions constitute, along with frequency distributions for housing characteristics and household preferences, a system of partial differential equations which solve for $R(\vec{Z},P)$.[5] Thus, a hedonic rent gradient is defined for pollution, P, and other household characteristics, $\vec{Z}$, as well.

As is illustrated in Figure 1, in which housing characteristics other than pollution are not incorporated, budget constraints for different households are obtained by vertically shifting the same rent gradient. Thus, all households face the same rent differential ΔR for a change in pollution level ΔP even though willingness to pay for that change may differ, i.e., $W^A \neq W^B$. However, turning to Figure 2, household A, located at P^o, may occupy a house with attributes $\vec{Z}^A$ while household B also located at P^o may occupy a house with a different set of attributes $\vec{Z}^B$. Household A, with income Y^A, would then face a rent gradient like that shown in Figure 2 defined by $R(\vec{Z}^A, P)$ and choose point "a", but household B with income Y^B, would now face a different rent gradient of $R(\vec{Z}^B, P)$ and choose to locate at point "b". Therefore, households with different housing characteristics may face different rent gradients over pollution when projected in the (X, P) plane. In general, ΔR, unlike the case shown in Figure 1, will no longer be constant across households at the same location. However, for each household i (i = A, B in Figure 2), it is still true that the rent differential, ΔR_i, for a change in pollution ΔP, calculated for the fixed vector of housing characteristics $\vec{Z}^i$, will exceed that household's willingness to pay, W^i, for the same change in pollution level at the same location. Note that households were asked their willingness to pay with the specific assumption that they remained in the same house and location. Thus, $\vec{Z}^i$, for a particular household was truly fixed --allowing the simple analysis in the (X,P) plane as shown in Figure 2.

The first hypothesis for testing the validity of the survey approach can be constructed as follows: for each household i in a community, $\Delta R^i \geq W^i$. It then follows that in each community the average rent differential across households, $\overline{\Delta R}$, must equal or exceed the average willingness to pay $\overline{W}$ for an improvement in air quality. In other words, if survey bids are a valid measure of willingness to pay, then for each community in our sample, $\overline{\Delta R} \geq \overline{W}$, i.e., average willingness to pay cannot exceed the average rent differential. Our second hypothesis is that, given the political history of air pollution control in the State of California as described in the introduction, mean bids in each community are non-negative, $\overline{W} > 0$.

Our dual test of the validity of survey measures must remain somewhat imprecise because hedonic rent gradients themselves only provide point estimates of the marginal rates of substitution (slopes of indifference curves) between pollution and other goods (money) for individuals with possible differing tastes and income. One does not have information necessary to estimate, for example, the shape of I^A in Figure 1 solely on the basis of the slope of the budget constraint, $R'_A(P^o)$, at point "a". Attempts to estimate individual willingness to pay (W^A in Figure 1) from hedonic rent gradients must thus introduce strong assumptions about the nature of preferences. (See, for an example of an hedonic approach which derives willingness to pay by making such assumptions, Harrison and Rubinfeld [1978].

SAMPLING AND DATA ANALYSIS

The previous section has presented a theoretical framework for a comparison between the survey technique and the property value approach for valuing public goods. In order to empirically implement the comparison, the two approaches require a consistent sampling procedure. This section describes the sampling procedure and results of the separate studies.

Sampling was restricted to households within the Los Angeles metropolitan area. The first concern was air pollution data. Air monitoring stations are located throughout the Los Angeles area providing readings on nitrogen dioxide (NO_2), total suspended particulate matter (TSP) and other pollutants. The objective was to relate as closely as possible the readings of two constituents of air pollution (NO_2 and TSP) to census tracts used both for the property value and survey studies. The air shed was divided into the following air quality regions: "good" (NO_2 < 9 pphm) (TSP < 90 $\mu g/m^3$); "fair" (NO_2 9-11 pphm) (TSP 9-110 $\mu g/m^3$); and "poor" (NO_2 > 11 pphm) (TSP > 110 $\mu g/m^3$).[2] Improvements from poor to fair and fair to good across the region are each associated with about a 30% reduction in ambient pollution levels. Consideration was given to wind patterns and topography of the area in making these distinctions.

Many variables may affect the value households place on air quality. To control for as many of these as possible in advance of the actual experiment, the sample plan identified six community pairs where each pair was relatively homogeneous with respect to socioeconomic, housing and community characteristics, yet allowed for a significant variation in air quality.[6]

The property value analysis attempts to provide external validation for the survey approach. The absence of such validation explains in our view, the lack of general acceptance of survey techniques. The objective, then, is to estimate the hedonic rent gradient R(Z, P) and calculate rent differentials associated with the poor-fair and fair-good air quality improvements for sample census tracts. These results are then utilized for comparison to the survey results.

A hedonic rent gradient was estimated in accordance with literature as recently summarized by Freeman (1979).[7] Housing sale price is assumed to be a function of housing structure variables (living area, bathrooms, fireplaces, etc.), neighborhood variables (crime rate, school quality, population density, etc.), accessibility variables (distance employment to centers and beach) and air quality as measured by total suspended particulate (TSP) or nitrogen dioxide (NO_2).[8] The primary assumption of the analysis is that variations in air pollution levels as well as other household, neighborhood and accessibility attributes are capitalized into home sale price. Implicit or hedonic prices for each attribute are then determined by examining housing prices and attribute levels.

The property value analysis was conducted at the household level in order to provide an appropriate comparison to the survey instrument. Thus, the household data used were at the micro level of aggregation and include a large number of characteristics.[9] Data was obtained for 634 sales of single family homes which occurred between January, 1977 and March, 1978 in the communities used for the survey analysis. In addition to the immediate attributes of the household, variables which reflected the neighborhood and community were included to isolate the independent influence of air quality differentials on home sale price.

As indicated by Mäler (1977) even under the Presumption of correct model specification, estimation of a single equation hedonic rent gradient may be hindered by severe empirical difficulties, primarily multi-collinearity. With respect to this problem, in each of three data categories--household, neighborhood, and air quality--multi-collinearity forced the exclusion of variables and the usage of proxy variables. For instance, collinearity between number of rooms, number of bedrooms and living area as quantitative measures of house size allowed the use only one--living area which serves as a proxy for all. Further, since housing density and population density measure essentially the same phenomenon, only the former is used in the estimated equations. The estimation procedure was not able to separate out the independent influence of each air pollutant. Thus, only one pollution measure, either NO_2 or TSP, was utilized to describe the level of air quality. In order to provide information concerning the sensitivity of our analysis, results are presented for each of these pollutants. Finally, contrary to expectation a collinearity problem did not exist between distance from beach and air pollution. This can be attributed, in part, to the success of the sample plan in isolating the effects of air quality.

Two alternative nonlinear specifications are presented in Table 1 alternatively using NO_2 or TSP to represent pollution level.[10] A number of aspects of the equations are worth noting.

First, approximately 90% of the variation in home sale price is explained by the variation in the independent variable set. Second, with only a minor exception, all coefficients possess the expected relationship to the dependent variable and are statistically significant at the one percent level. The exception is the crime rate in both the NO_2 and TSP equations. Third, in their respective equations, the log form of the pollution variables have the expected negative influence on sale price and are highly significant. The estimated relationship between house sale price and pollution is therefore consistent with the graphical analysis of Section 2; that is, the rent gradient is convex from below in the pollution/dollars plane. Finally, the stability or relative insensitivity of the regression coefficients to the particular pollution variable indicates that individuals have an aversion to pollution in general rather than to any one pollutant.

Estimation of the rent gradient was also completed using other forms of the pollution variables (linear, squared, cubic). Whereas the squared and cubic terms did not demonstrate statistical significance, the first order terms performed only marginally worse than the log formulation. Rent differentials have also been calculated for these and other forms with results nearly identical to those presented here.

The next step was to estimate the rent differential AR. for each individual household for each census tract. The rent differential! specifies the premium an individual household would have to pay to obtain an identical home in the next cleaner air region (poor to fair for six communities, fair to good for three communities). Due to the estimated functional form of the rent gradient, the calculated rent differential is dependent upon the value of all other variables.[11] The average home sale price change based on individual data in each census tract associated with an improvement in air quality, *ceteris paribus*, is shown in column two of Table 2 of the next section. Column one of Table 2 lists communities by air quality level. The table only shows for the log-linear NO_2 equation since, as noted above, other specifications give nearly identical results. The figures shown are derived by evaluating the hedonic housing expression, given the household's characteristics, for a pollution change from poor to fair or fair to good as the case may be. The resulting sale price differential is then converted to an equivalent monthly payment through the standard annualization procedure and division by twelve.[12] Since our hypothesis test is posed in terms of the average rent differential in the relevant communities, then a community mean and standard deviation are calculated. Column three of Table 2 shows the number of homes for which data was available to calculate average rent differentials and standard deviations for each community. Monthly rent differentials ranged from $15.44 to $45.92 for an improvement from poor to fair air quality and $33.17 to $128.46 for an improvement from fair to good air quality. The higher figures in each case are associated with higher income communities. Again, these average differentials should provide an upper bound for the survey results.

The survey approach followed the work of Davis (1963) and Bohm (1972) in gathering the information necessary for estimating a Bradford (1972) bid curve. The approach involves the establishment of a hypothetical market via a survey instrument. Through the work of Randall, et al., (1974) and Brookshire, et al., (1976), the necessary structure for constructing a hypothetical market for the direct determination of economic values within the Hicksian comsumer surplus framework has been developed. The survey reported here is consistent with this previous literature.

The hypothetical market was defined and described both in technical and institutional detail. The public good (air quality) was described by the survey instrument to the respondent in terms of easily perceived levels of provision such as visual range through photographs[13] and' maps depicting good, fair and poor air quality levels over the region. Respondents had little difficulty understanding the levels of air quality represented to them because of the sharp pollution gradient across the region.

Payment mechanism: [4] were specified within the survey instrument and the respondent was asked to react to alternative price levels posited for different air quality levels. In every case the basis for the bid for better air quality was the existing pollution situation as determined by location of their home shown on a map of the Log Angeles metropolitan area which depicted regional air quality levels. Various starting points for the bidding prices and differing information structures were included in the survey format. Biases from alternative starting points and information structures were not present in the. results [See Brookshire, et al. (1980)].[15]

The survey was conducted over the period of March, 1978. A total of 290 completed surveys were obtained for the above mentioned areas.[16] Sampling was random within each paired area.

Table 2 in the next section presents the mean bids and standard deviations and number of observations in Columns four and five respectively for each community for an improvement in air quality. Two types of bids are presented: proposed improvements from poor to fair air quality and from fair to good air quality. In poor communities--El Monte, Montebello and La Canada--the mean bids ranged from $11.00 to $22.06 per month. For the fair communities--Canoga Park, Huntington Beach, Irvine, Culver City, Encino and Newport Beach communities--the mean monthly amounts range from $5.55 to ***$28.18*** to obtain good air quality.

TEST OF HYPOTHESES

The previous sections have described a theoretical structure and two different empirical estimation techniques for determining the value of urban air quality improvements in the Los Angeles metropolitan area. The theoretical relationship between the valuation procedures ($\overline{\Delta R} > \overline{W}$) and the hypothesis that survey bids are non-zero ($\overline{W} > 0$) are tested in this section.

Table 2 presents the community average survey bids (column four) and corresponding rent differentials (column two). As is indicated, in each community the sample survey bids are non-zero and less than the calculated rent differentials in absolute magnitude. This establishes that the survey bid bounds are consistent with our theoretical arguments but does not indicate statistical significance, which is provided below.

With respect to the test of equality of mean survey bids to zero, Table 2 (column six)" presents the experimental results. The calculated t-statistics indicate rejection of the null hypothesis (that the population mean, $\mu_{\overline{W}}$ equals zero at the one percent level in every community sampled.) These resuYts are in accordance with the political situation of the region and indicate that individual households are willing to pay amounts significantly greater than zero for an approximate 30% improvement in air quality.

The comparison of the survey bids to the estimated rent differentials is presented in Table 2 (column seven). In this instance the compound hypothesis that population average rent differential ($\mu_{\overline{\Delta R}}$) equals or exceeds the population average survey bid ($\mu_{\overline{W}}$) is again tested using the t-statistic. Rejection of the null hypothesis requires that the calculated t-statistics be negative and of sufficient magnitude.[17] The standard t-test calculations (column seven, Table 2) imply that the hypothesis $\mu_{\overline{\Delta R}} \geq \mu_{\overline{W}}$ cannot be rejected for the population means $\mu_{\overline{R}}$ and $\mu_{\overline{W}}$ even at the 10% critical level. Although we present only the results for the hedonic housing equation in which log (NO_2) is the pollution measure, these results remain essentially unchanged for all communities, for all estimated hedonic rent gradients, regardless of the variable (NO_2 or TSP) utilized as a proxy for the general state of air quality. The results then are quite insensitive to the particular hedonic model specification, providing a degree of generality to the results.

The hypotheses tests indicate that the empirical analysis is entirely consistent with the theoretical structure outlined above. This conclusion, when combined with the absence of any identified biases [see Brookshire, et al. (1980)] suggests that survey responses yield estimates of willingness to pay for environmental improvements in an urban context consistent with a hedonic-market analysis. A further implication is that individual households demonstrated a non-zero willingness to pay for air quality improvements rather than free riding. This conforms to the previous survey results of Brookshire, et al. (1976) and Rowe, et al. (1980) as well as the experimental work of Scherr and Babb (1975), Smith (1977) and Grether and Plott (1979) concerning the role of strategic behavior. This seems to indicate that the substantive effort to devise a payment mechanism free of strategic incentives for consumers [see Groves and Ledyard (1977)] has been directed towards solving a problem not yet empirically observed. However, the conclusions of this experiment are not without qualifications. In the next section possible limitations of survey analysis and conclusions concerning the efficacy of employing surveys to value a wide range of non-market commodities are discussed.

CONCLUSION

There are a number of limitations in generalizing our results to all survey work. First, this experiment was conducted in the South Coast Air Basin where individuals have both an exceptionally well-defined regional pollution situation and a well-developed housing value market for clean air. The effect of clean air on housing values appears to be exceptionally well understood in the Los Angeles metropolitan area. Thus, the Los Angeles experiment may be a special case in which an informed populace with market experience for a particular public good allowed the successful application of the survey approach. In particular, situations where no well-developed hedonic market exists may not be amenable to survey valuation. Biases due to lack of experience must then be considered a possibility. However, existing studies by Randall et al. (1974) and Brookshire et al. (1976) and Rowe et al. (1980) of remote recreation areas certainly suggest that survey approaches provide replicable estimates of consumer's willingness to pay to prevent environmental deterioration, without prior valuation experience.

In summary, this paper set out to both theoretically and empirically examine the survey approach and to provide external validation for survey analysis. The theoretical model described in Section 2 predicts that survey responses will be bounded below by zero and above by rent differentials derived from the estimated hedonic rent gradient. In order to test the dual hypotheses a survey and a traditional analysis of the housing market were undertaken. Each was based upon a consistent but random sampling procedure in the Los Angeles Metropolitan area. The empirical results do not allow the rejection of either of the two hypotheses, thereby providing evidence towards the validity of survey methods as a means of determining the value of public goods .

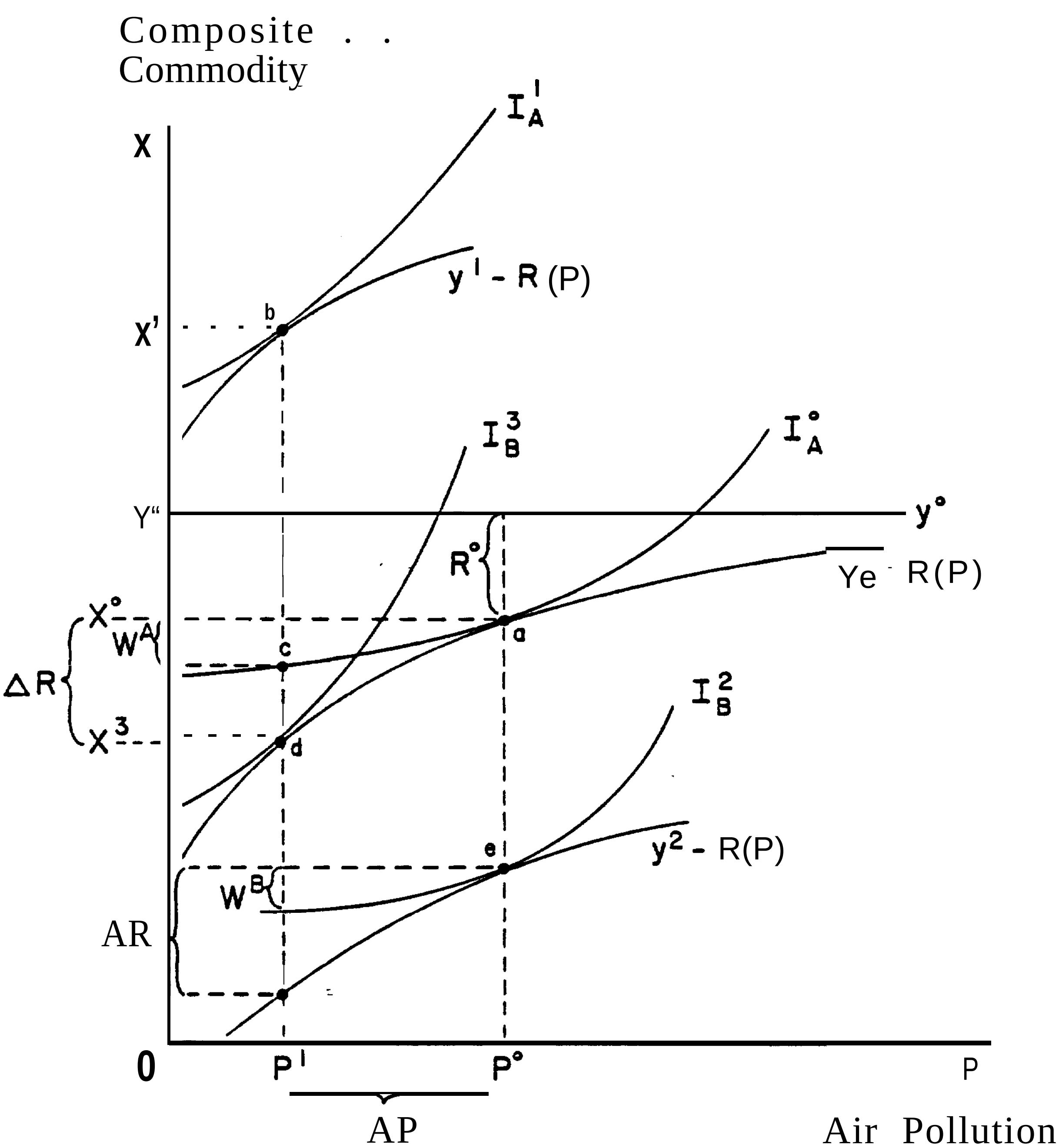


Figure 1

With identical housing attributes the identical rent differential, AR, exceeds individual willingness to pay, WA and W^B.

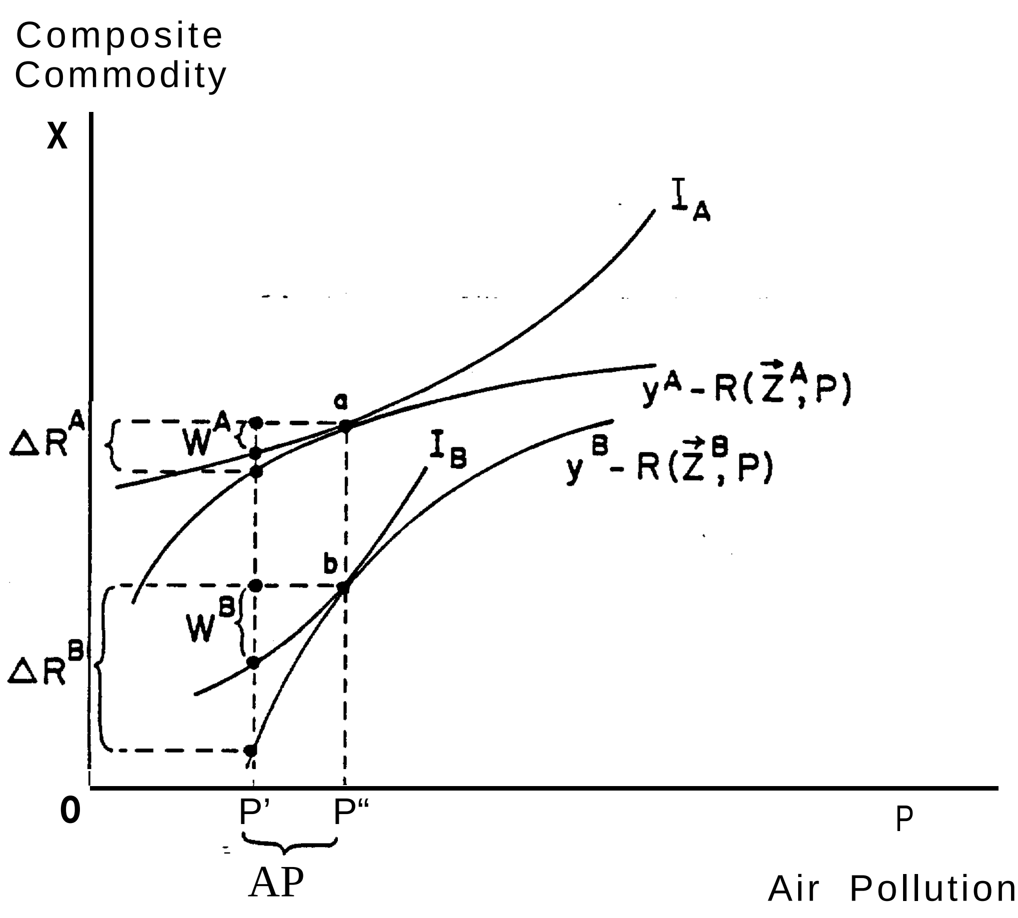


Figure 2

With differing housing attributes across households each individual rent differential exceeds that households willingness to pay.

TABLE 1

Estimated Hedonic Rent Gradient Equations[a]
Dependent Variable= Log (Home Sale Price in $1,000)

Independent Variable	NO_2 Equation	TSP Equation
Housing Structure Variables		
Sale Date	.01859?	.018654
	(9.7577)	(9.7727)
Age	-.018171	-.021411
	(2. 3385)	(-2.8147)
Living Area	.00017568	.00017507
	(12.126)	(12.069)
Bathrooms	.15602	.15703
	(9.609)	(9.66361
Pool	.058063	.058397
	(4.6301)	(4.6518)'
Fireplaces	.099577	.099927
	(7.1705)	(7.1866)
Neighborhood Variables		
Log (Crime)	-.08381	-.10401
	(-.5766)	(-1.9974'
School Quality	.0019826	.001771
	(3.9450)	(3.5769)
Ethnic L.opposition -(Pe cent White)	.027031	.043472
	(4.3915)	(6.2583)
Hous ng Density	-.000066926	-.000067613
	(9. 1277)	(-9.2359)
Publ c Safety Expenditures	.00026192	.00026143
	(4.7602)	(4.7418)
Accessibility Variables		
Distance to Beach	-.011586	-.011612
	(-7.8321)	(7.7822)
Distance to Employment	-.28514	-.26232
	(-14.786)	(14.15s)
Air Pollution Variables		
log (TSP)		-.22183
		(-3.8324)
log (No_2)	-.22407	
	(4.0324)	
Constant	2.2325	1.0527
	(2.9296)	(1.4537)
R^2	.8g	.89
Sum of Squared Residuals	18.92	18.97
Degrees of Freedom	619	619

at - Statistics in Parentheses

Table 2

Tests of Hypotheses

Community	roperty Value Results[a]		Survey Results		Tests of Hypotheses	
	$\overline{\Delta R}$ (Standard Deviation)	Number of observations	$\overline{W}$ (Standard Deviation)	Number of observations	t-statistics $\mu_{\overline{W}} > 0$[b]	t-statistics $\mu_{\overline{\Delta R}} > \mu_{\overline{W}}$[c]
Poor - Fair						
El Monte	15,44 (2.88)	22	11.10 (13.13)	20	3.78	1.51
Montebello	30.62 (7.26)	49	11.42 (15.15)	19	3.28	7.07
La Cañada	73.78 (48.25)	51	22.06 (33.24)	17	2.74	4.10
Sample Population	45.92 (36.69)	122	14.54 (21.93)	56	4.94	5.54
Fair - Good						
Canoga Park	33.17 (3.88)	22	16.08 (15.46)	34	6.07	5.07
Huntington Beach	47.26 (10.66)	44	24.34 (25.46)	38	5.92.	5.47
Irvine	48.22 (8.90)	196	22.37 (19.13)	27	6.08	5.08
Culver City	54.44 (16.09)	64	28.18 (34.17)	30	5.42	11..85
Encino	128.46 (51 .95)	45	16.51 (13.38)	37	7.51	12.75
Newport Beach	77.02 (41 .25)	22	5.55 (6.83)	20	3.63	7.65
Sample Population	59.09 (34.29)	393	20.31 (23.0)	186	12.02	14.00

[a]Rent differentials for the hedonic housing equation in which log (NO_2) is the relevant pollution variable are presented here. Essentially identical results are obtained using NO_2, TSP or log(TSP).

[b]The hypotheses to be tested were $H_0: \mu_{\overline{W}} = 0; H_1: \mu_{\overline{W}} > 0$. All test statistics indicate rejection of the null hypothesis at the 1% significance level.

[c]The hypotheses to be tested were $H_0: \mu_{\overline{\Delta R}} > \mu_{\overline{W}}; H_1: \mu_{\overline{\Delta R}} < \mu_{\overline{W}}$ All Test statistics indicate that the null hypothesis could not he rejected even at the 10% significance level.

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1. David S. Brookshire, Mark A. Thayer, William D. Schulze and Ralph C. d'Arge (forthcoming in the American Economic Review).

2. Alternatively we could define the utility function U(-P, X) which would be an increasing quasi-concave function of both arguments.

3. Primes or subscripts denote derivatives or partial derivatives respectively throughout the paper.

4. The second expression is, of course, a vector of conditions, one for each attribute.

5. For a continuous model one could specify a taste parameter in the utility function and specify a distribution of households over that parameter. To complete a closed model one also needs the distribution of housing units over characteristics.

6. The paired areas with associated census tract marker and air quality level are respectively (1) Canoga Park - #1345 - fair/El Monte - #4334 poor, (2) Culver City - #2026 - fair/Montebello - #4301.02 and part of #5300.02 - poor, (3) Newport Beach - central #630.00 - fair/Pacific - northeast portion of #2627.02 and southwest intersection - good; (4) Irvine - part of #525 - fair/Pales Verdes - portion of good; (5) Encino - portion of #1326 - fair/La Canada - south-central portioof #4607 - poor; (6) Huntington Beach - central portion of #993.03 poor/Redondo Beach - eastern portion of #6205.01 and #6205.02 - good. For a map showing the monitoring station locations in relation to the paired sample areas and the air quality isopleths see Brookshire, et al. (1980).

7. The estimation of a hedonic rent gradient requires that rather restrictive assumptions are satisfied. For Example, Mäler (1977), has raised a number of objections to the hedonic property value approach for valuing environmental goods. These include the possibility that transaction costs (moving expenses and real estate commissions) might restrict transactions leaving real estate markets in near constant disequilibrium; and that markets other than those for property alone might capture part of the value of an environmental commodity. The first of these criticisms is mitigated by the extremely fluid and mobile real estate market of the late 1970's in Los Angeles, where rapidly escalating real property values increased homeowner' equity so quickly that "housejumping" became financially feasible. The second of Mäler's concerns, that other prices, e.g., golf club fees and wages capture part of the willingness to pay can be addressed empirically. For example, attempts to test if wages from our survey data across the Los Angeles area reflected differences in pollution level produced negative results.

8. Note that we use sale price or the discounted present value of the flow of rents rather than actual rent as the dependent variable. Given the appropriate discount rate the two are interchangeable.

9. Housing characteristic data was obtained from the Market Data Center, a computerized appraisal service with central headquarters in Los Angeles, California.

10. Although" the nonlinear equations provide large t 'values on the air pollution coefficients, the coefficients on the pollution variables in the linear-equations possessed the expected relationship and were significant at the 1% level. Also, the calculated rent differentials associated with the linear specifications were larger than those from the nonlinear equations.

11. [t should be noted that the nonlinear estimated equations will give biased but consistent forecasts of rent differentials. However, the linear estimated equations in all cases forecast larger rent differentials than the nonlinear estimated equations presented here.

12. A capital recovery factor equal to .0995 which corresponds to the prevailing .0925 mortgage rate in the January, 1979 - March, 1978 period is used.

13. In developing photographs, two observational paths from Griffith Observatory in Los Angeles were chosen: (1) toward downtown Los Angeles, and (2) looking down Western Avenue. The approximate visibility (discernible objects in the distance, not visual range) for poor visibility was 2 miles, for fair visibility 12 miles, and for good visibility 28 miles.

14. Payment mechanisms are either of the lump sum variety, or well specified schemes such as tax increments or utility bill additions. The choice in the experimental setting varies according to the structure of the contingent market.

15. Questions have been raised as to problems of biases in the survey' approach. Strategic bias (i.e., free rider problems), hypothetical bias, instrument bias all have been explored. Generally speaking, problems of bias within the survey approach have not been prevalent. For a general review of the definition of various biases and results of different-experiments see Schulze et al. (forthcoming) and for investigations of strategic bias utilizing other demand revealing techniques see Scherr and Babb (1975) and Smith (1979).

16, Interviewer bias was not present. No records were kept that would enable the testing for non-respondent bias.

17. For instance, rejection of the null hypothesis ($\mu_{\overline{\Delta R}} \geq \mu_{\overline{W}}$) at the one percent level would require a calculated t-statistic less than -2.326 given a large number of observations. Since none of the calculated t-statistics are negative the null hypothesis cannot be rejected [See Guenther (1973)].

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APPENDIX C

VISIBILITY QUESTIONNAIRE

URBAN SURVEY: Economics Narrative

We are students at the University of Wyoming [New Mexico," Chicago] and are conducting this survey for a research project designed to help in valuing visibility in the national parks in the Southwestern United States.

The Clean Air Act, passed by Congress in 1970, declared a national goal of preserving the scenic beauty and pristine air quality of our national parks and wilderness areas.

Air quality, or the "cleanness" of the air, can be affected by either natural occurrences (e.g. dust and humidity) or by man-caused pollution (such as autc emissions or emissions released by industrial facilities). Consequently, visibility, which is the ability to see and appreciate distant objects, activities, scenes, or atmospheric phenomena, can be affected by either natural or man-caused pollution sources resulting in changes in the color and clarity of near and far distant vistas.

As you can see in these photographs taken at the Grand Canyon, air pollution can discolor a view to the point where its components cannot be clearly identified and its scenic beauty cannot be fully enjoyed by the viewer [SHOW GRAND CANYON PHOTOGRAPHS: SITUATION A-E].

These photographs represent five levels of visibility during morning and afternoon periods looking both east and west from Hopi Point at the Grand Canyon. Column A represents poor visibility, B below average, C average visibility, D above average, and E good visibility. Comparing the columns, we can see the variety of air quality conditions and resulting levels of visibility that can be observed in the Grand Canyon. The rows represent the different vistas while standing at Hopi Point. The first row represents the different visibility and air quality conditions looking east, in the morning from Hopi Point. The second row represents morning conditions looking west from Hopi Point. The third row shows the view from Hopi Point in the afternoon looking west.

PAST AND FUTURE USE

In the first part of our survey, we would like to ask a few questions about your use of the National Parklands.

El) How many days have you spent visiting the Grand Canyon National Park in the last 10 years? Please put an X by the number of days on your answer sheet for question El.

E2) How many days do you expect to spend visiting the Grand Canyon National Park in the next 10 years? Please put an X by the number of days on your answer sheet for question E2.

E3) How many days have you spent visiting National Parks in the Southwest (Arizona, Utah, New Mexico, and Colorado) in the last 10 years? Please circle the number of days by each National Park on your answer sheet for question E3.

E4) How many days for each National Park do you expect to visit in the next 10 years? Please circle the number of days by each National Park on your answer sheet for question E4.

[FOR EXISTENCE VALUE ANALYSIS, TURN TO PAGE 7 AND BEGIN WITH QUESTION E8. FOR uSER ANALYSIS (EVERY THIRD INTERVIEW), CONTINUE WITH QUESTION ES. NOTE: NUMBER OF VISITS MUST BE GREATER THAN ZERO IN QUESTIONS El AND E2 TO CONDUCT USER ANALYSIS.]

GRAND CANYON ANALYSIS

. . . -User-

This part of the survey is designed to determine how much you are willing to pay to improve visibility in the area of Grand Canyon National Park.

Although one does not usually place a dollar value on scenery, sunsets, or visibility, such things are valuable to most people. Since it does cost money to clean up man-made pollution to improve visibility in our National Parks, we are interested in finding out how much good visibility is worth to you.

First let's assume that visitors to Grand Canyon National Park are to pay for improvements in the air quality and therefore in the visibility, by paying an increase in daily entrance fees to be admitted into the park. Let's also assume that all visitors to the park would pay the same total daily fee as you would. Then, all the additional money collected would be used to finance the air quality improvements represented in the photographs.

Again, let us look at the photographs representing the different levels of visibility and air quality ranging from very poor (A) to very good (E) for east and west views in the morning and afternoon from Hopi Point in the Grand Canyon. We would like to know how much you are willing to pay as a total daily park entrance fee for your household for air quality improvements and resulting visibility improvements shown in Columns B through E. When deciding how much you are willing to pay for each improvement, you will always be comparing the improved air quality to the lowest air quality conditions as represented in Column A. Also, when considering how much you are willing to pay for each improvement, assume each photograph represents the visibility on a day that you would be visiting the Grand Canyon National Parks.

[SHOW COLUMNS A-B]

E5) This is Column A, representing very poor air quality and visibility. Please indicate on your answer sheet how much of an increase above the total daily park fees of $2.00 per carload you would be willing to pay for your household to improve the visibility to that shown in Column B. Put a B next to the highest dollar amount you would pay per day if you were visiting the Grand Canyon in question E5 on your answer sheet.

[MOVE COLUMN C TO COVER B]

Now, for your household, how much of an increase above the total daily park entrance fees of $2.00 per carload for your household would you pay for cleaner air if the visibility was improved from that shown in Column A to. that shown in Column C? Please put the letter C next to the highest amount you would pay per day in question ES on your answer sheet.

[MOVE COLUMN D TO COVER C]

For your household, how much of an increase above the total daily park entrance fees of $2.00 per carload would YOU be willing to pay for an improvement from Column A to Column D? Please put the letter D next to the amount in question E5.

[MOVE COLUMN E TO COVER COLUMN D]

And finally, for your household, how much of an increase above the total daily park entrance fees of $2.00 per carload would you pay to have air quality and visibility conditions on a day of your visit to Grand Canyon be like Column E as compared to Column A? Put the letter E next to the amount you would pay as a daily park entrance fee in question E5 on your answer sheet.

REGIONAL ANALYSIS

.... -User-

Unless new and current industrial facilities in the Southwest are required to utilize air pollution controls for particulate and sulfur oxide emissions, visibility in the region will become less than the current average.

Let's look at some pictures representing regional visibility. Columns A-E again represent air quality conditions from very poor (A) to very good (E). The rows represent morning conditions for the Grand Canyon, Mesa Verde and Zion National Parks. Row 1 looks out from Hopi Point towards the east in the morning at the Grand Canyon. Row 2 represents the vista from Hess Verde at Far View overlook towards the south in the morning. Finally, Row 3 is at Lava Point in Zion National Park looking southeast in the morning.

If current emission standards are maintained, the average conditions will be as seen in Column C. If, however, current emission standards on existing and proposed industrial facilities are relaxed or not enforced, then average air quality and visibility in the region will be represented as in Column B. As shown in Column B a deterioration in visibility would occur in the Grand Canyon, Zion and Mesa Verde National Parks. As a result, conditions as represented in Columns C, D, and E will occur less frequently. Conditions in Columns A and B would occur more frequently. We would like to know how much the maintenance of average regional air quality and visibility is worth to you.

E6) How much would you be willing to pay per day in addition to existing park entrance fees for your household at the Grand Canyon, Mesa Verde, or Zion National Parks to prevent a deterioration in visibility in the region as represented in moving from Column C to Column B. [SHOW PHOTOGRAPHS AND POINT TO COLUMNS C AND B FOR GRAND CANYON, MESA VERDE AND ZION.] Assume that entrance fees would be raised throughout the National Parks in the Southwest. Please put an R next to the dollar amount closest to the highest increase in daily entrance fees you would be willing to pay for your household for a <u>region-wide</u> preservation in visibility for question E6.

E7) If you answered "$0" to any part of questions E5 or E6, please answer question E7 on your answer sheet.

[TURN TO PAGE 11, QUESTION E11 (PLUME USER ANALYSIS)]

EXISTENCE VALUE ANALYSIS

-Grand Canyon-

This part of the survey is designed to determine your' concern for preserving visibility levels in Grand Canyon National Park.

Although one does not usually place a dollar value on scenery, sunsets, or visibility, such things are valuable to most people. Since it does cost money to clean up man-made pollution to improve visibility in our National Parks, we are interested in finding out how much good visibility is worth to you .

Unless new and current industrial facilities in the Southwest are required to meet current emission standards for particulate and sulfur oxides, air quality in the Grand Canyon will become less than the current average.

Again, let us look at the photographs representing visual air quality ranging from very poor in Column A to very good in Column E for east and west views in the morning and afternoon from Hopi Point. If current emission standards are maintained the average conditions will be as seen in Column C. [f, however, the current emission standards for sulfur oxide are not enforced, then average air quality and visibility in the region will become like Column B. As a result, conditions are represented in Columns C, D and E will occur frequently in the Grand Canyon. Such emission controls will likely make electricity more expensive.

E8) We would like to know if you would be willing to pay higher electric utility bills if the extra money collected would be used for additional air pollution controls to preserve current air quality and visibility levels at the Grand Canyon. How much extra would you be willing to pay at most, per month as an increase in your electric utility bill to preserve current average visibility as represented in Column C rather than have the average deteriorate to that shown in Column B? Please put an X next to the highest amount you would be willing to pay per month for your household on your answer sheet for question E8. [EMPHASIZE THEY ARE ANSWERING E8.]

EXISTENCE VALUE

. . . -Regional Analysis-

Unless new and current industrial facilities in the Southwestern United States are required to utilize air pollution controls for particulate and sulfur oxide emissions, visibility in the region will become less than the current average.

Let's look at some pictures representing regional visibility. Columns A-E again represent air quality conditions from very poor (A) to very good (E). The rows represent morning conditions for the Grand Canyon, Mesa Verde and Zion National Parks. Row 1 looks out from Hopi Point towards the east in the morning at the Grand Canyon. Row 2 represents the vista from Mesa Verde at Far View overlook towards the south in the morning. Finally, Row 3 is at Lava Point in Zion National Park looking southeast in the morning.

If current emission standards are maintained the average conditions will be seen in Column C. If, however, current emission standards on existing and proposed industrial facilities are relaxed or not enforced, then average air quality and visibility in the region will be represented as in Column B. As shown in Column B a deterioration in visibility would occur in the Grand Canyon, Zion and Mesa Verde National Parks. As a result, conditions as represented in Columns C, D and E will occur less frequently. Conditions in Columns A and B would occur more frequently. We would like to know how much the maintenance of average regional visibility is worth to you.

E8) How much more than you have already offered to pay for the Grand Canyon would you be willing to pay in higher electric utility bills per month to preserve current average air quality and visibility levels throughout the Parklands of the Southwest? Visibility conditions as represented in the photographs in Column C would be maintained as opposed to allowing air quality and visibility to deteriorate to the new average levels shown in photographs in Column B. Please place an R by the increase in monthly electric utility bills you would be willing to pay for your household for question E8.

E9) If you answered "$0" to E8, please answer E9 on your answer sheet.

[TURN TO PAGE 11, QUESTION E12 (PLUME EXISTENCE VALUE)]

PLUME ANALYSIS (USER)

E1O) Problems other than regional haze can be associated with industrial development in the Southwest region. Plumes also can reduce visibility by disrupting a vista on the horizon. These photographs represent two situations whereby in picture A no plume can be seen looking west from Hopi Point in the Grand Canyon. Pciture B is identical, however, a plume is visible. We would like to know how much you are willing to pay in addition to the daily park entrance fees of $2.00 for your household for prevention of plume blight over the Grand Canyon. Please put the letter A next to the highest dollar amount you would pay per day if you were visiting the Grand Canyon for question E1O on your answer sheet.

[CONTINUE WITH SOCIO-ECONOMIC QUESTIONS ON THE LAST PAGE OF ANSWER SHEET]

PLUME ANALYSIs (EXISTENCE VALUE)

En) Problems other than regional haze can be associated with industrial development in the Southwest region. Plumes can reduce air quality and impair visibility by visually disrupting a vista on the horizon. We would like to know if you are concerned with preserving visibility in Grand Canyon National Park from plume blight.

These photographs represent two situations whereby in picture A no plume can be seen looking west from Hopi Point in the Grand Canyon. Picture B is identical, however, a plume is visible. Again focusing on the possibility of higher utility bills, how much extra would you be willing to pay at most, monthly, as an increase in your electric utility bill to preserve the vista as seen in picture A rather than have plume blight as represented in picture B? Please put the letter A next to the highest amount you would be willing to pay per year for your household on your answer sheet for question En.

[CONTINUE WITH SOCIO-ECONOMIC QUESTIONS ON LAST PAGE OF ANSWER SHEET]

ANSWER SHEET

E1)

______ 1 Day	______ 5 Days	______ 9 Days	______ 13 Days
______ 2 Days	______ 6 Days	______ 10 Days	______ 14 Days
______ 3 Days	______ 7 Days	______ 11 Days	______ 15 Days
______ 4 Days	______ 8 Days	______ 12 Days	______ More than 15 Days

E2)

______ 1 Day	______ 5 Days	______ 9 Days	______ 13 Days
______ 2 Days	______ 6 Days	______ 10 Days	______ 14 Days
______ 3 Days	7 ______ Days	______ 11 Days	______ 15 Days
______ 4 Days	______ 8 Days	______ 12 Days	______ More than 15 Days

E3)

Zion Nat. Park 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 More than 15
Mesa Verde Nat. Park 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 More than 15
Bryce Canyon Nat. Park 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 More than 15
Canyonlands Nat. Park 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 More than 15

E4)

Zion Nat. Park 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 More than 15
Mesa Verde Nat. Park 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 More than 15
Bryce Canyon Nat. Park 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 More than 15

E5)

$ .00 ______/day	$4.00 ______/day	$ 15.00 ______/day
.50 ______/day	5.00 ______/day	20.00 ______/day
1.00 ______/day	6.00 ______/day	25.00 ______/day
1.50 ______/day	7.00 ______/day	50.00 ______/day
2.00 ______/day	8.00 ______/day	75.00 ______/day
2.50 ______/day	9.00 ______/day	100.00 ______/day
3.00 ______/day	10.00 ______/day	More than $100.00 ______/day

E6)

$ .00 ______/day	$ 4.00 ______/day	$ 15.00 ______/day
.50 ______/day	5.00 ______/day	20.00 ______/day
1.00 ______/day	6.00 ______/day	25.00 ______/day
1.50 ______/day	7.00 ______/day	50.00 ______/day
2.00 ______/day	8.00 ______/day	75.00 ______/day
2.50 ______/day	9.00 ______/day	100.00 ______/day
3.00 ______/day	10.00 ______/day	More than $100.00 ______/day

E7) Answer only if you answered $.00 to the above questions. Did you bid zero because you believe that:

_____ The air quality improvements represented in the columns are not significant.

_____ The source' of the air pollution should be required to pay the costs of improving the air quality.

_____ Other (specify) ______________________________

____

E8)

$ .00 _____/year	$25.00 _____/year	$50.00 _____/year	$100.00 _____/year
5.00 _____/year	30.00 _____/year	60.00 _____/year	125.00 _____/year
10.00 _____/year	35.00 _____/year	70.00 _____/year	150.00 _____/year
15.00 _____/year	40.00 _____/year	80.00 _____/year	175.00 _____/year
20.00 _____/year	45.00 _____/year	90.00 _____/year	200.00 _____/year
		More than	$200.00 _____/year

E9)

$ .00 _____/year	$25.00 _____/year	$50.00 _____/year	$100.00 _____/year
5.00 _____/year	30.00 _____/year	60.00 _____/year	125.00 _____/year
10.00 _____/year	35.00 _____/year	70.00 _____/year	150.00 _____/year
15.00 _____/year	40.00 _____/year	80.00 _____/year	175.00 _____/year
20.00 _____/year	45.00 _____/year	90.00 _____/year	200.00 _____/year
		More than	$200.00 _____/year

E10) Answer only if you answered $.00 to the above questions. Did you bid zero because you believe that:

_____ The air quality improvements represented in the columns are not significant.

_____ The source of the air pollution should be required to pay the costs of improving the air quality.

_____ Other (specify) ______________________________

____

En)

$ .00 _____/day	$ 4.00 _____/day	$ 15.00 _____/day
.50 _____/day	5.00 _____/day	20.00 _____/day
1.00 _____/day	6.00 _____/day	25.00 _____/day
1.50 _____/day	7.00 _____/day	50.00 _____/day
2.00 _____/day	8.00 _____/day	75.00 _____/day
2.50 _____/day	9.00 _____/day	100.00 _____/day
3.00 _____/day	10.00 _____/day	More than $100.00 _____/day

E12) $ .00 ____/day . $ 4.00 ____/day $ 15.00 ____/day
.50 ____/day 5.00 ____/day 20.00 ____/day
1.00 ____/day 6.00 ____/day 25.00 ____/day
1.50 ____/day 7.00 ____/day 50.00 ____/day
2.00 ____/day 8.00 ____/day 75.00 ____/day
2.50 ____/day 9.00 ____/day 100.00 ____/day
3.00 ____/day 10.00 ____/day More than $100.00 ____/day

E13) ____1 time ____4 times ____7 times ____10 times
____2 times ____5 times ____8 times ____11 times
____3 times ____6 times ____9 times ____12 times

E14) ____1 time ____4 times ____7 times ____10 times
____2 times ____5 times ____8 times ____11 times
____3 times ____6 times ____9 times ____12 times

E15) $ .00 ____/year $25.00 ____/year $50.00 ____/year $100.00 ____/year
5.00 ____/year 30.00 ____/year 60.00 ____/year 125.00 ____/year
10.00 ____/year 35.00 ____/year 70.00 ____/year 150.00 ____/year
15.00 ____/year 40.00 ____/year 80.00 ____/year 175.00 ____/year
20.00 ____/year 45.00 ____/year 90.00 ____/year 200.00 ____/year
More than $200.00 ____/year

E16) Home zip code ____________ E17) ____ Rural ____ Suburban ____ Urban

E18) Education: under 12 years ____
High School ____
College - no degree ____
Bachelor's degree ____
Post-graduate degree ____

E19) Age group: under 18 ____
18-24 ____
25-34 ____
35-44 ____
45-54 ____
55 & over ____

E20) Sex: ____Male ____Female .

E21). How many members are there in your household? ____ persons

E22) Are you the primary income earner in your household? ____yes ____no

E23) Would you please indicate which of the following groups your annual household income falls in:

____ less than $5,000
____ $ 5,000-7,499
____ $ 7,500-9,999
____ $10,000-14,999
____ $15,000-19,999
____ $20,000-24,999
____ $25,000-29,999
____ $30,000-34,999
____ $35,000-39,999
____ $40,000-44,999
____ $45,000-49,999
____ $50,000-54,999
____ $55,000-59,999
____ $60,000-64,999
____ $65,000-69,999
____ $70,000-74,999
____ $75,000 and up

INTERVIEWING SUPPLEMENT

[Additional information to be used by interview teams only if necessary. Please note on answer sheet if this material was used!]

Scientific Basis of Photographs

The photographs you have been shown have been produced in the following manner: Throughout the National Park System, photographs are being taken twice a day (morning and afternoon) every day of the year at major overlooks. Sophisticated electronic equipment, an instrument called a telephotometer, is used to get a physical measure of visibility at the same time the photos are being taken. This physical measure is called apparent contrast. Apparent contrast is a measure of visual air quality. This measure is based on the difference in light between a distant target (a mountain, for instance) and the background sky. Apparent contrast can also be measured directly in the photographs, which allows calibration between physical measurements and the photographs. As a result of this data collection effort, we know how often conditions shown as in columns A-E occur over a typical year.

What Causes Poor Visibility

Humidity (water in the air), dust (especially fine particulate), and the gasses making up the atmosphere themselves all reduce visibility. Man-caused pollution can contribute to poor visibility. Two types of fine particulate are partly caused by man: sulfates and nitrates. Emissions of nitrogen oxides (gasses formed from atmospheric gasses under high temperature and/or pressure) react in the atmosphere to form nitrates. Both automobiles and industry are major sources of nitrogen oxides. Emissions of sulfur oxides (gasses resulting from, for example, a combination of sulfur in fuels or ores with oxygen) also react in the atmosphere to form sulfates. Industry, especially power plants and smelters, is the primary source of sulfur oxide emissions. The contribution of sulfates and nitrates to poor visibility has been determined by taking air samples during known visibility conditions and running the air sample through a filter to capture particulate matter. Sulfates and nitrates have been :shown to make a significant contribution to the visibility problem. Records from airports in the Southwest show that visibility has declined from an average of about 100 miles to about 80 miles over the last twenty years.

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