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Department of
Agriculture

Forest Service

REPORT TO CONGRESS

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Potential Impacts of Aircraft Overflights of National Forest System Wildernesses

Prepared pursuant to Section 5, Public Law 100-91, National Park Overflights Act of 1987

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PREFACE/ACKNOWLEDGMENTS

This Report to Congress provides the U.S. Department of Agriculture, Forest Service response to Public Law (PL) 100-91, the National Park Overflight Act of 1987. The information presented herein represents the combined efforts of dozens of scientists and technicians, and is a summary of work conducted over a 3-year period. The authors of this report, Dr. Lawrence Hartmann, Robin T. Harrison and William Makel, have abstracted large sections of several technical reports that were prepared for this effort. Acknowledgment of these information sources is provided at the beginning of this report's chapters.

To create a more readable document, many technical details and terms have been simplified. Also, some background information has been provided to explain why and how this study was conducted. For those wishing to read about these studies in more detail, and go over the extensive data tables, the source technical reports are available from the National Technical Information Service (NTIS), Department of Commerce, Springfield, VA.

Completion of this work required combining, for the first time, two fields—psychoacoustics and wilderness sociology—into a new field we have called wilderness psychoacoustics, meaning the study of how wilderness users respond to the acoustic environment. Considerable thought (and sometimes heated discussion) was required to blend these two disparate fields. The following individuals, listed by their affiliation, were instrumental in contributing to the birth of this new field.

- *BBN Systems and Technologies*—Dr. Sanford Fidell, Dr. Barbara Tabachnick, Ms. Laura Silvati, Mr. Karl Pierson, Mr. Matt Sneddon, and Mr. Rick Howe
- *Colorado State University*—Dr. Glen Haas and Dr. Mike Manfredo
- *Arizona State University*—Dr. Richard Knopf
- *Texas A&M University*—Dr. James Gramman
- *University of Wyoming*—Dr. Thomas Buchannan.

Other major contributors to this study are:

- *Harris Miller Miller & Hanson Inc.*—Mr. Nickolas Miller, Mr. Grant Anderson, Mr. Richard Horonjeff, and Mr. Carl Hanson
- *United States Geological Service*—Mr. Kenneth King
- *Hubbs Sea World Research Institute*—Dr. Ann Bowles.

Members of a Core Team, who provided agency oversight for this effort:

- *USDA Forest Service*—Dr. Lawrence Hartmann, sociology; Mr. Robin Harrison, P.E., acoustics; and Mr. William Makel, National coordinator.
- *USDI National Park Service*—Mr. Steve Hodapp, Dr. Wes Henry, Mr. Elmer Hernandez, and Mr. Richard Ernenwein.

Special thanks goes to the following:

• *USDA Forest Service*—Dr. Anne Fege, Mr. John Eckert, and Ms. Andrea Fowler of the Washington Office, plus all of the field personnel who assisted in the field work.

Finally, other valuable input was provided by our Technical Review Group (see appendix C), composed of recognized experts from several related fields.

OVERVIEW

REPORT TO CONGRESS *Wilderness Aircraft Overflight Study*

WHY WAS THIS REPORT PREPARED?

Congress—in Public Law (PL) 100-91 passed on August 18, 1987—directed the Forest Service (FS) and the National Park Service (NPS) to conduct studies of aircraft overflights which may be impacting visitors or resources of the National Forest System wildernesses and the National Parks and report the results to Congress. The NPS, but not the FS, is required to make recommendations for legislative and regulatory action which should be taken regarding the information gathered in the study.

WHAT IS THE OBJECTIVE OF THE REPORT?

To provide Congress with facts and information about the impacts of aircraft overflights on visitors and resources of the National Forest System wildernesses. A separate Report to Congress will be prepared by the NPS for the National Park System lands.

HOW DID WE ORGANIZE TO DO THE ASSESSMENT?

The NPS and FS cooperatively participated in the aircraft overflight studies through an interagency agreement. The main studies were conducted by contracting with firms having the required technical expertise A Core Team, composed of FS and NPS personnel, directed and monitored this effort. This procedure allowed us to utilize the best experts in the appropriate fields while avoiding the need to increase staff for a limited-term project.

The San Dimas Technology and Development Center (SDTDC) provided acoustical expertise and technical oversight to both agencies and a FS National Coordinator. FS Research provided wilderness sociological expertise.

The FS will continue to cooperate and provide technical input to NPS until completion of the NPS studies.

WHAT WAS STUDIED?

The major emphasis of this study was to determine the effects of aircraft overflights on visitor enjoyment. Input from wilderness visitors was obtained by means of personal and telephone interviews of such visitors during and shortly after their wilderness visits. This was done so as to assess the actual impact from exposure to aircraft overflights on people using wilderness, rather than merely assess the general public's opinion about the philosophical question of whether aircraft overflights are compatible with wilderness.

Surveys of both FS wilderness managers and wilderness visitors were conducted to provide the basis of assessing the impact of aircraft overflights on the safety of wilderness visitors. Analytic studies of current literature were conducted to assess the effects of aircraft overflights on wildlife and cultural resources. A review of literature was also made to assess the effects of aircraft altitude on noise levels in wilderness. Benefits to wilderness visitors and benefits that further the purposes for which the National Forest System is managed were reviewed.

WILDERNESS VISITOR ENJOYMENT

WERE ALL WILDERNESSES INCLUDED IN THESE STUDIES?

Not all wildernesses administered by the FS are included in these studies. A sample of wildernesses representing a broad spectrum of aircraft exposure conditions and visitor use conditions were selected in which to conduct an assessment of impacts. As stipulated in PL 100-91, this report does not consider any National Forest System wilderness in Alaska, nor does it apply to any aircraft flights associated with landing fields in or adjacent to National Forest wilderness.

WHAT WILDERNESSES WERE INCLUDED IN VISITOR SURVEYS?

The Superstition, Cohutta, Golden Trout, Glacier Peak, Dolly Sods, Indian Peaks, Scapegoat, High Unitas, Caney Creek, Bridger, Wild Rouge, and Pemigewasset wildernesses were included in the visitor surveys. Visitors to all twelve wildernesses were interviewed by telephone shortly after returning home from their wilderness trip. A total of 1,180 completed interviews was obtained; 100 interviews in all of the wildernesses except Bridger and Scapegoat, which had 99 and 81, respectively.

Visitors to the Golden Trout, Superstition, and Cohutta Wildernesses were also interviewed on-site. A total of 920 completed interviews was obtained; 185 interviews in the Golden Trout Wilderness, 343 in the Cohutta Wilderness, and 392 in Superstition Wilderness.

Data on wilderness user demographics, activities, and use patterns were similar between the surveys conducted for this assessment and other wilderness user studies.

WHAT ACOUSTIC MEASUREMENTS WERE MADE?

Acoustic measurements made in conjunction with the on-site visitor surveys included long-term average A-weighted sound levels, short-term recording of indigenous and overflight sound levels, and at-ear measurements of the self-noise of hikers and horseback riders.

Acoustic measurements in conjunction with the telephone interview surveys included hourly sound levels over a 24-hr period, the long-term average sound level, and measurement of the sound level of individual aircraft flyovers.

Several additional acoustic measurement studies developed more information about the nature and extent of overflights and indigenous sound levels in FS wildernesses.

WHAT WAS LEARNED?

- Aircraft noise intrusions did not appreciably impair surveyed wilderness users overall enjoyment of their visits to wildernesses nor reduce their reported likelihood of repeat visits.

- The majority of wilderness users interviewed were not annoyed by overflights, a minority (16 percent) was annoyed in some degree, and a smaller minority (4 percent) highly annoyed by overflights.

- Three of the most often mentioned reasons for visiting wilderness (selected from a list of possible reasons) were experiencing peace and quiet (89 percent of respondents); viewing scenic vistas without hearing sounds of civilization (87 percent); and hearing the sounds of nature (81 percent).

- Most visitors (76 percent) were very or extremely satisfied with the absence of sounds of civilization. However, visitors who were annoyed by aircraft noise reported less satisfaction with the absence of sounds of civilization.

- Overflights were only rarely cited as the least-liked feature of visits to wildernesses.

- Low-altitude, high-speed aircraft were reported as the most annoying type of aircraft to hear or see.

- Although many visitors were not exposed to noise from low-altitude, high-speed flights, those who were exposed were often annoyed by them.

- The intensity of aircraft noise-induced annoyance decreased with elapsed time between exposure and self-report.

- For the same level of aircraft noise exposure, the prevalence of annoyance among wilderness visitors was greater than that of residential populations.

- Annoyance associated with overflights was more strongly related to noise exposure than to the visibility of aircraft or their condensation trails.

- Annoyance with overflights can be more accurately predicted from actual physical measures of noise exposure, than from the visitors' own reports of numbers of aircraft noticed.

- Military tactical aircraft (both fixed and rotary wing) were reported to be more annoying than small propeller-driven aircraft or high-altitude jet transports.

- Although wildernesses are often overflown by commercial air transports at high altitudes, most are overflown less frequently by small, propeller-driven aircraft at intermediate altitudes, and fewer are regularly overflown by helicopters and tactical military aircraft at low altitude.

- Aircraft altitude alone is a poor predictor of overflight noise audible to wilderness visitors.

- Aircraft are readily audible at great distances in wilderness because of the low levels of indigenous sounds.

- Levels of indigenous sounds in coniferous forests are predictable to a considerable degree from wind speed.

- Aircraft overflights are audible even when their sound levels are comparable to the level of indigenous sounds.

SUMMARY

Few adverse impacts to wilderness users were found resulting from aircraft overflights of FS-managed wildernesses. The worst case found was a fairly small percentage of wilderness visitors who experienced varying degrees of noise-induced annoyance. Further, comparing overflights reported by visitors with actual overflights identified by acoustic recorders, it appears that many visitors do not notice aircraft even when they are present. This is especially true for high-altitude jet aircraft.

As would be expected, it appears that the most meaningful aircraft-related problems for wilderness users are in those wildernesses at which the greatest numbers of outdoor recreationists are most commonly exposed to the noisiest overflights; i.e., low-altitude, high-speed tactical military operations and low-flying helicopters. The problem generated by these types of flights is largely due to the startling of visitors. Military overflights are not a problem in all wildernesses at all times, as they do not occur in all wildernesses and generally do not occur on a frequent basis. Therefore, these types of flights are not encountered by most wilderness visitors.

VISITOR AND EMPLOYEE SAFETY

HOW WAS THIS STUDY CONDUCTED?

Historical records were examined to identify long-term wilderness safety issues. A year-long survey of FS wilderness managers was initiated to catalog reported accidents. Finally, participants in the wilderness visitor surveys were questioned directly.

WHAT WAS LEARNED?

FS Annual Reports show that between 1979 and 1989, three accidents were reported in which aircraft were reported to have caused accidents to people on the ground. In each case, low-flying military jets spooked horses which in turn threw their riders. No other aircraft-caused accidents of people on the ground were reported during this 10-yr period.

A managers' survey of 264 FS wildernesses was conducted throughout calendar year 1990. No accidents were reported where aircraft flying overhead caused accidents to wilderness visitors or employees on the ground.

Respondants to the on-site visitor surveys were questioned about accidents. Of the 1,180 visitors contacted, 2.7 percent (32 visitors) reported involvement in an accident during their visit. None were related to aircraft overflights.

Results of these studies indicated that while there is potential for aircraft to cause accidents to either wilderness visitors or employees, incidents are rare. The only circumstances under which aircraft posed a threat to visitor or employee safety was when visitors on horseback were startled by low-flying military aircraft.

WILDLIFE

HOW WAS THIS STUDY CONDUCTED?

Existing literature on the impacts of aircraft overflights to wildlife was reviewed. No field studies were conducted.

WHAT WAS LEARNED?

Studies of effects of human intrusions on animals often find profound impacts. It is thus commonly assumed that aircraft overflights are equally damaging. The literature suggests that animals respond differently to aircraft overflights. Aircraft overflights are often initially startling, but animals generally adapt to them very well under most circumstances. Effects of overflights are subtle because animals adapt by habituating behaviorally and physiologically to the challenge. In fact, the study led to the conclusion that overflights generally pose negligible risks of consequential biological effects on wildlife.

WHY WEREN'T FIELD STUDIES CONDUCTED?

The major deficiencies of prior studies relating to this subject are the lack of knowledge on impacts to wildlife populations, and the lack of proper documentation of actual sound exposure. The conduct of long-term studies to determine these impacts is beyond the scope of this effort.

CULTURAL RESOURCES

HOW WAS THIS STUDY CONDUCTED?

Existing literature on the impacts of aircraft overflights to cultural resources was reviewed. No field studies were conducted.

WHAT WAS LEARNED?

Many cultural resources are remote and uninhabited, so documented observations of aircraft noise effects on cultural resources are rare. Generally, concerns that aircraft noise causes damage are based on speculation. There is, however, some current evidence that long-term effects of noise exposure could result in damage by initiating or accelerating the deterioration process. The evidence of potential damage risk is more theoretical than empirical.

Cultural resources in National Forest wildernesses are not currently threatened by sonic booms. No National Forest wildernesses are located within supersonic Military Operating Areas (MOA's). High-altitude supersonic flight tracks cross wildernesses, but the overpressures produced at these altitudes are very low, and well below the threshold of risk to cultural resources.

Very limited information has been obtained on the response of structures to subsonic aircraft and helicopters. Measurement programs have been conducted which conclude there is normally a minimal risk of damage to structures from light, low-flying, subsonic jet aircraft and light helicopters. However, a recently developed prediction method places a definite risk of damage to prehistoric structures from low overflights of heavy bombers and a significant risk of damage to these resources from heavy helicopters.

ALTITUDE RESTRICTIONS

WHY LOOK AT ALTITUDE RESTRICTIONS?

Many have speculated that the impact of aircraft noise on wilderness will be reduced if airplanes fly at a higher altitude, since it is commonly known that sound levels decrease with distance from a source.

HOW WAS THIS STUDY CONDUCTED?

A review of existing literature on how altitude affects loudness on the ground.

WHAT WAS LEARNED?

Increases in aircraft height generally reduce loudness, but with "diminishing returns." The sound-level reductions become ever smaller with increasing height. In general, moderate-to-large benefits (4 to 10 dB, or so) require an approximate doubling of the distance between the aircraft and the sound-sensitive area on the ground. Where existing distances are small, their doubling may come easily. On the other hand, where existing distances are large, their doubling is essentially impossible.

Only when current aircraft overflights are at very low altitude (1,000 ft, or below) will significant reductions in sound be realized by increasing altitude. Conversely, for most flights, practical increases in altitude will not greatly change the impact of sound at ground level.

OVERFLIGHT BENEFITS

WHAT ARE THE BENEFITS TO WILDERNESS VISITORS?

Many Americans, who cannot travel on foot or horseback, value and wish to see the beauties of wilderness. Persons with disabilities; the elderly; or persons restricted by time or family constraints are some examples. For such persons, scenic overflights may be the only wilderness experience available to them.

WHAT ARE THE BENEFITS TO THE FS?

A review of aviation operations on National Forests having wilderness (excluding Alaska) indicates that about 6,000 hr of flying over wilderness is done annually in support of forest management objectives.

Fire Management in the wilderness has both emergency and non-emergency aspects; both often involve support by aircraft. Fire detection and suppression account for over 60 percent of FS flying over wildernesses. Aviation operations in support of resource management accounts for an additional 20 percent of the FS flying over wildernesses.

The use of aircraft in law enforcement and search and rescue account for another 17 percent of the use. When life-threatening situations involving visitors or Government employees occur, aircraft are frequently the only effective means to respond. Of 3,159 search and rescue operations reported in the FS Annual Wilderness Reports between 1979 and 1989, inclusive, over 47 percent (1,500) utilized aircraft to assist with the search and rescue operation.

FS policy requires line officer approval of any management use of aircraft in wildernesses, except for take-off and landing from approved airstrips. This policy minimizes the intrusions of aircraft into the wilderness environment, but allows aircraft to be used to help protect wilderness and the safety of the wilderness visitor.

CHAPTER 1

INTRODUCTION

The purpose and background of the Wilderness Aircraft Overflight Study mandated by PL 100-91 are presented in this chapter, as are the study design—including the development of a new field of study, new metrics for sound and the human response, and the timing of measurement of human response. The limitations set by Congress in PL 100-91 and those resulting from technical considerations are discussed. The selection of contractors, cooperation with other Federal agencies, public involvement, and the establishment of a Technical Review Group are also discussed.

Congress directed the Forest Service to assess the impacts of aircraft overflights on wilderness resources.

PURPOSE

The primary purpose of this study is to respond to legislative direction to assess the impacts of aircraft overflights on National Forest System wildernesses. A secondary objective is to develop information which will help wilderness managers assess impacts to specific wildernesses and user groups, and work with airspace users to mitigate impacts.

BACKGROUND

Wilderness was set aside by Congress for preservation and protection in its natural condition. It is defined as "an area of undeveloped Federal land retaining its primeval character and influence...which is protected and managed so as to preserve its natural conditions and which (1) generally appears to have been affected primarily by the forces of nature, with the imprint of man's work substantially unnoticeable, and (2) has outstanding opportunities for solitude..." In recent years, some wilderness visitors have indicated that airplanes flying over wilderness have interfered with their solitude and desire to get away from the sights and sounds of modern civilization.

Congress—in PL 100-91 passed on August 18, 1987—directed the FS and the NPS to conduct studies of aircraft overflights which may be impacting visitors or resources of the National Forest System wildernesses and the National Parks and report the results to Congress. The NPS, but not the FS, is required to make recommendations for legislative and regulatory action which should be taken regarding the information gathered in the study. To ensure cost effectiveness and consistency of study approach, the two agencies agreed to jointly participate in the aircraft overflight studies. The studies are continuing on NPS lands.

A survey of FS managers of wildernesses (excluding Alaska) was conducted in the fall of 1988. Forty-nine percent identified a concern in one or more categories of aircraft overflights. Forty-one percent responded that there was no problem in their particular wilderness. Ten percent of the managers did not respond to the survey. This indicates a general concern of managers about the impacts of aircraft overflights on wilderness resources.

STUDY DESIGN

Figure 1 shows the relationships among studies which have contributed information to this report. The initial study, begun in September 1989, produced a planning document which reviewed technical literature on aircraft noise effects and on outdoor recreation, described means for accomplishing study goals, analyzed the feasibility of alternative projects, and recommended a research program. The planning document also provided much of the technical context for the research summarized in this report.

Several analytic studies were conducted under the FS/NPS interagency study program. One collected information about overflight exposure of FS wildernesses and NPS units into a computerized database and developed working definitions of certain terms in the legislative language of PL 100-91. Another study reviewed effects of aircraft overflights on wildlife resources. Yet others addressed safety, the effects of aircraft altitude on noise levels at ground level, the effects of aircraft noise on cultural resources, and the benefits of aircraft overflights.

The remaining studies undertaken in FS wildernesses were empirical, rather than analytic, in nature. These field studies were of two types: (1) Studies intended to characterize indigenous sound levels and aircraft noise intrusions in wildernesses, and (2) studies intended to characterize visitor responses to aircraft overflights of wildernesses. Figure 2 shows the wildernesses included in the visitor surveys.

Development of a New Field

The major effort of the FS portion of this study was designed to assess what, if any, adverse impacts to wilderness visitors are associated with overflights of National Forest System wildernesses based upon the respondent's actual exposure to aircraft and how this personally affected the respondent's experience. The study combines two fields of scientific inquiry for the first time—*psychoacoustics* (the study of human response to acoustic conditions) and *wilderness sociology* (the study of human group behavior in a wilderness setting).

Prior recreation studies that asked how actual overflights affected the respondent's personal experience generally collected little, if any, acoustical data and, therefore, could not correlate aircraft exposure to the individuals' response. Some studies asked hypothetical or philosophical questions concerning the impacts of aircraft overflights and revealed abstract perceptions rather than actual experience. On the other hand, previous studies of the wilderness acoustical environment ignore the human dimension; they concentrated only on the physical measurements of sound. Both psychoacoustics and wilderness sociology have their own set of commonly accepted limitations and assumptions. However, this study creates a new area of inquiry—*wilderness psychoacoustics*—and thus creates new additional assumptions and limitations.

Community noise studies commonly seek a "dose-response relationship" to relate the reactions of individuals within a community to an acoustic stimulus. The usual independent variable is a time-averaged sound level, from one or a combination of sources. The dependent variable is usually "percent highly an-

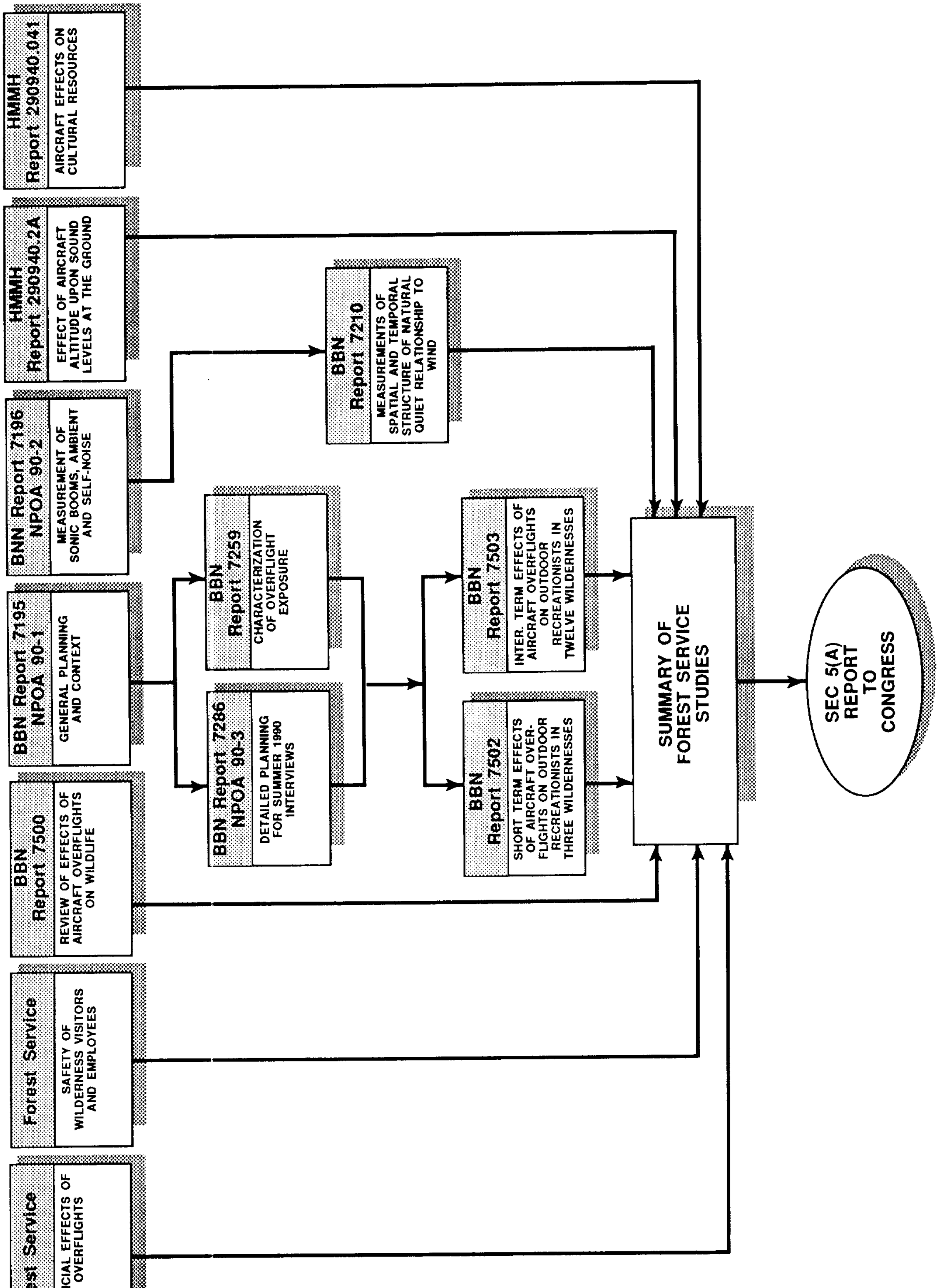


Figure 1. Study effort contributions by contractors and Forest Service.

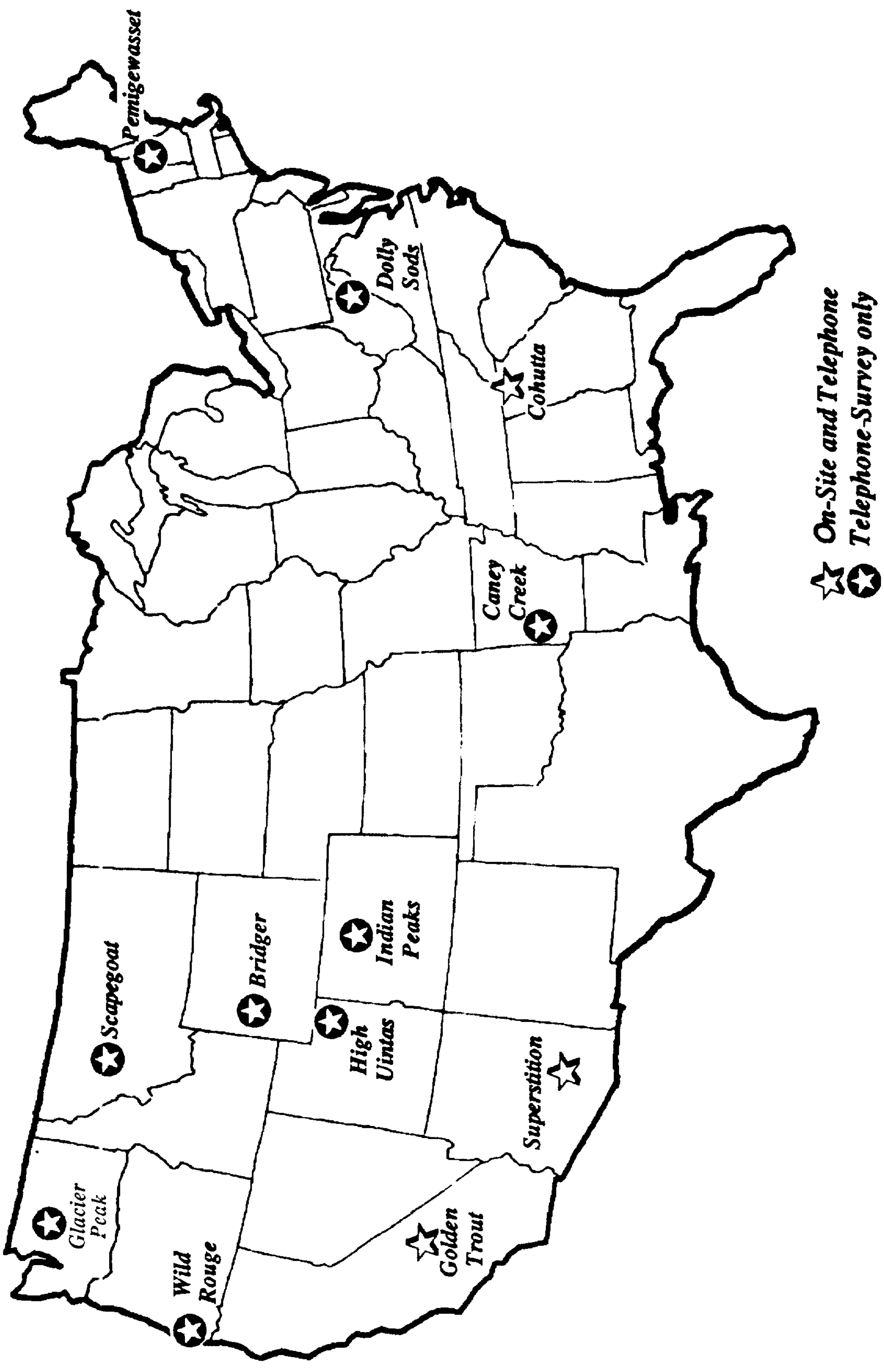


Figure 2. Wildernesses surveyed.

noyed," as determined from surveys of the affected community. There have been many well-controlled and documented studies of this type that have focused on airport noise, and much is known about community reaction to this noise. Knowing the relationship between the measured noise and the response of a number of communities to that noise is very useful, since then one can predict the response from similar communities to a given noise dose. Working backwards, a decisionmaker can select an acceptable level of annoyance for the given community, and using the dose-response relationship, determine a "noise budget" which would be acceptable to the community.

However, the situation of people recreating in wilderness has several important differences from residential or urban communities, where acoustic exposure is fairly constant from one day to the next. People in communities have time to habituate to exposure levels and self-select for noise tolerance. Further, when people are indoors, structures provide substantial noise attenuation With the exception of high-altitude commercial flights, aircraft exposure in wilderness is likely to be sporadic and is completely different on different days. Wilderness visitors spend only a small amount of time in the wilderness and may have an entirely different set of exposure levels, expectations, motivations, social situations, and past experiences related to wilderness recreation as compared to their residences.

Through discussions with scientific colleagues about this new field of wilderness psychoacoustics, it has become clear that many factors, which are of minor importance in urban and residential areas, are of great importance in wildernesses. Because of the pioneering nature of this study, even seemingly obvious definitions and concepts have had to be thoroughly scrutinized before they could be adopted from community noise studies. This analysis is still going on as part of the NPS investigation of impacts on lands that they manage.

Development of New Metrics

These differences between community noise studies and the new field of wilderness psychoacoustics necessitated major modifications in the metrics to be used. "Percent highly annoyed" has been so successful in past community noise response studies that it has been repeated as the prime response variable of interest in this study. However, human response

The impact of aircraft overflights in wildernesses differs significantly from impacts in residential or urban communities.

variables commonly used in wilderness sociology studies were also considered—such as enjoyment and non-return to the area.

Determining the appropriate noise measurement metric to use in the wilderness situation is not straightforward, since the background is so much quieter in many of these areas than in more populated areas. This study has resulted in the development of techniques to remove instrument noise, which in older work has contaminated outdoor sound level measurements, but is unimportant in community noise situations. Thus we report levels at some wilderness sites that are even lower than those previously reported in the literature.

Determining Appropriate Time of Response

In community noise studies, where noise is largely the same from one day to the next and people live in the same area for long periods of time, the issue of when to measure human response to noise exposure has little meaning. In the wilderness situation, however, this issue has considerable importance because of the inconsistency of exposure. Given that this was a new area of study and no information was available as to the most appropriate measurement point in a visitor's wilderness visit, it was decided to investigate visitor response to overflights both close to the time of exposure and after their return home from their wilderness visit.

GENERAL LIMITATIONS AND ASSUMPTIONS

In accordance with PL 100-91, this report does not consider any National Forest System wilderness in Alaska, nor does it apply to any aircraft flights associated with landing fields in or adjacent to National Forest wilderness. Benefits of aircraft overflights for military training, commercial airlines, general aviation, State agencies, private companies, etc. have not been considered. Only benefits to wilderness visitors or those that further the purposes for which the National Forest System is managed are included in this report.

Not all wildernesses administered by the FS are included in this study. Wildernesses were stratified by aircraft exposure and amount of use. A purposive sample of wildernesses representing a broad spectrum of aircraft exposure conditions and visitor use conditions were selected in which to conduct this assessment and provide information to assess impacts. Data on wilderness user demographics, activities, and use patterns were similar between the surveys conducted for this project and other wilderness user studies.

The findings in this report are not necessarily applicable to National Parks. Continuing NPS studies are anticipated to produce findings about the impacts of aircraft overflights on park resources, as well as tools to help predict such impacts. The results of the NPS studies are not expected to appreciably alter the findings for National Forest wildernesses that are contained in this report.

CONTRACTORS

Rather than conduct the required study internally, a decision was made to contract out most of the study while having a Core Team, composed of FS and NPS personnel, direct and monitor this effort. There were several benefits to this approach: (1) Flexibility in contracting and monitoring procedures were gained while retaining the option to conduct some components of the study internally; (2) the best experts in the needed fields were used for only the length of time needed; and (3) it was not necessary to establish a permanent staff for a limited-term project.

Proposals were solicited from acoustical engineering firms as the prime contractor (with wilderness sociologists serving as subcontractors), with the goal of obtaining the highest quality team capable of dealing with the new field of wilderness psychoacoustics. An Architectural and Engineering contract, administered by the NPS Denver Service Center, provided the flexibility to take advantage of the knowledge gained in each phase of the study in writing new work orders for subsequent phases.

Based solely on the quality of the combined acoustical and sociological teams and their ability to do the job, the firm BBN Systems and Technologies, a division of Bolt Beranek and Newman Inc., was selected as prime contractor. Harris Miller Miller & Hanson (HMMH) Inc. was added later as a second contractor. Sociological input to the contractors was provided by the Department of Recreation Resources and Landscape Architecture at Colorado State University; HBRS, Inc.; and other independent experts from research agencies both within government and academia, working under contract to BBN and HMMH.

COOPERATION AMONG FEDERAL AGENCIES

Section 6 of PL 100-91 requires the Chief of the FS to consult with other Federal agencies that are engaged in analysis of the impacts of aircraft overflights over Federally owned land. This consultation was accomplished through formal agreements, membership in a Technical Review Group, scientific presentations, a project newsletter, other correspondence, and personal contacts.

The NPS & FS were charged with determining the impacts of aircraft overflights on the resources of National Park units and National Forest System wildernesses, respectively. Since separate studies would overlap to a large extent, and since both the NPS and the FS have unique areas of expertise and experience which could be integrated to best serve the public with respect to the required studies, it was decided to execute an interagency agreement to conduct a joint study. This agreement provides for the joint funding and participation in major architect/engineering contracts, and sets up a Core Team composed of FS and NPS personnel with expertise in acoustics, aviation, wilderness sociology, engineering, contracting, and resource management.

The FS coordinated the study project from its San Dimas Technology and Development Center (SDTDC) in southern California, where expertise in acoustics, aviation, and recreation management are located. Additional expertise in wilderness sociology was provided by the Intermountain Forest and Range Experiment Station in Missoula, Montana. Input on the benefits of aircraft overflights to the FS was obtained from the various Resource Staffs in the Washington Office under the leadership of Fire and Aviation Management.

Airspace over National Forest wildernesses and NPS lands provides a variety of largely uninhabited geographic and topographic settings needed by the Department of Defense to conduct aircraft testing and pilot training activities. These activities are important to maintaining a strong National defense. The Secretaries of Agriculture, Interior, and Defense desire to share information about these activities to reduce their impact on the public that uses National Forest wilderness and National Parks for recreation, and to mitigate other resource impacts. To this end a Memorandum of Understanding was executed to establish procedures for interdepartmental coordination during the period of the study.

The National Aeronautics and Space Administration (NASA) has a program to study the environmental effects of commercial supersonic airplanes, including annoyance due to sonic booms. In addition, NASA, in a cooperative program with the Federal Aviation Administration (FAA) has initiated a program to assess the impact of high-altitude aircraft en route noise on the population of the United States in low ambient noise areas. SDTDC and NASA Langley Research Center executed an interagency agreement to enable (1) the FS to more fully assess the impacts of military and commercial aircraft on wilderness visitors and (2) NASA to more fully assess the reactions of people to sonic booms and en route noise in low ambient noise environments. FS personnel presented papers at the 1989 FAA/NASA En Route Noise Symposium.

Membership on the Technical Review Group, discussed in more detail below, includes persons employed by various Federal agencies who possess unique qualifications important to this study. NASA and the Departments of Transportation and Defense are all represented on the Group. Coordination with the Air Force's National Sonic Boom Impact Technology Program (NSBIT) and the Armstrong Aerospace Medical Research Laboratory (AAMRL) has been especially important because of the applicability of their work to this study. Their facilities at Wright-Patterson Air Force Base in Ohio were visited and cooperation maintained throughout the study. Agencies not having representatives in the Group were kept informed through the project newsletter, individual correspondence, and personal contacts.

TECHNICAL REVIEW GROUP

Due to the complexity and technical difficulty of the study, the Technical Review Group was formed. It is composed of persons with technical expertise and experience relevant to the study (see appendix C). As can be seen, they represent a broad range of technical fields: Psychoacoustics, acoustical engineering and measurements, statistics, survey research, and airspace management, as well as representatives from wilderness user groups and aircraft operators. They meet periodically with the Core Team to review progress and products developed, and offer both technical and administrative suggestions.

PUBLIC INVOLVEMENT

The primary emphasis of public involvement during the study was to obtain information directly from wilderness visitors. As part of the study design, it was decided to get input from wilderness visitors by means of personal and telephone interviews of those individuals during and shortly after their wilderness visits. This was done so as to assess the actual impact from exposure to aircraft overflights on people using wilderness, rather than merely assess the general public's opinion about the philosophical question of whether aircraft overflights are compatible with wilderness.

Information from other members of the public who had concerns about our study of aircraft overflights of wilderness was obtained by several means. A public announcement was made and meeting held to announce the study at its beginning and to answer any questions from the press and interested individuals. The inclusion of representatives from wilderness user groups and aircraft user organizations on the Technical Review Group helped provide input throughout the study from these segments of the public. A mailing list of interested individuals and organizations was developed and maintained so that periodic updates about the study's progress could be sent out. Scholarly papers on the technical aspects of the study were presented at various conferences and society meetings (e.g., National Wilderness Conference, Acoustical Society of America, Noise-Con 90, FAA/NASA En Route Noise Symposium, the Third Symposium on Social Science in Resource Management, etc.) The study also has been discussed at additional various meetings within and outside the agency.

CHAPTER 2

EFFECTS OF OVERFLIGHTS ON VISITOR ENJOYMENT

This chapter presents the background, rationale, goals, objectives, program design, and an overview of studies that were conducted. A glossary and discussion of acoustic and other technical terms are provided in appendixes for the convenience of readers unfamiliar with technical terms and acronyms used in this report.

***NOTE**: This material is abstracted from a number of BBN Systems and Technologies technical reports that they prepared for this study. The BBN reports of greatest interest here are: No. 7503, "Intermediate-Term Effects of Aircraft Overflights on Outdoor Recreationists in Three Wildernesses"; No. 7195, "A Research Plan for PL 100-91 Aircraft Overflight Management Studies"; No. 7333, "Study Plan for Onsite Interviews in Three Wildernesses"; No. 7286,, "Recommendations for Design of Survey Instruments for PL 100-91 Field Studies for Summer, 1990"; No. 7259, "Estimation of Aircraft Overflights and Noise Exposure in National Parks and Forest Service Wildernesses"; No. 7196, "Acoustic Measurements of Sonic Booms and Ambient Sound Levels in the Selway-Bitterroot Wilderness Area"; No. 7210, "Measurements and Analysis of Natural Quiet in Coniferous Forests".*

The impacts of aircraft overflights on visitor enjoyment, including the pursuit of quiet and solitude were investigated.

BACKGROUND

Nature of Aircraft Noise in Wildernesses

Noise—that is, sound having amplitude, frequency content, situational or temporal qualities that are inappropriate to the particular setting—is a form of energy, not a material substance. Unlike many other forms of pollution, noise leaves no physical residue, and at the levels of present concern, is not known to produce long-term, irreversible impacts. The bulk of what is known about effects of aircraft noise on people has been learned from laboratory studies and field studies conducted in residential and occupational settings. A large body of knowledge, derived from community-based studies of reactions to aircraft noise exposure in airport environs, is the most directly relevant for present purposes.

Community-response noise studies are not fully applicable to predicting reactions to aircraft noise exposure in wildernesses, however. The settings, social content, and the nature of aircraft noise exposure differ in wilderness and urban airport environments in important ways. For example, the circumstances under which aircraft noise is experienced in wildernesses differ considerably from those under which aircraft noise is experienced in urban areas. In the urban case, aircraft noise is often experienced in an indoor setting, in which outdoor noise is attenuated by about 15 to 20 dBA by structures. Residential populations in airport environs may self-select to some extent for tolerance to noise exposure. Their long-term exposure to predictable patterns of aircraft noise exposure also provides opportunities for habituation. Additionally, indoor aircraft noise exposure in residential settings occurs in the context of all of the other expected noises of industrial society, including the nearly continuous noise of surface transportation and self-generated noises of daily life.

In contrast, aircraft noise in wildernesses is often experienced in a recreational setting in which an absence of noise intrusions of external origin may be expected. Overflights of wildernesses may also be audible for longer durations than identical overflights of urban areas, since low levels of indigenous sounds in wildernesses are less effective in masking aircraft noise than urban noise. Wilderness visitors may self-select to some extent for intolerance to noise exposure, or may incur considerable opportunity costs to visit wildernesses. Either of these latter factors could render wilderness visitors more sensitive to environmental conditions in wildernesses than in residential areas. Further, their motivations for visiting wildernesses, and the social environment of outdoor recreation, may be quite different from those of residential living. Since visits to wildernesses are relatively brief (rarely more than a few days) and visitors' exposure to aircraft noise are so unpredictable from an individual viewpoint, wilderness visitors may have little opportunity to habituate to overflights. Aircraft noise intrusions in wilderness settings are generally heard in the absence of masking created by other noises of industrial society. However, noises heard in wildernesses are not limited to those produced by aircraft. Noises from other non-indigenous sources, including distant motorized equipment, surface transportation, and other recreational and nonrecreational land uses may propagate over long distances.

These differences in circumstances of aircraft noise exposure may be summarized as follows:

1. While aircraft operations in airport environs are quite predictable in time and space, aircraft operations in wildernesses can be more sporadic (i.e., infrequent, intermittent, and unpredictable) and spatially variable.
2. Aircraft overflights in wildernesses may be audible at considerably greater distances from observers than in airport neighborhoods.
3. As a rule, aircraft noise intrusions produced by aircraft overflying wildernesses are fewer in number, and cumulative noise exposure is lower in magnitude, than that produced by large transport aircraft approaching and departing major civil airports. A potential exception to this rule is noise exposure associated with low-altitude, high-speed operation of military jet aircraft, which is absent from airport environs.
4. Onset rates of noise produced by low-altitude, high-speed aircraft may be considerably more rapid than those characteristic of airport environs (potentially as much as 70 dB/s).
5. Nighttime operations may occur relatively more often in the vicinity of some Military Training Routes (MTR's) over or near wildernesses than in urban airport neighborhoods.
6. High-altitude supersonic flight operations in airspace near wildernesses can create impulsive aircraft noise absent from residential neighborhoods.
7. Although lower in absolute level, nonmilitary aircraft noise intrusions are often audible for considerably longer periods of time in the generally low ambient noise conditions of wildernesses than in urban settings.
8. The aircraft fleet overflying certain wildernesses is composed of a greater proportion of rotary wing and smaller, piston-powered, fixed-wing aircraft than that operating at major civil airports.
9. Symbolic associations with wildernesses may lead to motivations, expectations, and preferences for environments which lack non-indigenous sounds such as aircraft.

Knowledge of Aircraft Noise Effects on Wilderness Visitors

Two distinct research literatures are relevant to PL 100-91 studies of effects of overflights on outdoor recreationists. One of these is a mature literature on individual and community response to noise exposure. The other is a more recent body of outdoor recreation research which encompasses basic studies of motivation, expectations, and preferences for outdoor experiences, as well as more applied, policy-oriented studies related to management problems in limits on use, littering, crowding, user conflict, and vandalism.

The former literature developed over many years in response to expressed public concerns about the impacts of aircraft overflights on residential communities. These concerns have led to Federal and local legislation, regulatory standards, formal impact assessment criteria, tools for characterizing noise exposure, and both theoretically and empirically derived dosage-response relationships between noise exposure and the prevalence of noise-induced annoyance.

The latter literature, developed over a period of three decades, supports fewer useful inferences for present purposes. For example, while identification and measurement of outdoor recreation motivation and desired psychological experiences have been exhaustively studied, the recreation sociology literature has not clarified the effects of physical stimuli on experiences. Numerous studies have sought patterns of association between experience preferences and environmental attribute preferences. Efforts to demonstrate links between recreational experience and environmental factors have had only limited success. The findings of these studies lack the consistency needed for unambiguous interpretation.

In fact, the outdoor recreation literature generally lacks meaningful predictors of recreation satisfaction. If anything is predictive of recreation satisfaction, it is the character of the social context surrounding the experience. One implication of the importance of social interaction to outdoor recreationists is that they may be willing to tolerate a wide range of aircraft overflight exposure. Furthermore, visitors to outdoor recreational sites may be highly adaptable. Familiarity with and attachment to outdoor recreational places stemming from repeat visits can lead outdoor recreationists to return repeatedly even after environmental changes.

The lack of useful theory or consensus about linkages between environment and experience in outdoor recreation, coupled with the near total lack of inquiry into matters related to aircraft overflight effects in outdoor recreational circumstances, make it difficult to draw substantive conclusions from this literature for present purposes. No body of theory concerning the impacts of aircraft overflights upon outdoor recreationists was either comprehensive or consistent enough to direct the course of study conducted for purposes of PL 100-91.

Rationale for Studies

The initial work undertaken for the interagency research program concentrated on establishing relationships among indigenous sound levels, aircraft noise intrusions, and the reactions of wilderness visitors to overflights. A pragmatic rationale was developed for overflight studies, starting from statements of program goals. The rationale was developed not only from analyses of these goals, but also from consideration of objectives solicited from many experts—including representatives of five FS Research and Experiment Stations, eight academic departments of Forestry, Recreation Sciences, Management Sciences and Agricultural Economics, and three aircraft noise consulting firms. The primary emphasis was on establishing a quantitative relationship between measures of overflights and measures of reactions to overflights.

OVERVIEW OF STUDIES

Two field studies dealing principally with acoustic issues were conducted in FS wildernesses. One of these studies was intended to characterize sonic boom exposure in the Selway-Bitterroot Wilderness (Bitterroot, Clearwater, Nezperce, and Lolo National Forests). In addition to measurements of sonic booms, measurements were made in the Selway-Bitterroot Wilderness of indigenous sound levels and self-noise of outdoor recreationists. The second of these acoustic field studies characterized the statistical properties of indigenous sound levels and its dependence on wind speed in coniferous forests.

A related field study of natural indigenous sounds and aircraft noise intrusions was undertaken for NPS to determine whether Special Federal Air Regulation (SFAR) 50-2 had succeeded in substantially restoring natural quiet to Grand Canyon National Park (as required by Section 3 of PL 100-91). This study, still in progress, has produced (1) extensive field measurements of natural indigenous sounds and aircraft noise intrusions in backcountry areas, (2) a review of the suitability of conventional aircraft noise contouring methods in outdoor recreational environments, and (3) improved methods of mapping aircraft noise impacts in wildlands. (See appendixes E and F for detailed discussions of quantifying aircraft noise exposure and natural quiet.)

Both field studies of visitor reactions to overflights were preceded by design and review strategies. The on-site and telephone interviews of visitors to FS wildernesses were subsequently conducted in accordance with these designs.

GOALS OF STUDIES

Acoustic Measurement Study

The overall goal of the acoustic measurement studies was to characterize indigenous sound levels and aircraft noise intrusions in wildernesses. Several studies focused on short- and long-term measurements of indigenous sound sources such as wind, water, and animals in wildernesses. Place-oriented measurements (both single and multiple point) of indigenous sound levels and overflights were made at a number of sites, as were at-ear measurements of the sounds of activities of wilderness visitors. Acoustic measurements were also made to support social surveys in which aircraft noise exposure was monitored over large areas.

These studies required not only collection of large amounts of acoustic information in field settings, but also development of automated methods for processing, analyzing, and representing this information. Means were developed for automated classification of aircraft noise intrusions, for rejection of artifacts of measurement such as spurious wind noise, and for calculation and display of the audibility of aircraft over large areas.

Visitor Reaction Studies

The basic goal of the on-site and telephone interviews was to produce information to report to Congress on "what, if any, adverse impacts to wilderness resources are associated with overflights of National Forest System wilderness areas" [Section 5(a), PL 100-91]. The information of greatest utility for this purpose was direct evidence of potential adverse effects of aircraft overflights on wilderness visitors. The preferred interpretation of empirical evidence of aircraft impacts was a quantitative dosage-response relationship between aircraft noise exposure and the prevalence of annoyance among wilderness visitors.

Instruments recorded the natural background sounds of the wilderness and the acoustical impacts of aircraft overflights.

A dosage-response relationship provides:

- Consistency with established practice for characterizing aircraft overflight impacts on communities.
- Comparability of findings with a large body of existing information.
- A simple and readily interpretable graphic representation supporting summary statements about overflight impacts.

STUDY METHODS

Aircraft Overflight Database

An aircraft overflight database was developed to support selection of sites for field surveys of recreationists' opinions about overflights. These wildernesses are overflown by aircraft of several types, including:

- High-altitude commercial jet transport aviation
- Military aircraft (divided into several categories of operations)
- Small, propeller-driven aircraft
- Other types of aircraft overflights (including air taxi and commuter flights, as well as flights conducted for Government administrative purposes).

Sightseeing tour aircraft were not included in the database since tour aircraft are of minor use over National Forest wildernesses. The database was designed to permit separate estimates of each source of overflight exposure. In addition, the database contains information about airfields in and adjacent to wildernesses, since PL 100-91 exempts such flights from consideration. Appendix D defines terms such as "adjacent" and "overflights" for purposes of the database.

Information in the database was gathered from several sources including (1) maps and charts from National Oceanic and Atmospheric Administration (NOAA), (2) FAA planning documents, (3) Bureau of Land Management (BLM) wilderness status maps, (4) publications and charts produced by the Defense Mapping Agency, (5) a low-altitude military flight activity database produced by Oak Ridge National Laboratories (ORNL), and (6) information published by the Aircraft Owners and Pilots Association (AOPA).

While information about locations of jet transport, military, and general aviation routes is readily available, accurate information about the numbers of flights traversing these routes is difficult to obtain for reasons such as timeliness, cost, and difficulty of access. For example, FAA collects information on use of high-altitude jet routes in 15-day periods. However, FAA does not consolidate these data from its 24 Air Traffic Control Centers, nor are 15-day printouts retained after collection. Only a partial set could be obtained for a single season for this study. Likewise, operational information about military routes and operating areas was long delayed for a variety of reasons.

Military overflights occur along military training routes (MTR's) and within military operating areas (MOA's), restricted areas (RA's), refueling tracks and anchors, and in other nonallocated airspace. Routes and areas flown by military aircraft over and adjacent to FS wildernesses were identified and populated with operations according to 1986-vintage information in a database prepared by the military. Although of questionable accuracy and currency, these data on levels and types of activity were the best available in a timely manner.

Low-altitude Federal airways ("Victor" airways) are air corridors extending between navigational aid (NAVAID) points for use by visual flight rules (VFR) and instrument flight rules (IFR) flights. Unlike most airline and military routes, Victor airways are not constrained flight paths. Aircraft operators may fly through any airspace which is not otherwise prohibited or controlled. Because information about general aviation operations is not available on a local basis, estimates of general aviation activity over wildernesses are speculative. Similarly, FAA publishes only National estimates of the volume of air taxi and commuter flights. FAA's National Airport System Plan estimates arrival/departure activities for all public use airports in four categories of flight activity. These estimates are incorporated in the aircraft overflight database.

Since direct measurement of aircraft noise of all wildernesses was unaffordable, exposure was estimated from information about numbers of overflights. Not all overflights produce equal amounts of noise exposure, however. Differences in noise exposure are associated with various categories of overflights and, within each category, with type of aircraft, altitude, and distance of the overflight from the wilderness. Information about only some of these variables was available for inclusion in the database.

Exposure estimates for each wilderness were ultimately based on prediction equations for each wilderness. The equations take into account number and type of overflights and the relative amount of noise expected from each type of overflight due to altitude and distance from the wilderness. For example, high-altitude jet transport flyovers contribute less to the final predicted exposure value than those along low-altitude MTR's. Flights within MOA's, which are distributed over a large area, contribute less to exposure than those along more narrowly constrained MTR's. Information provided by FS on problems associated with aircraft noise was also considered in the noise exposure prediction equations.[1]

Noise exposure prediction equations were based on estimated numbers of flights divided by estimated proximity of overflights to the observer. Two components of proximity were (a) typical altitude, and (b) lateral distance of expected flight track from the wilderness. For more widely dispersed flight areas, the number of overflights was further reduced by a factor of three, under the assumption that such an area (e.g., a MOA) has about three times the ground coverage of a more narrowly defined route (e.g., an MTR). A constant estimated average value replaced altitude for types of flight for which specific altitudes could not be estimated. This constant takes into account the relatively high elevation of many wildernesses.

Use of Aircraft Overflight Database for Site Selection

FS wildernesses were divided into four exposure strata for purposes of selecting interviewing sites for two social surveys. The major criterion for stratification was overall level of estimated aircraft noise exposure. An additional criterion for areas with high noise exposure was the type of overflight: Low-altitude, high-speed, high noise level (i.e., military) aircraft or other. Military overflights differ from other types of aircraft in the onset rate and absolute level of their noise signatures and their potential impacts.

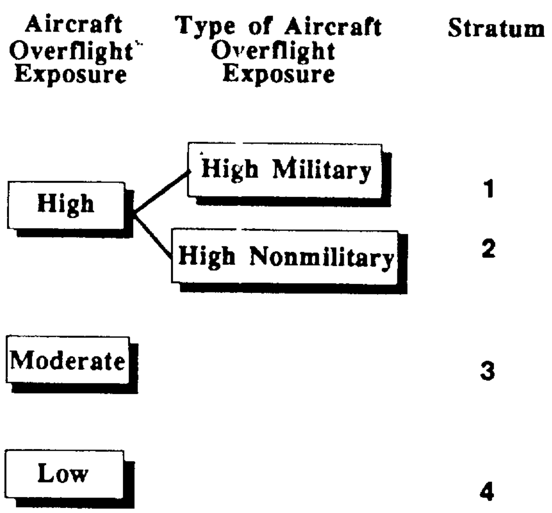


Figure 3. Stratification plan based on aircraft overflight exposure.

[1] *The FS identified 30 wildernesses as potentially having problems due to overflights based on a variety of criteria: Reported number of overflights by managers and their evaluation of whether overflights posed a problem, existence of flight routes or special airspace over the area, or existence of acoustic or social measurements.*

Figure 3 shows the stratification of wildernesses based on noise exposure. Wildernesses were first rank ordered by estimated aircraft overflight exposure and grouped into three strata: High, moderate, and low. Within the high exposure stratum, areas were ranked by estimated noise exposure due to military tactical overflights alone, and then divided into areas with high and low military aircraft noise exposure. This division produced two substrata within the high noise stratum.

Assessment of Short-term Reactions to Overflights

The most intense impacts of overflights on outdoor recreationists ("immediate impacts") are most likely to be the ones that occur during and shortly after exposure. These immediate reactions are also the ones most suitable for linking directly and reliably to exposure through a quantitative dosage-response relationship. Longer term reactions may also be linked to cumulative noise exposure, although often at greater cost and with some loss of precision.

Immediate reactions of outdoor recreationists to overflights are difficult to gauge, since it is impractical with presently available technology to solicit an interview immediately upon exposure. (Miniaturized, computer-based instrumentation for simultaneous monitoring of individual response and noise exposure may be available for use in the future.) It was, therefore, decided to focus on recreationists' short and intermediate-term delayed reactions to overflights.

Delayed self-reports of immediate reactions solicited days or weeks after exposure may be less reliable indicators of overflight impacts for several reasons—including imperfect recall, decay of reactions over time, rationalization, and the effects of other intervening variables. Information about short-term and intermediate-term reactions to aircraft overflights may be collected in several ways. Controlled interviewing was preferred, for present purposes, to diary and other methods for several reasons:

- Since no real-time measurements of personal noise exposure could be linked directly to diary entries, there was little advantage to seeking per-event responses to questionnaire items.
- Wilderness visitors are often unable to report their locations with sufficient accuracy to estimate their aircraft noise exposure.
- Making written diary entries may impose a greater burden on the time of wilderness visitors than a short, structured personal interview.
- The instruction to attend to overflights and record reactions to them in diary entries may call specific attention to the object of the study and thus bias responses.

- There is no practical means of monitoring compliance with instructions, controlling the order of questioning, or verifying the time of entries or identity of respondents.

Assessment of Intermediate-term Reactions to Overflights

Intermediate-term impacts are those reported by visitors within 1 to 2 wk of their conclusion of a wilderness visit. Intermediate-term impacts are of interest because they can support analyses of cumulative and integrated reactions of wilderness visitors' to overflights. Information about intermediate-term impacts can also provide perspective useful for interpreting the short-term effects of overflights. For example, respondents who describe themselves as greatly affected by individual overflights might, on several days' reflection, still report considerable satisfaction with a visit to a wilderness, and might report themselves to be less affected by those overflights.

Intermediate-term responses were assessed by means of a telephone survey administered to visitors in their homes shortly after a visit to a wilderness. This time frame was chosen as one that was long enough to have permitted respondents to form overall impressions of their recreational experiences, yet not so long that their memories of their experiences had become indistinct or highly rationalized. A telephone survey was chosen in preference to a mail survey because it offered greater control over:

- The time period between the end of the visit and the interview
- The order of questioning of respondents
- The identity of the respondent.

RESULTS OF ACOUSTIC MEASUREMENT AND PREDICTION PROJECTS

Five studies developed information about the nature and extent of overflights and indigenous sound levels in FS wildernesses:

- A study was conducted of sonic boom exposure and indigenous sound levels in the Selway-Bitterroot Wilderness in Montana and Idaho.
- Two sets of simultaneous measurements at multiple measurement points were made to characterize the indigenous sound levels of coniferous forests.
- Extensive acoustic measurements were made in conjunction with on-site interviews of recreationists in three wildernesses.
- Short-term monitoring of overflights was accomplished in conjunction with telephone interviews of visitors to nine additional wildernesses.
- A database was developed of estimated over flights of FS wildernesses.

The results of these studies are discussed below.

Acoustic Measurements Made in Selway-Bitterroot Wilderness

Measurements were made in the Selway-Bitterroot Wilderness of sonic booms, military aircraft overflights, and ambient sound levels at four sites. Other measurements were also made of the self-noise of wilderness visitors. Monitoring of sonic booms extended over a 19-day period during September and October 1989, during which two sonic booms were recorded. The two booms were produced by SR-71 reconnaissance aircraft flying at a speed of Mach 3 at a slant range of at least 25 miles from the measurement point. The booms were low in level (approximately 0.25 lb/ft^2) and relatively long in duration (more than a third of a second). These values are fairly typical of carpet booms produced in straight and level flight at high altitude and substantial slant range by large supersonic aircraft. Figure 4 shows the time histories of the booms.

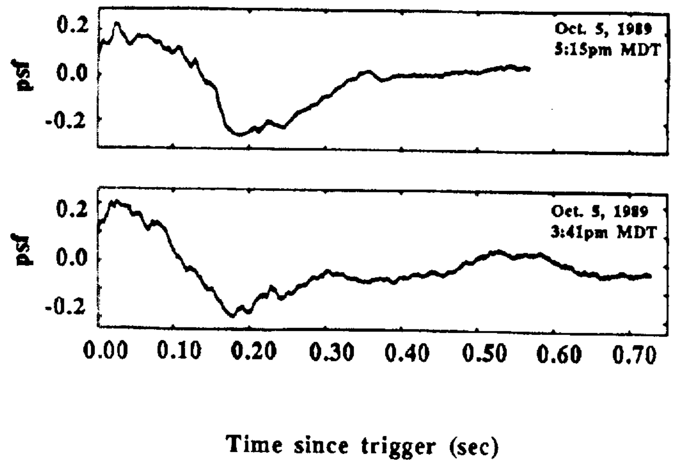


Figure 4. Time histories of sonic booms in Selway-Bitterroot wilderness.

Figure 5 shows an overflight of the Selway-Bitterroot Wilderness by an F-111 aircraft at relatively low altitude and flight speed. The time history of the overflight is seen in three dimensions. The frequency content of the overflight is plotted along the horizontal axis, with low frequencies on the left side and high frequencies on the right. Time increases along the vertical axis in half-second increments. Energy is represented as the height of the curves. The maximum A-weighted sound level observed during the course of the flyover exceeds the indigenous sound levels of the forest by about 48 dBA.

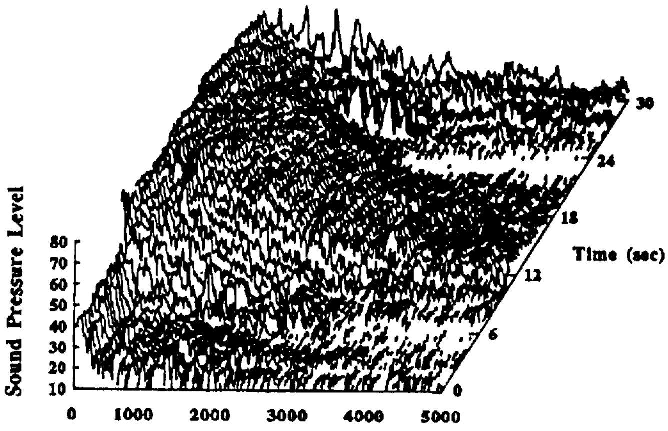


Figure 5. Distribution of sound pressure levels of F-111 flyover in Selway-Bitterroot wilderness.

Considerable variability in sound levels was observed during place-oriented measurements of indigenous sound levels in the Selway-Bitterroot Wilderness. Ambient sound levels also varied considerably over time and place within forests, as shown in figure 6.

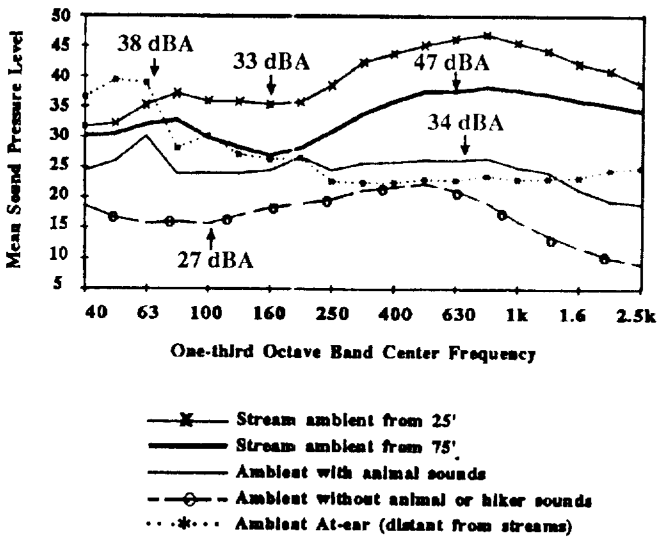


Figure 6. Variability in sound pressure levels for multiple locations in Selway-Bitterroot wilderness.

Acoustic Measurements Made in Kaibab and Sequoia National Forests

Two sets of simultaneous measurements at eight-position arrays—both in the Kaibab National Forest, adjacent to Grand Canyon National Park in Arizona and in the Golden Trout Wilderness, Sequoia National Forest, in the central California Sierra Nevada mountains—revealed that the indigenous sound levels of Forests has predictable statistical properties. In particular, distinctive patterns of correlation of sound levels in time, space, and frequency can be used to characterize indigenous sound levels in mathematical terms. These patterns of correlation can also be used to quantify the degree to which man-made noises intrude upon the indigenous sound levels of wildernesses.

Analysis of the contribution of wind noise to ambient levels in forests revealed a strong relationship between A-level and wind velocity. Figure 7 shows that much of the variability in sound levels in coniferous forest is predictable from wind speed.

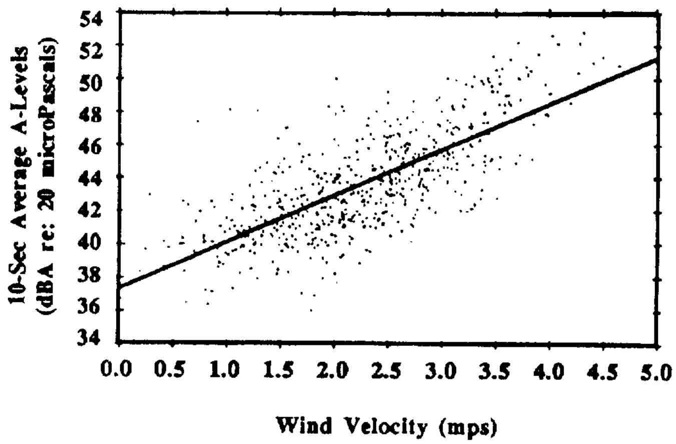


Figure 7. Least squares regression of averaged A-level and wind velocity over 2-hour period.

At-ear measurements of personal noise exposure and self-noise displayed even more variability than place-oriented measurements. This variability was due to the range of activities of visitors to wildernesses: Hiking, conversation, horseback riding, white water rafting, etc. These measurements of indigenous sound levels and self-noise indicated the need to take both sources of masking noise into account when evaluating the impact of aircraft overflights on outdoor recreationists in wildernesses.

Acoustic Measurements Made in Conjunction with On-site Survey

Acoustic measurements were made in three Wildernesses (Golden Trout, Cohutta, and Superstition) with varying levels and types of overflight exposure, visitor density, and ecotypes to support construction of a dosage-response relationship. Golden Trout Wilderness is exposed to moderate levels of overflights (primarily by low-level military aircraft) with high visitor use dispersed over a large area of coniferous forest. Cohutta Wilderness, Chattahoochee National Forest, in Georgia and Tennessee is characterized by exposure to high-altitude commercial overflights and high visitor use in a dense deciduous forest. Superstition Wilderness, Tonto National Forest, in Arizona has high exposure to both military and nonmilitary aircraft operations in an arid ecosystem with high, but concentrated, levels of visitor use.

Acoustic measurements made at each of the three wildernesses included:

- Continuous automated measurement of long-term average A-weighted sound levels at fixed locations.
- Short-term recording of indigenous sound levels and overflight sound levels throughout the audible range near interview sites.
- At-ear spectral measurements of the self-noise of hikers and horseback riders.

The latter measurements were made to permit comparisons with wide area measurements of aircraft noise. These acoustic measurements were supplemented by logs of overflights maintained by field personnel which time-tagged individual overflights at several locations.

Acoustic measurements were made in the Golden Trout Wilderness at four locations over a 16-day period in July 1990. Measurements in the Cohutta Wilderness extended over a 12-day period at three locations in August 1990. Automatic noise monitors were stationed at four locations in the Superstition Wilderness for three days in November-December 1990. More than 2,000 hr of continuous long-term acoustic measurements were made in the three wildernesses. These measurements included (1) noise levels averaged over 15-min intervals and (2) levels of events which exceeded thresholds intended to discriminate aircraft noise from indigenous sounds.

Table 1 displays representative values of integrated sound levels of indigenous sounds at all measurement stations in the three wildernesses. Levels of indigenous sounds are estimated separately for day (0700-2000) and night (2000-0700) hours using L_{eq} values, while average day-night sound levels of indigenous sounds are presented using day-night average sound level. This is a 24-hr energy average sound level with a 10-dB penalty for nighttime, and is expressed as L_{dn} in notation. Artifacts of measurement—such as wind noise—have been removed from these estimates, as have high level noise intrusions caused by known aircraft overflights, thunder, and animal noise.

Maximum aircraft noise levels in excess of 100 dBA were observed during some 15-min intervals in the Golden Trout Wilderness. Maximum 15-min interval levels of indigenous and aircraft noise recorded in the Superstition Wilderness were approximately 30 dBA lower than levels found in the other two wildernesses. Minimum 15-min interval levels of ambient and aircraft noise levels ranged from 20 to 25 dBA in the three wildernesses.

Figure 8 compares the spectral content of indigenous sounds in each wilderness averaged over several hours of recordings. Differences in spectral shapes are associated

Representative 15-minute sound levels in Golden Trout Wilderness

	L_{eq} (day) (dB)	L_{eq} (night) (dB)	L_{dn} (dB)
Trout Meadow	42	23	40
Little Kern Bridge	38	32	40
Lower Pyles	48	48	54
Forks of the Kern	47	47	53

Representative 15-minute sound levels in Cohutta Wilderness

	L_{eq} (day) (dB)	L_{eq} (night) (dB)	L_{dn} (dB)
Hickory Ridge	44	44	50
Brayfield Clearing	43	43	49
Beech Bottom	52	52	58

Representative 15-minute sound levels in Superstition Wilderness

	L_{eq} (day) (dB)	L_{eq} (night) (dB)	L_{dn} (dB)
First Water	33	33	39
Fremont Saddle	35	26	35
Peralta Trailhead	42	35	43
Black Mesa	29	29	35

Table 1. Values of L_{eq} and L_{dn} representative of ambient levels in three wildernesses.

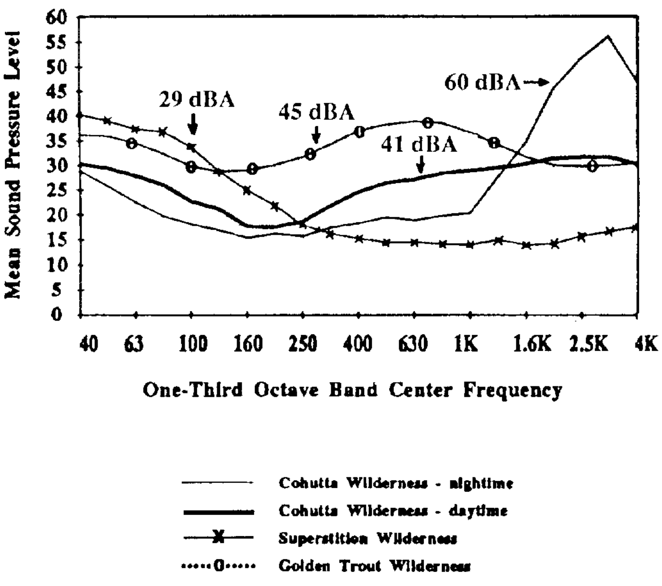


Figure 8. Comparison of typical ambient spectra for three wildernesses.

with differences in ecotypes, animal activity, and wind-induced noise. As seen in figure 8, the ambient spectrum of a coniferous forest (Golden Trout Wilderness) with moderate wind has a concentration of energy around 630 Hz and an A-weighted level of 39 dB. The spectrum of a dense deciduous forest (Cohutta Wilderness) with slight wind shows a similar concentration of energy around 630 Hz, a level of 27 dBA during the day, and an abrupt increase in energy in bands above 1 kHz due to animal noise at night. The ambient spectrum in a desert (Superstition Wilderness) shows little energy at frequencies greater than 400 Hz. Average A-levels of indigenous sounds in these wildernesses differ by 30 dBA.

Ambient sound levels recorded at the ear of a hiker are relatively low in comparison with those of self-noise. Levels of self-noise show greater variability over time than levels on indigenous sounds, and an integrated value about 13 dB greater than that of indigenous sounds. The average level of an at-ear recording of horseback riders differed little from that of the at-ear recording of individual hikers.

Figure 9 depicts the time history of low-altitude, high-speed overflights of the Golden Trout Wilderness by a pair of F/A-18 fighter aircraft. The onset rate of the aircraft noise is on the order of 70 dB per second while the peak level exceeds the indigenous sounds of the forest by about 40 dBA.

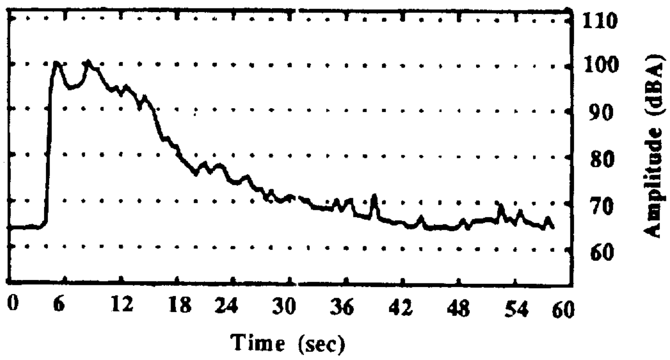


Figure 9. Time history of F/A-18 flyover in Golden Trout wilderness.

Figures 10 through 14 show typical time histories of five aircraft overflights: A high-altitude jet and a low-altitude helicopter in Golden Trout Wilderness, a low-flying military jet and a propeller-driven light aircraft in Superstition Wilderness, and a high-altitude transport jet in Cohutta. The figures show differences in acoustic characteristics of the different types of overflights, notably the greater sound level of helicopters and low-flying military jets. In general, the time histories document an increase in sound level above indigenous sound levels through the duration of the flyovers followed by an eventual decline in sound levels to original levels of indigenous sounds. However, the time history of a high-altitude overflight of Cohutta Wilderness shows virtually no variation over time.

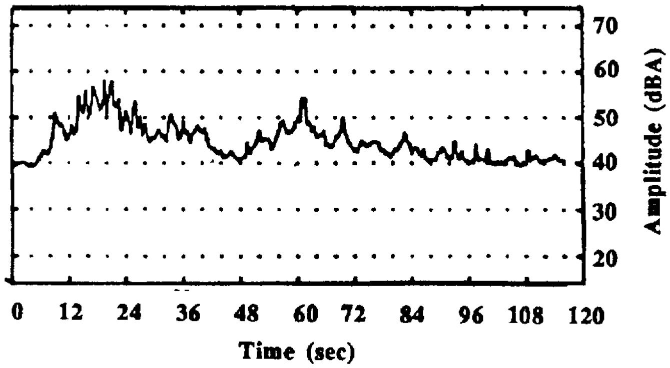


Figure 10. Time history of high-altitude flyover in Golden Trout wilderness.

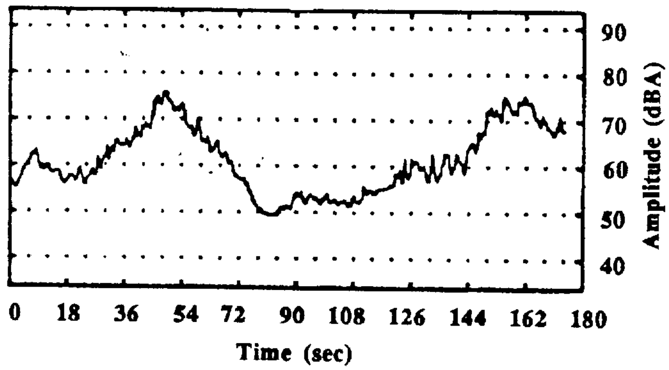


Figure 11. Time history of low-flying helicopter in Golden Trout wilderness.

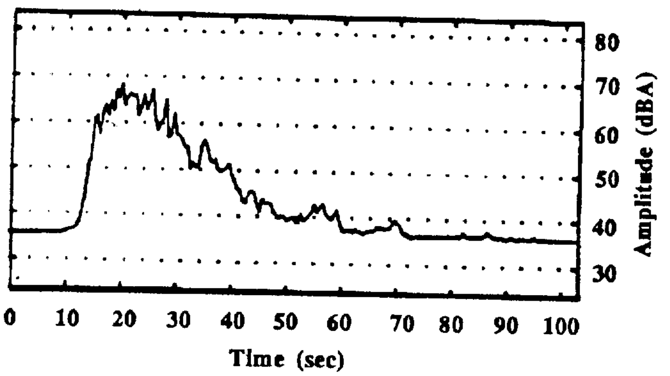


Figure 12. Time history of T-38 flyover in Superstition wilderness.

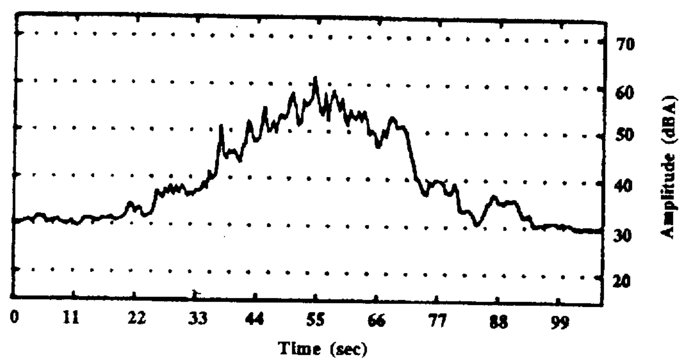


Figure 13. Time history of propeller-driven plane in Superstition wilderness.

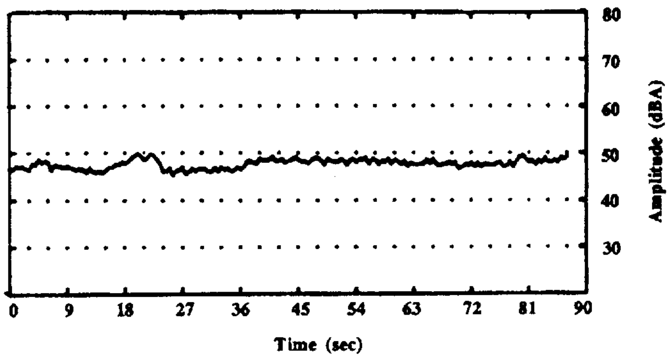


Figure 14. Time history of high-altitude jet flyover in Cohutta wilderness.

Table 2 estimated L_{dn} values averaged over all measurement points for noise exposure for the time period of on-site interviewing in Golden Trout, Cohutta, and Superstition wildernesses. The estimates should not be viewed as values of ambient sound levels, but rather as exposures likely to be experienced by most visitors to these wildernesses. For example, these estimates omit the influence of nocturnal animal noise for Cohutta wilderness, since day use visitors (the bulk of the survey respondents) were not present in the wilderness at night to experience this exposure. Separate estimates are provided for the L_{dn} values associated with ambient and aircraft activity combined. Note that overflights do not control long-term noise exposure in either the Cohutta or Superstition wildernesses.

Wilderness	Ambient L_{dn} (dB)	Aircraft L_{dn} (dB)	Total L_{dn} (dB)
Golden Trout	47	50	52
Cohutta	52	47	53
Superstition	38	34	39

Table 2. Estimated cumulative exposure in three wildernesses.

Acoustic Measurements Made in Conjunction with Telephone Survey

Less comprehensive measurements of overflight noise were made at nine other wildernesses in which visitors were interviewed by telephone. As discussed in the following section, these wildernesses were selected both for their noise exposure and visitor use. Glacier Peak Wilderness (Mt. Baker and Wenatchee National Forests in Washington) was chosen for its high visitor use and high exposure to military aircraft operations. Dolly Sods Wilderness, Monongahela National Forest, in West Virginia was chosen for high military overflight exposure and moderate visitor use. Indian Peaks Wilderness, Arapaho and Roosevelt National Forest, in Colorado and Scapegoat Wilderness, Helena, Lewis and Clark, and Lolo National Forests, in Montana were chosen for high exposure to nonmilitary overflights and high and moderate visitor use, respectively.

Two wildernesses were chosen for their moderate exposure to aircraft overflights (with no distinction between military and nonmilitary operations): High Uintas Wilderness, Ashley and Wasatch National Forests, in Utah (high visitor use) and Caney Creek Wilderness, Ouachita National Forest, in Arkansas (moderate visitor use). Wild Rogue Wilderness, Siskiyou National Forest, in Oregon; Bridger Wilderness, Bridger-Teton National Forest, in Wyoming; and Pemigewasset Wilderness, White Mountain National Forest, in New Hampshire were wildernesses chosen for their low aircraft overflight exposure. The two former wildernesses have high visitor use, while the latter has moderate visitor use.

Acoustic measurements made in each of these nine wildernesses included hourly noise levels over a 24-hr period and the long-term average noise level. In addition to average levels, estimates were made of the distribution of sound levels over frequency. These measures were supplemented by measurement of the sound exposure level of individual aircraft flyovers. As much as 2-hr of spectral data were recorded in each wilderness near a trail registration station at each wilderness. A log of aircraft overflights accompanied the measurements to document times of aircraft activity.

More than 200 overflights were observed by field personnel in the nine wildernesses during the course of data collection. Of these overflights, 64 percent were high-altitude jets; 16 percent were small, propeller-driven aircraft; 2 percent were military tactical aircraft; and 17 percent were unclassified[1]. Figure 15 shows the distribution of types of aircraft observed in each wilderness.

Table 3 summarizes integrated A-weighted sound levels measured at each wilderness. The columns of the table contain values of L_{dn} derived from on-site

Wilderness	Ambient L_{dn} (dB)	Aircraft L_{dn} (dB)	Total L_{dn} (dB)
Glacier Peak	46	42	47
Dolly Sods	42	25	42
Indian Peaks	42	37	43
Scapegoat	38	24	39
High Uintas	33	32	36
Caney Creek	37	16	37
Bridger	32	24	32
Wild Rogue	40	15	40
Pemigewasset	48	21	48

Table 3. Estimated cumulative exposure for nine wildernesses (rounded to nearest dB).

[1] *Aircraft overflights which were unidentifiable for reasons such as overcast skies, forest canopy, or barriers to lines of sight were categorized as "unclassified."*

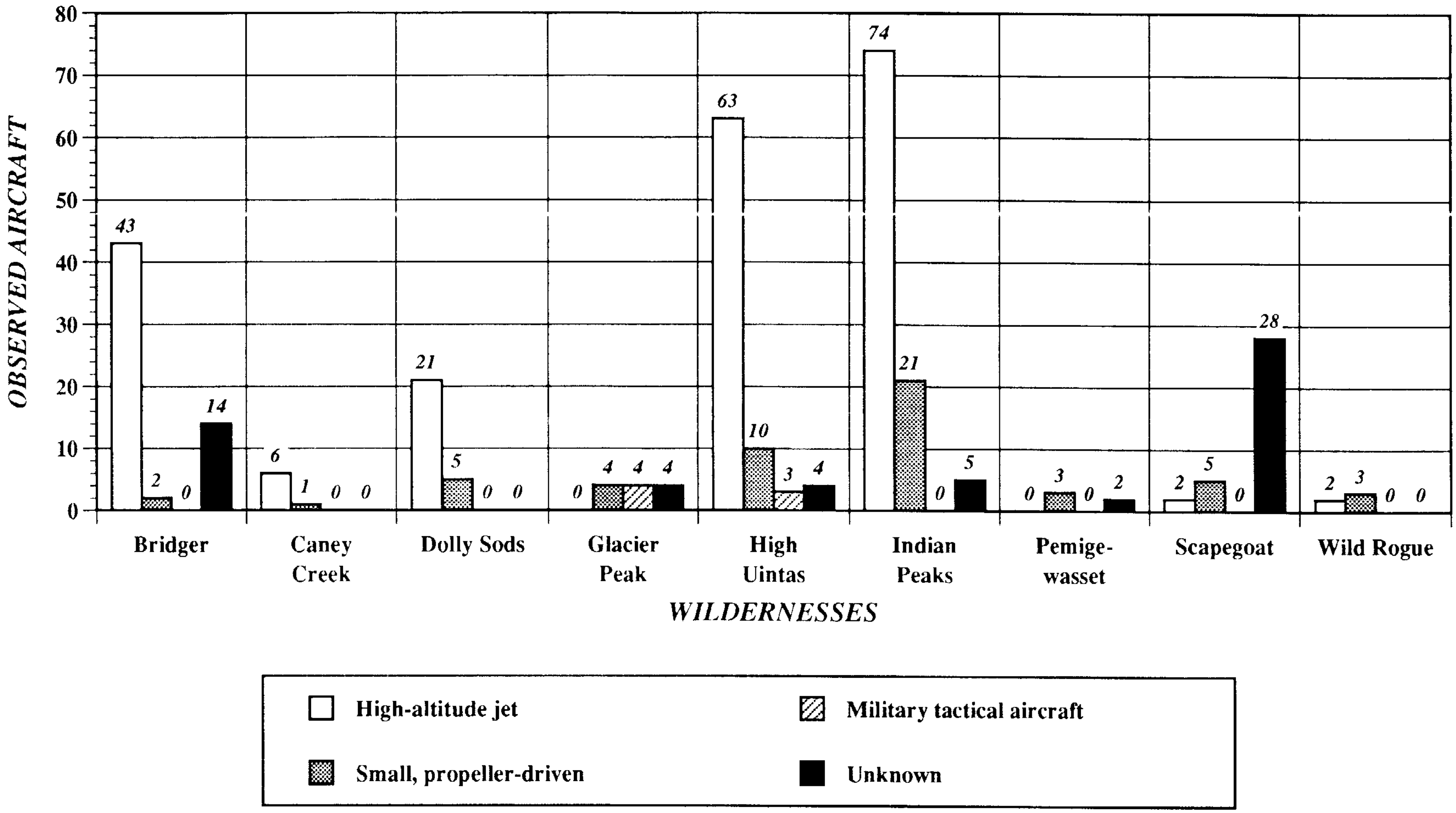


Figure 15.
Distribution of aircraft types observed in nine wildernesses.

measurements. The leftmost of the three L_{dn} columns estimates the level due to indigenous sources (i.e., the ambient level unaffected by aircraft noise intrusions). The middle of the three L_{dn} columns estimates the partial L_{dn} due to aircraft noise intrusions, while the rightmost column shows the total L_{dn} at the site. Indigenous exposure levels ranged from 32 dB in Bridger Wilderness to 52 dB in Cohutta Wilderness[2]. Indigenous and total integrated exposure levels in most wildernesses differed little, since aircraft noise intrusions did not dominate total exposure at most sites.

Table 4 summarizes peak levels of aircraft overflights observed in ten wildernesses. The leftmost of the two columns of figures contains information about the highest half-second aircraft noise levels observed during the course of measurements at each site. The highest levels, observed in the Golden Trout Wilderness, were created by low-altitude, high-speed overflights by military tactical aircraft. The rightmost of the two columns of figures contains information about peak levels averaged over multiple measurement locations (in the cases of Golden Trout and Superstition Wildernesses), or over multiple aircraft noise events at a single measurement point in the other wildernesses.

Wilderness	Maximum Peak Level (dBA)	Average Peak Level (dBA)
Golden Trout	107	93
Superstition	79	66
Glacier Peak	87	79
Dolly Sods	63	58
Indian Peaks	70	63
Scapegoat	57	56
High Uintas	66	61
Bridger	60	54
Wild Rogue	47	47
Pemigewasset	58	53

Note: Peak levels of aircraft flyovers in Cohutta Wilderness were not obtained due to elevated ambient levels and low aircraft noise levels. Peak levels of aircraft flyovers in Caney Creek Wilderness were unobtainable from logs of field observations.

Table 4. Estimated peak levels of aircraft overflights.

[2]*These figures are intended as estimates of integrated noise levels during daytime hours when visitors are typically present in greatest numbers. If noise exposure created by nocturnal animals noise (e.g., noise of large populations of frogs and insects) were permitted to influence these estimates, they could be considerably higher in some cases.*

Estimated Overflight Exposure in FS Wilderness

The extent of aircraft overflight exposure in FS wildernesses can only be approximated within the limits of the accuracy of estimates in the aircraft overflight database (discussed earlier, under "Study Methods") and the relatively small number of wildernesses in which acoustic measurements were made. Also, wildernesses near airports may experience greater aircraft noise impacts than indicated by the database, since noise from airport takeoffs and landings were excluded as directed by PL 100-91. Further, impacts from overflights may suddenly change with changes in flight patterns around the airports. For these reasons, individual wildernesses were not ranked by exposure.

Table 5 shows estimates of overflight exposure in the four categories based on the exposure measurements made in the 12 wildernesses visited during field surveys. Measurements were averaged over the wildernesses in each stratum included in field study[3]. Estimated values of L_{dn} contained in table 5 reflect contributions of aircraft alone without regard for indigenous or other noise sources.

Stratum	Average L_{dn}[1]	Average Peak Level
High-Military Exposure	34	68
High Non-Military Exposure	36	60
Moderate Exposure	24	61
Low Exposure	20	51

[1]Values represent contribution to day-night exposure level by aircraft alone.

Table 5. Estimate of exposure in four categories of wildernesses.

Conclusions Regarding Wilderness Noise Environments

Major findings of acoustic measurement studies include the following:

- Although wildernesses are often overflown by commercial air transports at high altitudes, most are overflown less frequently by small, propeller-driven aircraft at intermediate altitudes, and fewer are regularly overflown by helicopters and tactical military aircraft at low altitude.

[3]*Estimates for the "moderate" stratum do not include Golden Trout Wilderness, since measurements were taken during a period of extensive military flight activity, producing the highest exposure values among the 12 wildernesses.*

- Aircraft altitude alone is a poor predictor of overflight noise exposure audible by wilderness visitors
- Aircraft noise intrusions on the indigenous sounds of wildernesses are readily audible in large areas.
- The degree of aircraft noise intrusions on the indigenous sounds of wildernesses is readily quantifiable in statistical terms.
- The indigenous sounds of wildernesses under FS management, although variable in time and space, have distinctive acoustic qualities and characteristic statistical properties.
- Levels of indigenous sounds (at least in coniferous forest) are predictable to a considerable degree from wind speed.
- The maximum sound pressure of the single highest (acoustic) level overflight controls the daily integrated noise exposure of many wildernesses.
- Aircraft overflights are audible even when their A-weighted sound pressure levels are comparable to the A-weighted level of indigenous sounds.

IMPACTS ON VISITOR ENJOYMENT

Field Study Goals

Two field studies were conducted to investigate the impacts of aircraft overflights on visitors to FS wildernesses. The on-site study was designed to associate visitor responses with acoustic measurements of aircraft overflight exposure, with the goal of synthesizing a quantitative dosage-response relationship. The intent of this study was to produce information for linking a measure of aircraft overflight exposure with a measure of reactions to that exposure among wilderness visitors.

The telephone interview study was designed to provide supporting evidence for the dosage-response relationship synthesized under the on-site study. Acoustic measurements made in conjunction with the telephone survey were less extensive than those made for the on-site study, and were not made at the time of respondents' wilderness visits.

As noted earlier, the on-site study assessed short-term impacts of aircraft overflights, since these reactions are suitable for linking directly and reliably to exposure by means of a quantitative dosage-response relationship. Short-term impacts of overflights are also worth assessing because they permit analyses of issues of economic, managerial, regulatory, and theoretical importance.

The telephone study was intended to increase understanding of wilderness visitors' reactions to overflights in the context of reflections on complete visits. Intermediate-term impacts (measured within 1 to 2 wk of visitors' completion of a wilderness visit) can support analyses of integrated reactions of outdoor recreationists to overflights.

Selection of Wildernesses

The optimal plan for selecting sites and respondents is often the use of a stratified random sample. Stratification provides subsamples to assure that the full range of characteristics of interest is sampled; for example, all levels of noise exposure and visitor use. A random sample of sites is then selected within each stratum in a way that all sites have an equal chance to be chosen. Similarly, within each site a random sample of visitors is selected, with equal (or specified) probability of selection for all visitors. For this study, neither of these strategies is prudent. The inaccessibility of wildernesses poses difficulties for random selection of sites. It is likely that a random selection process would identify at least some locations in which noise measurements are impractical, or in which a means for tracking visitors would be unduly expensive.

Since random sampling of sites is unlikely to meet the goals of this study, a purposive sample is preferred. Such a sample offers opportunities for cost-effective acoustic measurement and contact with large numbers of potential respondents. External validity can be achieved by careful attention to the dimensions along which recreational areas vary; dimensions chosen on the basis of their importance and relevance to the impact of aircraft overflight exposure. Methods of selecting visitors within sites necessarily depend on the volume of visitor use. For more remote sites, even an exhaustive sample may prove to be barely adequate for statistical analysis.

Wildernesses were selected for study on the basis of levels of aircraft noise exposure and visitor use. For each of the four strata (fig. 3) wildernesses were further categorized into high, moderate, and low visitor use, in units of recreation visitor days—RVD's, defined as the quotient of recreational visitor hours (RVH's) divided by 12. Figure 16 shows the 12 strata produced by this scheme. The high visitor use substrata included wildernesses with more than 40,000 RVD's per year. The moderate visitor use substrata included wildernesses with 10,000 to 40,000 RVD's per year. The low visitor use substrata included wildernesses with fewer than 10,000 RVD's per year.

The following considerations also affected site selection:

- Inclusion of areas of both high and low levels of indigenous sounds
- Inclusion of three ecotypes (arid, coniferous forest, and deciduous forest)

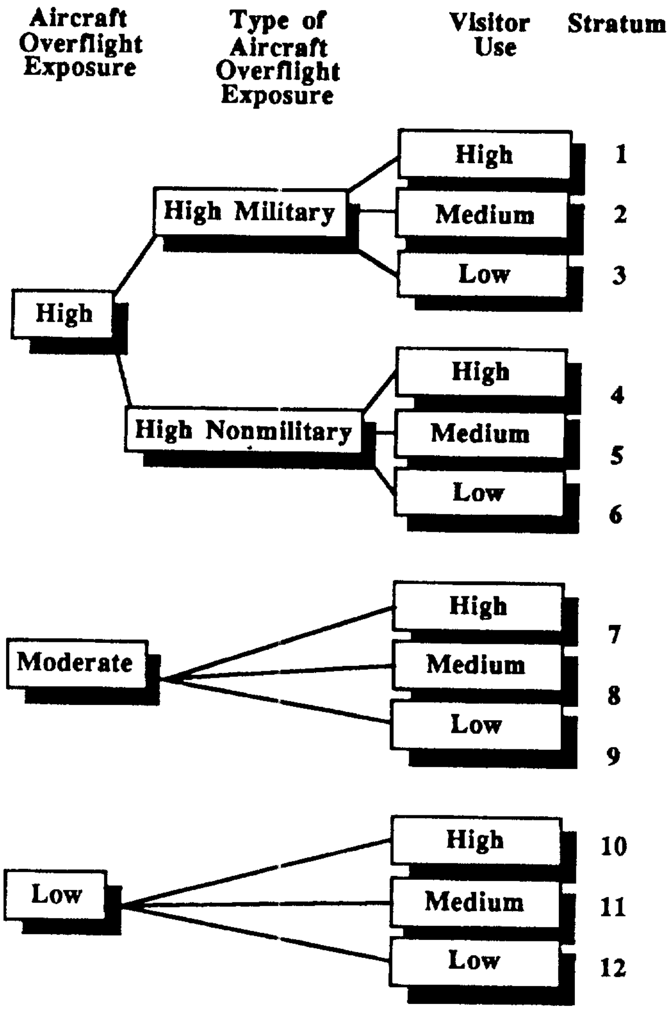


Figure 16. Stratification plan based on aircraft overflight exposure and visitor use.

- Opportunities for soliciting opinions from both hikers and stock users
- Survey of both day-use and overnight visitors
- Inclusion of areas exposed to helicopter as well as fixed-wing overflights.

The cost and difficulty of logistical support for on-site interviewing and coordinated acoustic measurements in remote wilderness locations limited the study to three wildernesses. A total sample of 800 respondents from the three wildernesses was sought. This sample was composed of 300 visitors in each of the Superstition and Cohutta Wildernesses and 200 visitors in the Golden Trout Wilderness (in which visitor use was more widely dispersed and more difficult to sample.)

The lower cost of telephone interviewing without coordinated acoustic measurements permitted 12 wildernesses to be selected for the intermediate-term study. The 12 are the Superstition, Cohutta, Golden Trout, Glacier Peak, Dolly Sods, Indian Peaks, Scapegoat, High Unitas, Caney Creek, Bridger, Wild Rouge, and Pemigewasset. Wildernesses selected from eight of the strata for both studies are shown in table 6. Two sites were selected from each of the four high visitor use strata and one from each of the four moderate visitor use strata for telephone interviews. A total sample of 1,200 respondents—100 from each of 12 wildernesses—was sought (fig. 1).

Wilderness	State	Visitor Use (RVD's)	Stratum
Glacier Peak	Washington	187,700	1
Superstition	Arizona	98,200	1
Dolly Sods	West Virginia	17,000	2
Cohutta	Georgia, Tennessee	77,300	4
Indian Peaks	Colorado	62,700	4
Scapegoat	Montana	23,400	5
Golden Trout	California	69,600	7
High Uintas	Utah	296,100	7
Caney Creek	Arkansas	11,500	8
Wild Rogue	Oregon	48,500	10
Bridger	Wyoming	198,400	10
Pemigewasset	New Hampshire	22,600	11

Table 6. Wildernesses selected for short- and intermediate-term studies of aircraft overflight impacts.

Interviewing Procedures

For on-site interviews, interviewers were trained to verbally administer questionnaires to wilderness visitors throughout daylight hours. On-site interviewing was conducted (1) at two campsites and four trail heads within the Golden Trout Wilderness, (2) at two campsites within the Cohutta Wilderness, and (3) at two trail heads within the Superstition Wilderness.

Interviewing sites were located near areas in which acoustic measurements were made. In general, trails expected to be overflown were divided into segments corresponding to several hours' hike each. A noise monitor was located in each segment, out of view of the trail. Interviewers were stationed at the boundaries of instrumented areas to conduct interviews with visitors traveling in each direction. For example, outbound respondents (those exiting a wilderness upon completion of a visit) were typically interviewed at a trail head, while inbound respondents (those proceeding farther into a wilderness) were typically interviewed hours to days into their visits.

Group administration of the on-site interview was made possible by providing each respondent with separate interview answer sheets. Response information was coded on-site, entered into a computerized database at a support site at each wilderness and transmitted to off-site computers.

The survey instrument measured several visitor reactions (selected after extensive consideration of alternatives) to overflights:

- Annoyance due to aircraft noise
- Annoyance due to the sight of aircraft
- Enjoyment of trip
- Intention to return to the wilderness.

Items soliciting aspects of visits that recreationists liked most and least were included in the questionnaire to allow spontaneous mention of overflights and to provide perspective on the relationship between aircraft flyovers and other disfavored aspects of outdoor recreational experiences, such as conditions of trails, number of other people seen, and absence of visible signs and sounds of civilization.

An additional item was included in the questionnaire to evaluate impacts associated with the different types of aircraft specified in PL 100-91: High-altitude commercial jets, low-flying military aircraft, private aircraft and helicopters. Visitors also provided the date and time of the start of their visits and the activities in which they engaged during their visits. This information was collected in part to allow activities and itineraries to be associated with overflight exposure. The information was also collected to determine whether the sensitivity of visitors to exposure varied with their activities at the time of exposure, particularly activities associated with water and stock use.

For telephone interviews, the first adult member of the household, 18 years or older, contacted was interviewed if he/she participated in the trip and agreed to be interviewed. Data files containing responses for completed interviews were analyzed on an ongoing basis.

All of the response measures for the on-site interviews noted above were included in the telephone questionnaires. The telephone interviews included additional items concerned with:

- How aircraft affected visits
- Formal complaint behavior
- Wilderness experience
- Factors contributing to wilderness selection for visits
- The importance of wildernesses in respondents' lives
- Satisfaction with specific aspects of the wilderness visit (including trail conditions,

Wilderness visitors were interviewed to determine their reactions to aircraft overflights.

number of other people seen, and absence of visible sights and sounds of civilization)
- Information about accidents.

Sample Size and Response Rate

Completed interviews were obtained from 96 percent of 954 on-site visitors approached in three wildernesses. The total of 920 completed interviews was composed of 185 interviews in the Golden Trout Wilderness, 343 in the Cohutta Wilderness, and 392 in Superstition Wilderness. No statistically reliable differences were found among visitors who granted interviews and those who did not on the basis of apparent age, gender, party size, time of day, day of week of approach, and wilderness visited.

Completed interviews were obtained by telephone from 92 percent of 1,284 self-registrants at the 12 wildernesses. The total of 1,180 completed interviews was composed of 100 interviews in all of the wildernesses except Bridger and Scapegoat which had 99 and 81, respectively. While completion rate of interviews differed among wildernesses (visitors to Superstition and High Uintas were less likely to agree to participate), no differences among visitors who did and did not grant interviews were found on the basis of sex, apparent age, length of visit, or size of party.

Response to Key Items

Figure 17 shows percentages of respondents in the short- and intermediate-term studies who reported an intent to revisit wildernesses. Nearly all visitors to all wildernesses reported their intent to return. No visitor among the 2,020 interviewed cited aircraft-related reasons for not returning. Intention to return cannot therefore serve as a useful measure of the impact of overflights on wilderness visitors. As seen in figure 18, reports of enjoyment of visits are also concentrated in the most positive categories. Only minor variation in enjoyment of visits was observed among wildernesses.

Only a few visitors took the opportunity to spontaneously mention aircraft-related factors as the most favored or disfavored aspects of a wilderness trip. No respondent mentioned aircraft as a most-liked aspect. Fewer than 1 percent of all respondents in both the short- and intermediate-term studies mentioned aircraft-related factors as aspects of the trip liked least. Aircraft-related factors were mentioned by far fewer visitors than inadequate trail maintenance, crowding, weather, etc. as least liked aspects of wilderness visits.

The type of aircraft most often noticed by respondents varied considerably among the 12 wildernesses, due in part to differences in the mix of aircraft overflying the various wildernesses. Table 7 shows percentages

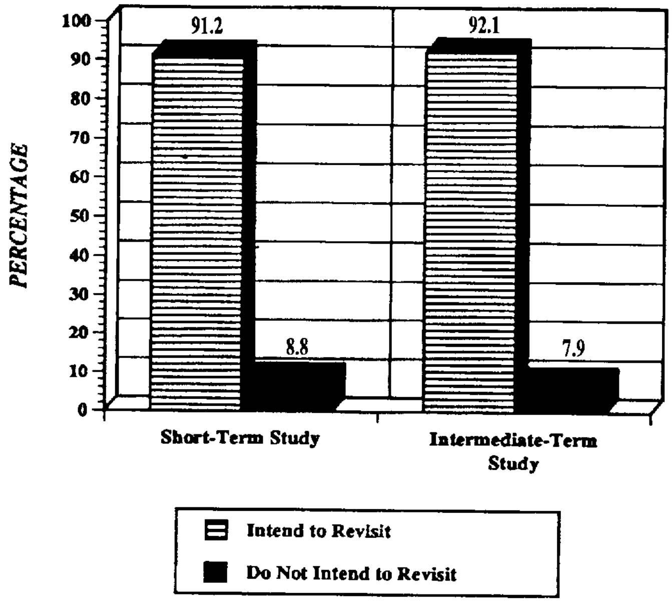


Figure 17. Intended future visits.

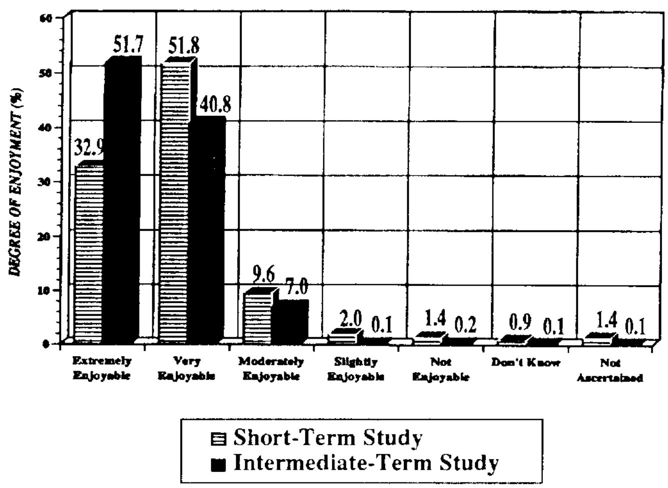


Figure 18. Degree of visit enjoyment.

Type of Aircraft Noticed

Response	Percentage (Mult. Responses Permitted) All Sites (N=920)	Golden Trout (N=185)	Cohutta (N=343)	Superstition (N=392)
None	41.0	26.5	52.2	38.0
High Alt. Jet	33.3	39.5	21.6	40.6
Helicopter	9.6	40.5	2.0	1.5
Low Flying Jets	13.0	45.4	4.7	5.1
Sm. Pvt. Airplane	23.6	11.9	20.4	31.9
Other	4.0	8.1	5.0	1.3
Don't know	0.8	0.5	0.6	1.0
Refused	0.1	0.5	0.0	0.0
Not ascertained	0.0	0.0	0.0	0.0

Table 7. Percentage of respondents by types of aircraft noticed in three wildernesses.

of respondents noticing each type of aircraft in the short-term (on-site) survey. High-altitude jets were reported as noticed most often; with small private planes, low-flying jets, and helicopters noticed with decreasing frequency. The "other" category included responses which were not readily and unambiguously coded, including "small plane," "larger plane," "airplanes." "sea planes," "light planes," and "civilian planes." Table 8 shows corresponding percentages for the intermediate-term (telephone) survey. High-altitude jets and small private planes were reported as noticed most often, with fewer reports of noticing low-flying jets and helicopters.

ticing aircraft was that the aircraft had no effect on their visits. The "other" category included many types of responses such as: It was disruptive, intrusive, unexpected, it disturbed peace and quiet, it was a reminder of civilization, it was just noticeable, and it made trip more pleasurable and exciting. No reliable differences in these percentages were observed among wildernesses.

Annoyance due to aircraft noise varied considerably among the three wildernesses in which on-site interviews were conducted, and among the 12 wildernesses supporting telephone interviews. Figure 20 shows percentages responding in each annoyance category in three wildernesses supporting on-site study of short-term responses. Figure 21 shows corresponding percentages found in the study of intermediate-term responses in 12 wildernesses.

Type of Aircraft Noticed

Percentage (Multiple Responses Permitted)

Response	All sites (N=1180)	Golden Trout N=100)	Cohutta (N=100)	Superstition N=100)	Glacier Peak (N=100)	Dolly Sods (N=100)	Indian Peaks (N=100)	Scapegoat (N=81)	High Uintas (N=100)	Caney Creek (N=100)	Bridger (N=99)	Wild Rogue (N=100)	Pemigewasset (N=100)
None	44.1	44.0	65.0	46.0	35.0	57.0	41.0	45.7	26.0	71.0	20.2	27.0	51.0
High Flying Jet	34.6	34.0	18.0	30.0	51.0	19.0	38.0	37.0	57.0	12.0	63.6	32.0	24.0
Helicopter	13.8	20.0	1.0	21.0	20.0	18.0	4.0	13.6	8.0	4.0	20.2	28.0	12.0
Low Flying Jet	12.3	28.0	4.0	9.0	27.0	13.0	7.0	4.9	16.0	4.0	10.0	3.0	19.0
Small Private Airplane	25.8	15.0	11.0	33.0	30.0	12.0	28.0	29.6	30.0	11.0	37.2	48.0	24.0
Other Aircraft	2.7	6.0	0.0	0.0	3.0	6.0	3.0	1.2	5.0	2.0	6.0	2.0	1.0
Don't know	3.4	2.0	7.0	3.0	1.0	3.0	2.0	6.2	4.0	5.0	1.0	7.0	0.0
Refused	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Not Ascertained	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 8. Percentage of respondents by types of aircraft noticed in 12 wildernesses.

Figure 19 shows how aircraft affected telephone respondents' visits to the 12 wildernesses (this question was not asked during the on-site interview). The most common response among visitors who reported no-

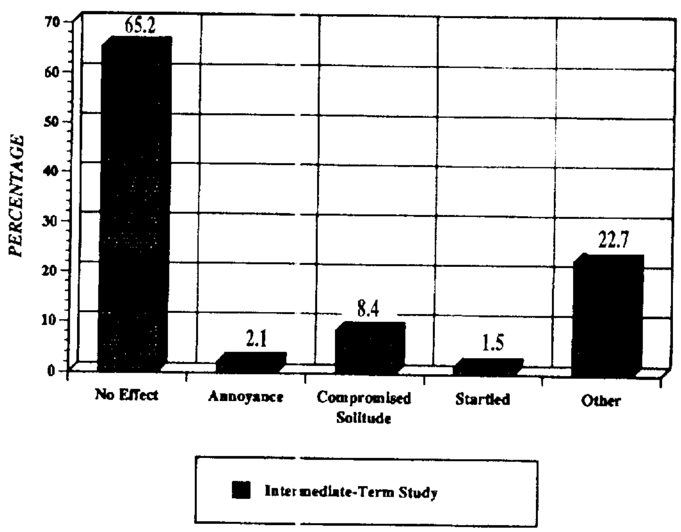


Figure 19. How visitors were affected by aircraft.

Annoyance due to the sight of aircraft followed the same response pattern as annoyance due to aircraft noise, but at a lower prevalence rate. For example, fewer than 16 percent of respondents in Golden Trout Wilderness reported annoyance due to seeing aircraft in the short-term study, as compared with 24 percent annoyed by aircraft noise in that wilderness. Fewer than 10 percent of the 1,180 respondents in the intermediate-term study were annoyed to any degree. Figure 22 compares annoyance due to sight and sound of aircraft in the 12 wildernesses in which visitors were interviewed by telephone.

Figure 23 displays the type of aircraft judged most annoying to hear among respondents who reported noticing more than one type of aircraft. Responses are combined over the three wildernesses supporting

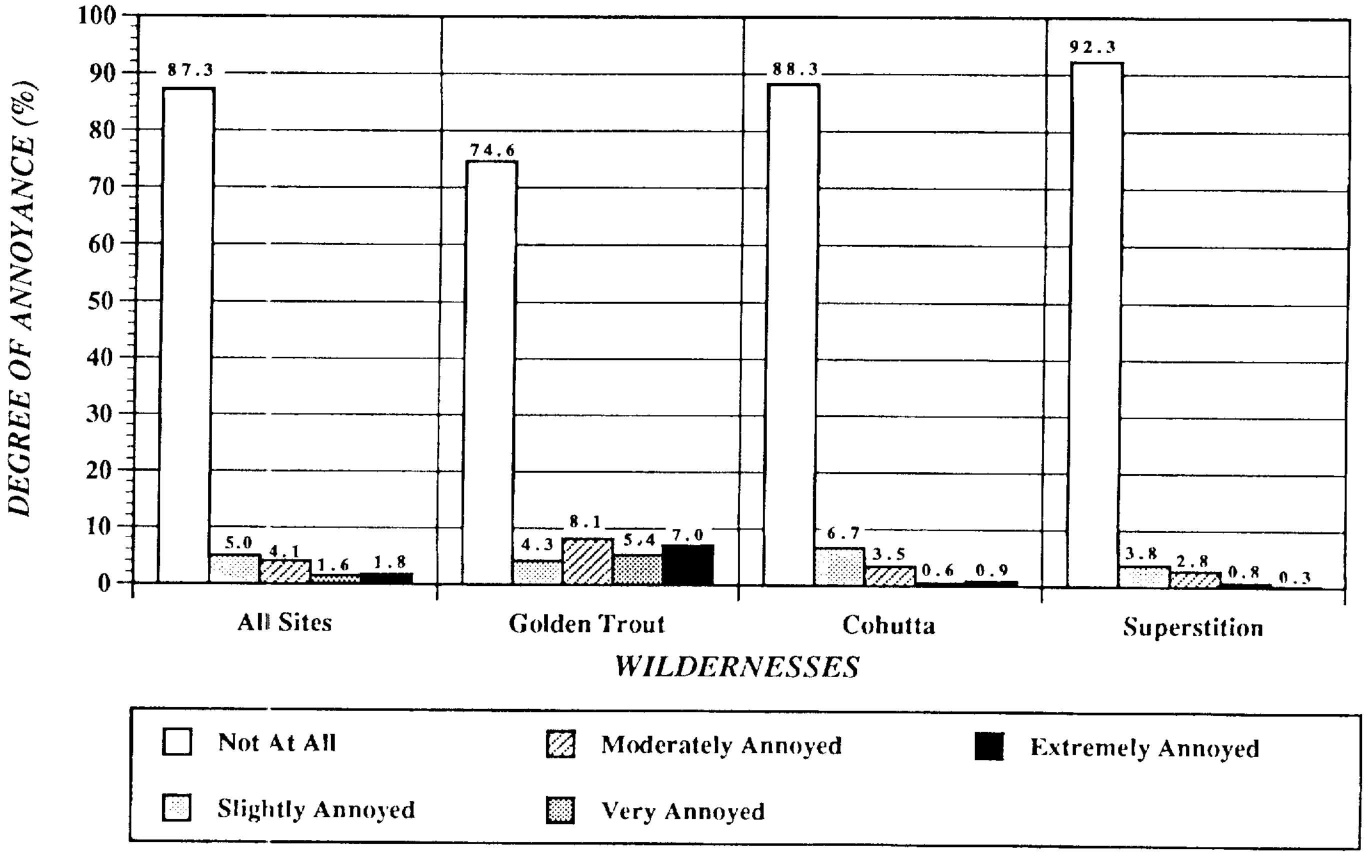


Figure 20. Degree of annoyance due to aircraft noise in three wildernesses.

on-site interviews and over the 12 wildernesses supporting telephone interviews due to small sample sizes. Visitors judged low-flying jets and helicopters more annoying to hear than high-altitude jets and small private aircraft.

Responses to several questionnaire items revealed a general satisfaction and enjoyment with wilderness visits. The three most often mentioned reasons for visiting wilderness were experiencing peace and quiet (89 percent), viewing scenic vistas without hearing sounds of civilization (87 percent), and hearing the sounds of nature (81 percent). Most wilderness visitors were very or extremely satisfied with the absence of (a) sounds of civilization (76 percent) and (b) visual signs of civilization (68 percent).

Relationships Among Items

About 10 percent fewer respondents questioned at all sites in both surveys were annoyed by the sight than by the sound of aircraft overflights. Respondents who were annoyed by the sight of aircraft also tended to be annoyed by the sound of aircraft, although the reverse was less often the case. Only about 2 percent of respondents were annoyed only by the sight of aircraft.

Little relationship was noted between the activities in which visitors engaged (primarily water- and stock-related activities, in addition to hiking and picnicking) and whether they noticed aircraft. Activities were also unrelated to annoyance by either the sight or sound of aircraft overflights. Wilderness visit enjoyment showed little relationship with annoyance due to the sound or sight of aircraft.

No statistically reliable relationships were found between annoyance due to the sight or sound of overflights and respondents' reported intent to revisit. Intention to revisit was also unrelated to aspects of visits that respondents reported liking least.

Nonacoustic variables explored in this study (including likelihood of non-return, non-enjoyment of visit, duration of visit, dissatisfaction with wilderness conditions, or frequency of reporting complaints) in general failed to predict annoyance due to the sound of aircraft. In the short-term (on-site) study, the only variable reliably predicting annoyance was the wilderness visited, which is of course in itself related to overflight exposure. In the intermediate-term (telephone) study, the only reliable predictor of annoyance was satisfaction with the absence of sounds of civilization. On a scale

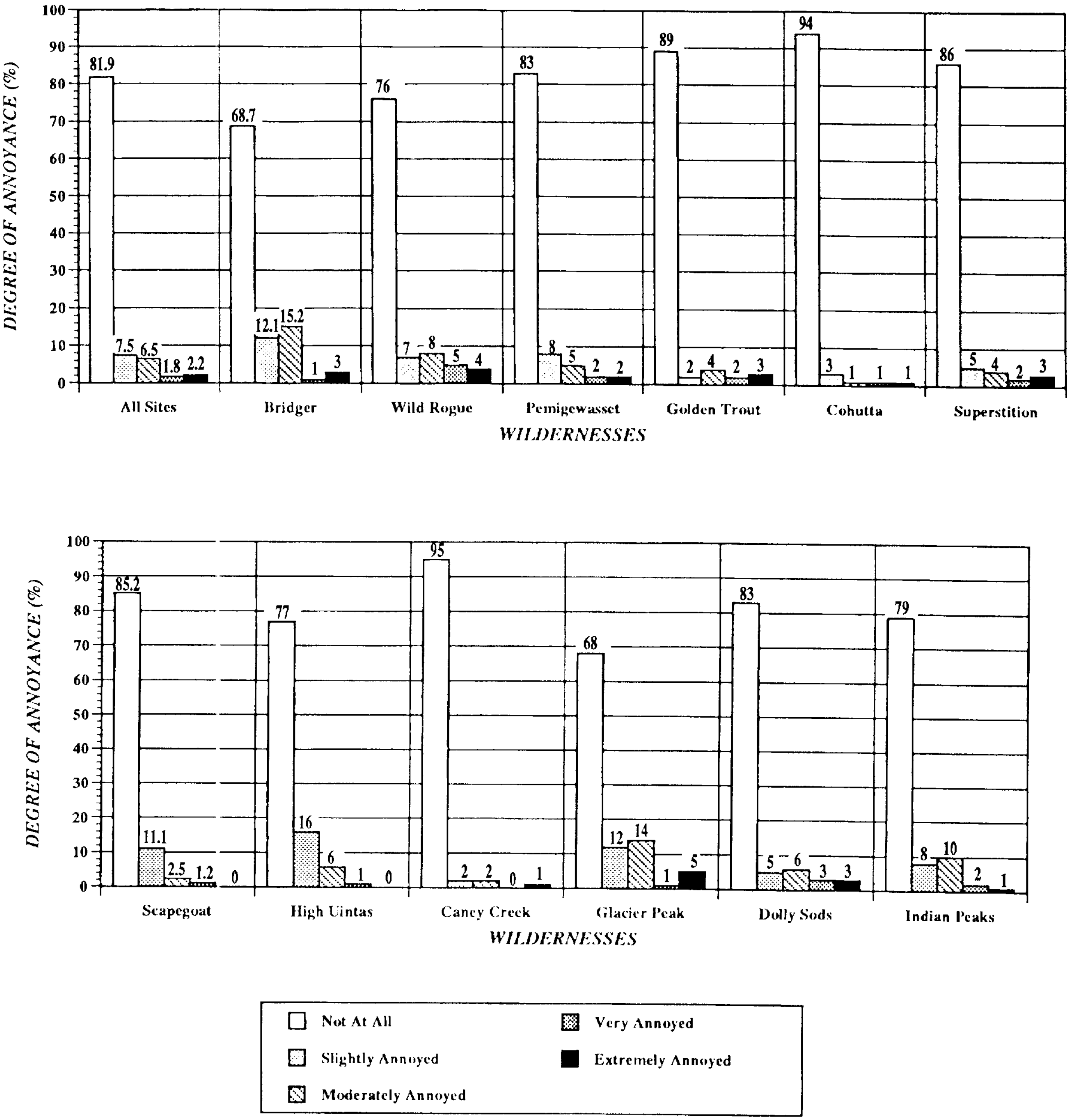


Figure 21. Degree of annoyance due to noise in 12 wildernesses.

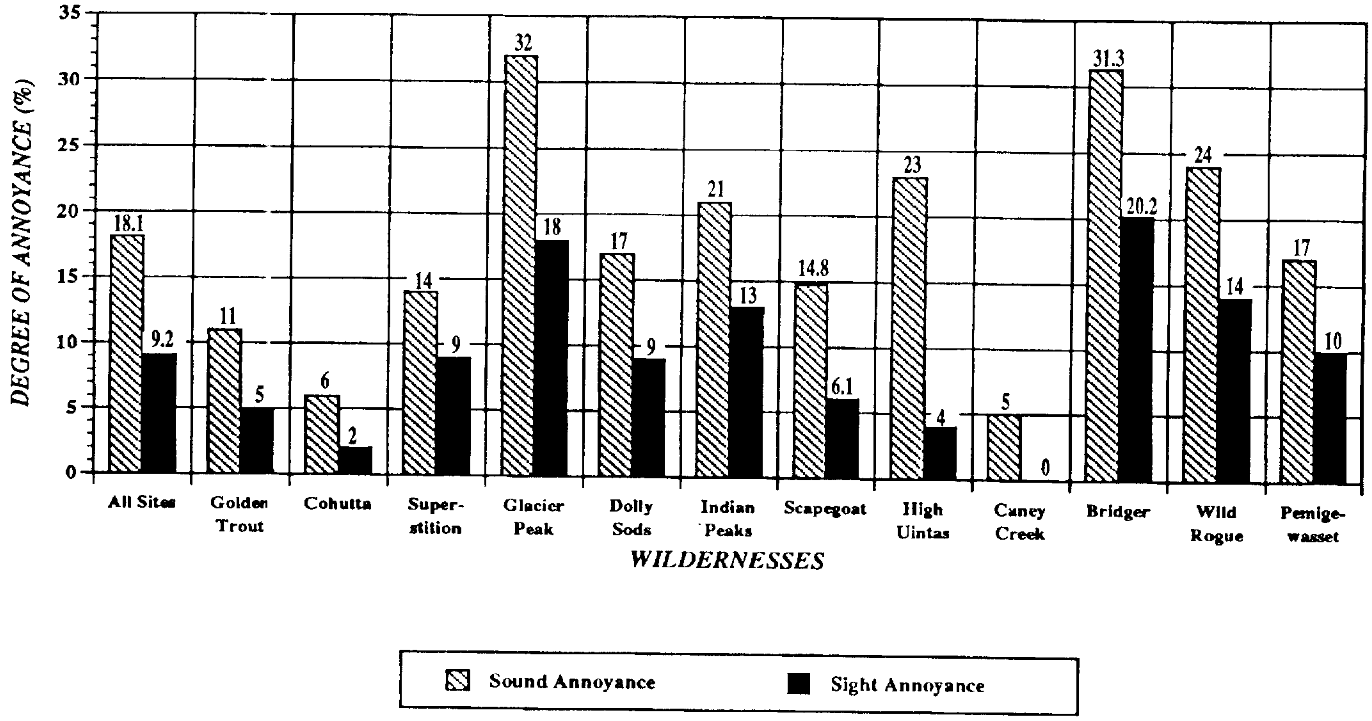


Figure 22. Annoyance due to the sight and sound of aircraft.

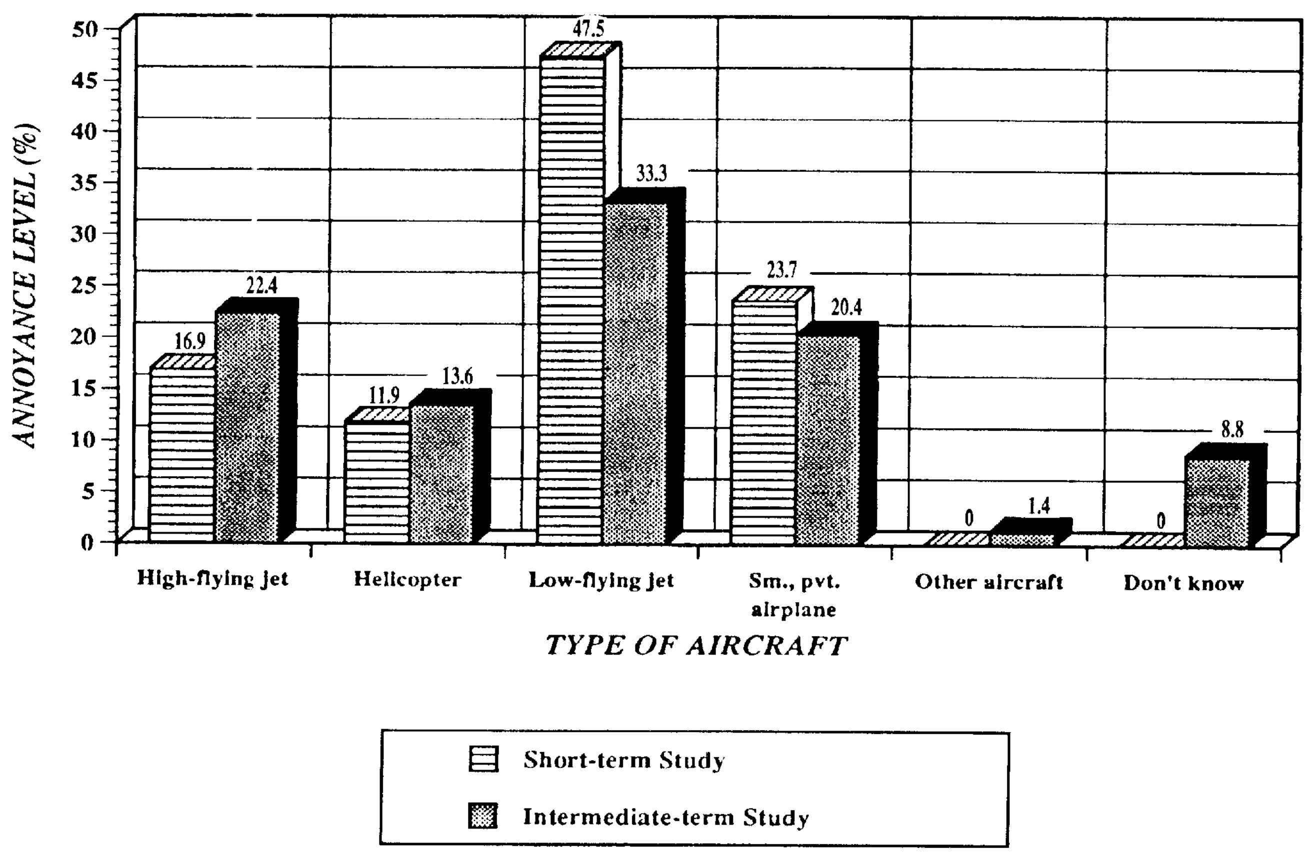


Figure 23. Most annoying type of aircraft to hear.

of 1 to 5 of increasing satisfaction, respondents who reported any degree of annoyance with aircraft noise produced an average satisfaction with absence of sound of civilization of 3.4, while those who were not annoyed by aircraft noise reported an average satisfaction of 4.1.

Dosage-Response Relationships

The noise exposure of places visited by outdoor recreationists can be expressed in a number of ways. The metric most commonly used to assess impacts of transportation noise on residential communities is L_{dn}. The appropriateness of a long-term cumulative noise metric such as L_{dn} for purposes of predicting reactions to overflights by short-term visitors to outdoor recreation sites is questionable. Nonetheless, an effort was made for the sake of consistency with prior practice in residential settings to predict the prevalence of annoyance among wilderness visitors from knowledge of L_{dn} values.

Additional dose-response analyses were also conducted with other metrics of aircraft noise exposure. These metrics included the maximum sound level of overflights, the duration of a wilderness visit, and the recreationists' self-report of the number of aircraft noticed during a visit. The former measure is highly correlated with L_{dn} values under the circumstances of exposure common in many wildernesses, while the latter two measures are correlated with L_{dn} to a lesser degree.

A dosage-response relationship between place-oriented measures of cumulative noise exposure and the prevalence of aircraft noise annoyance among wilderness visitors was developed from information collected during the short-term (on-site) survey. Figure 24 shows the relationship between the current data (three wildernesses) and a conventional, empirically derived dosage-response relationship between the prevalence of annoyance in residential settings and exposure to transportation noise. The values of L_{dn} plotted on the abscissa are those produced by aircraft activity in the three wildernesses, and do not reflect the contributions (if any) of indigenous sounds to total exposure in units of L_{dn}.

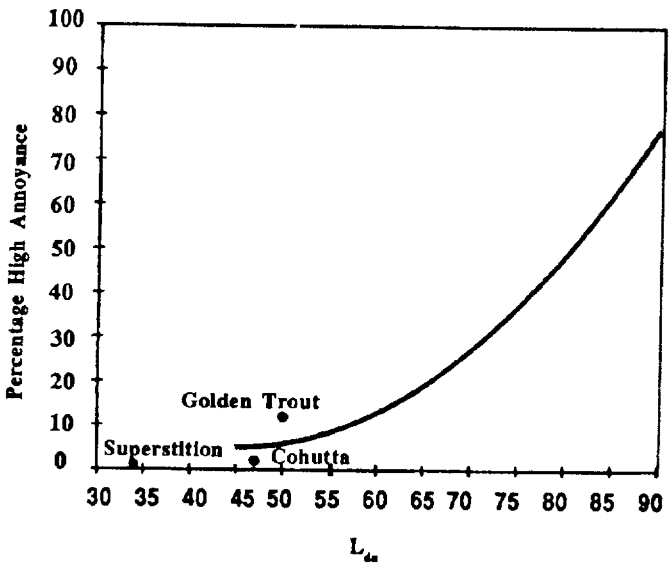


Figure 24. Prevalence of annoyance in three wildernesses in relation to empirical dosage-response relationship for residential exposure.

The relationship overestimates the prevalence of annoyance in Cohutta Wilderness, but underestimates it in Golden Trout. Since this residential relationship is undefined for L_{dn} values below 45 dB, it makes no prediction about the prevalence of annoyance in Superstition Wilderness.

Figure 25 shows the relationship between the current data and a theoretically derived dosage-response relationship between the prevalence of annoyance in residential settings and exposure to general transportation noise. The slope of this curve is that of the growth of loudness (the subjective impression of sound intensity) with sound level (a physical measurement of the amount of energy sound contains). The position of the curve on the abscissa, which reflects the aggregate influence of nonacoustic factors on annoyance judgments, is given by a decibel-like quantity known as D^*. D^* is essentially a L_{dn} value above which people describe themselves as highly annoyed by noise exposure.

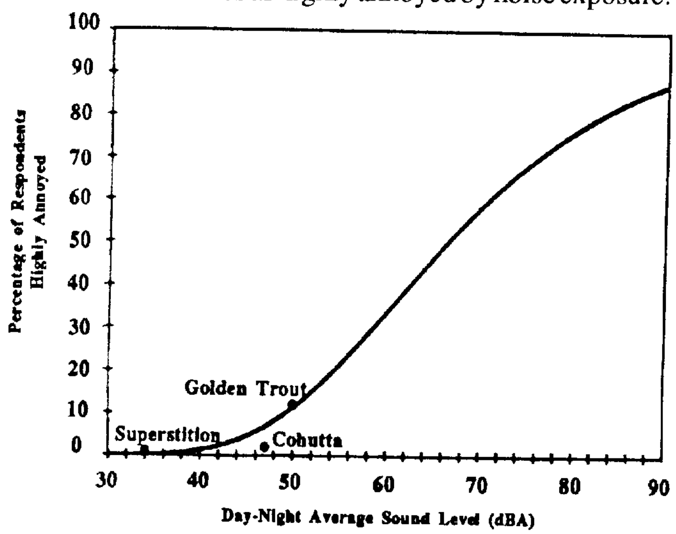


Figure 25. Prevalence of annoyance in three wildernesses in relation to theoretical dosage-response relationship for residential exposure.

The mean value of D^* for a large body of residential annoyance studies is 72 dB. The value that yields the best fit to the current data set (62.1 dB) is approximately 10 dB lower. If this finding can be replicated and generalized, it would imply that residents of urban communities will tolerate ten times more aircraft noise exposure than visitors to wildernesses before describing themselves as highly annoyed by the noise.

Results of Surveys

The major findings of the social surveys of wilderness visitors' short-term and intermediate-term reactions to aircraft overflights may be summarized as follows:

- Aircraft noise intrusions did not appreciably impair respondents' overall enjoyment of their visits to wildernesses nor reduce their reported likelihood of repeat visits.
- The majority of wilderness users interviewed were not annoyed by overflights. A minority (16 percent) was annoyed in some degree, and a smaller minority (4 percent) was highly annoyed by overflights.
- Three of the most often mentioned reasons for visiting wilderness (selected from a list of possible reasons) were: experiencing peace and quiet (89 percent of respondents); viewing scenic vistas without hearing sounds of civilization (87 percent); and hearing the sounds of nature (81 percent).
- Most visitors (76 percent) were very or extremely satisfied with the absence of sounds of civilization.
- Overflights were only rarely cited as the least-liked feature of visits to wildernesses.
- The most significant impact of aircraft overflights on respondents was associated with the noise exposure that they create.
- Low-altitude, high-speed aircraft were reported as the most annoying type of aircraft to hear or see.
- Although many respondents were not exposed to noise from low-altitude, high-speed flights, those who were exposed were often annoyed by them.
- The prevalence of aircraft noise-induced annoyance among respondents was predictable from physical measurements of noise exposure.
- The intensity of aircraft noise-induced annoyance decreased with elapsed time between exposure and self-report.
- For the same level of aircraft noise exposure, the prevalence of annoyance among respondents was greater than that of residential populations.
- Demographic and most other characteristics of respondents (e.g., age, sex, group size, number of previous visits, etc.) had negligible influences on their annoyance with overflights.
- Annoyance associated with overflights was more strongly related to noise exposure than to the visibility of aircraft or their condensation trails.
- Reactions to overflights were better predicted from physical measures of noise exposure than from self-reports of numbers of aircraft noticed.
- A theory-based interpretation of the reactions of respondents to aircraft noise exposure in wilderness settings suggests that they are approximately 10 dB less tolerant of noise than in residential settings.
- Military tactical aircraft (both fixed and rotary wing) were reported to be more annoying than small propeller-driven aircraft and high-altitude jet transports.
- Overall enjoyment of visits and intention to return were unrelated to (and thus could not be predicted by) any observed nonacoustic variables.
- Respondents who were annoyed by aircraft noise reported less satisfaction with the absence of sounds of civilization.

Conclusions

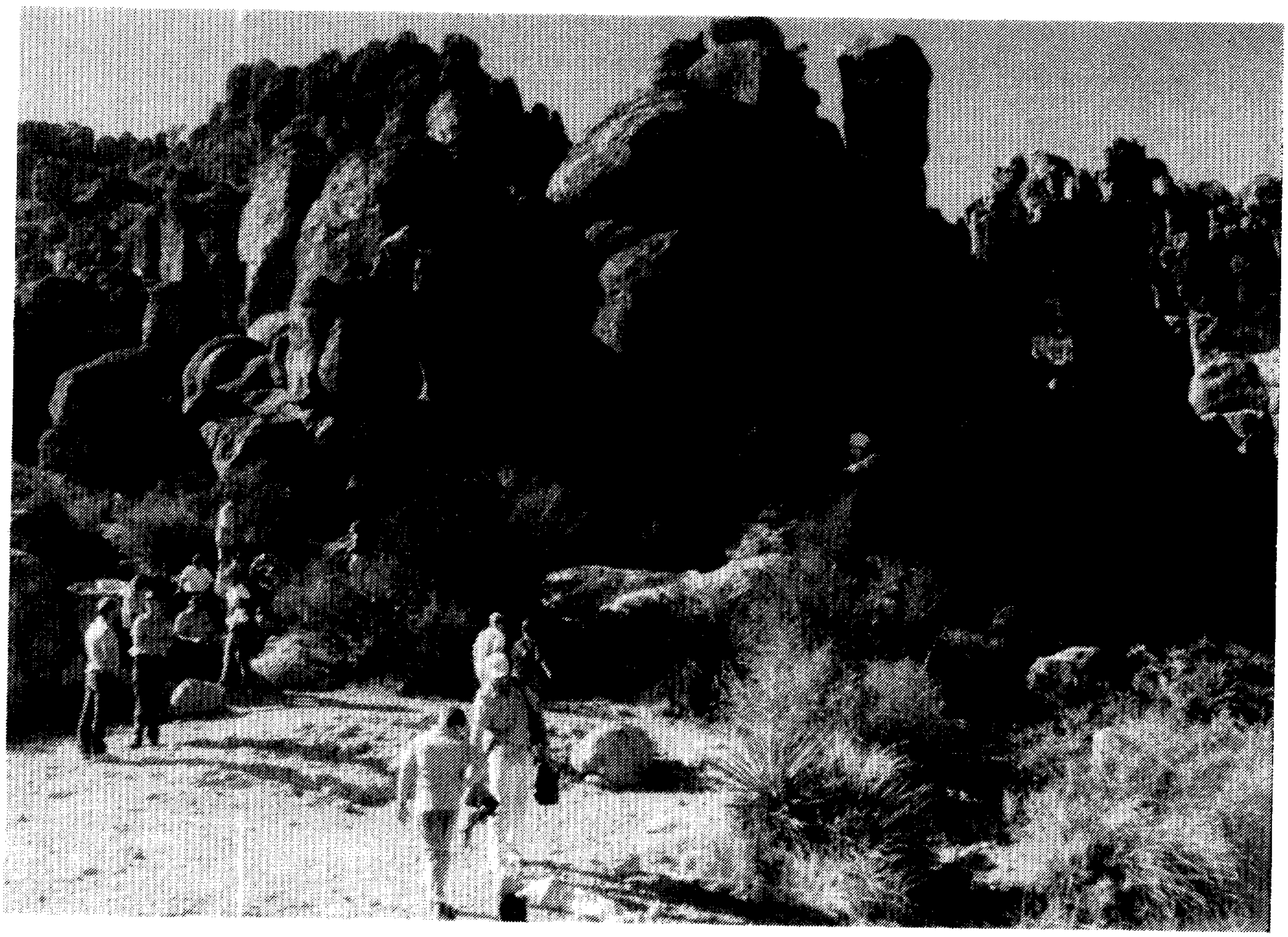
The above results were developed from our sample of wilderness users. While the sample wildernesses selected were carefully chosen to represent a cross-section of overflight exposure levels and visitor densities, generalization of inferences drawn from these studies to other wildernesses must be made with care because of the purposive rather than random selection of study sites. Generalizations are also affected by the relatively short duration of interviewing (opinions of visitors to wildernesses might differ on a seasonal basis) and by the uniqueness of some wildernesses. Finally, since some of the analyses were conducted on combined data from various wildernesses, not all results apply equally to each individual wilderness.

Nonetheless, some general conclusions can be made from the results provided above. Few adverse impacts to wilderness users were found resulting from overflights of FS-managed wildernesses. Seeing aircraft had less impact on visitors than hearing them. The principal adverse impact was aircraft noise-induced annoyance of a fairly small percentage of outdoor recreationists. This result holds true regardless of the age, sex, experience level, trip characteristics, or any other demographic variables examined.

The reader should be aware that the questionnaires used were designed in such a way to permit spontaneous mention of adverse impacts of aircraft by the responding wilderness users before probing further to ask directly about overflights. Results showed that few people would mention aircraft spontaneously, and even when more probing questions were asked, a large majority of respondents did not feel that aircraft overflights adversely impacted their recreational experience, and did not influence their plans to return to the area. Respondents to the telephone interview, who had more time to reflect on the trip as a whole and place any annoyance from aircraft overflights in perspective with their enjoyment of the total trip, reported even less annoyance with overflights. However, the data show that wilderness visitors are less tolerant of aircraft noise than residential populations.

Comparing overflights reported by visitors and actual overflights identified by acoustic recorders, it appears that many visitors do not notice aircraft even when they are present. This is especially true for high-altitude jet transport aircraft.

As would be expected, it appears that the most meaningful aircraft-related problems for wilderness users are in those wildernesses at which the greatest numbers of outdoor recreationists are most commonly exposed to the noisiest overflights; i.e., low-altitude, high-speed tactical military operations and low-flying helicopters. The problem generated by these types of flights is largely due to startling visitors. Military overflights are not a problem in all wildernesses at all times, as they do not occur in all wildernesses and generally do not occur on a frequent basis. Therefore, these types of flights are not encountered by most visitors.



The majority of wilderness users interviewed were not annoyed by overflights.

CHAPTER 3

WILDERNESS VISITOR AND EMPLOYEE SAFETY

To determine the impact of aircraft overflights on the safety of people on the ground, three studies were conducted: A review of FS Annual Reports from 1979-1989; a survey of managers of 264 FS wildernesses; and a survey of 1,180 visitors to FS wildernesses. This section summarizes those studies and provides conclusions.

NOTE: *This material is abstracted from Hartmann, Lawrence A., Dumas, Christopher P., and Hall, Laurie L. (In progress), Safety in FS Wildernesses. (This publication is a Technical Report to be published by the Intermountain Forest and Range Experiment Station, Ogden, Utah).*

The public has expressed concern for the safety of wilderness visitors exposed to low level military overflights.

BACKGROUND

PL 100-91 was not directed at aircraft crashes that happened within wildernesses, and therefore those types of accidents are not considered in this report. The focus of this investigation was to identify any accidents to people on the ground which were caused by aircraft flying overhead. While existing records provide some information on accidents in wilderness and search and rescue operations, no systematic study had been conducted which would have provided the information needed to show the relationship between aircraft overflights and accidents to visitors and employees in wildernesses. Therefore, a three-part study was initiated.

First, historical records were examined to identify long-term wilderness safety issues. Second, a year-long survey of FS wilderness managers was initiated to catalog reported accidents among both wilderness visitors and FS employees. Additional information was obtained on search and rescue operations in wildernesses through that survey. Finally, wilderness visitors were contacted directly through a telephone survey to examine reporting rates of accidents.

Results of these studies indicated that while there is potential for aircraft to cause accidents to either wilderness visitors or employees, those circumstances are rare. During the study period (calender year 1990), no accidents reported to FS wilderness managers were a result of aircraft overflights. Additionally, none of the 1,180 respondents to a telephone survey of visitors to 12 wildernesses conducted during the summer of 1990 reported accidents related to aircraft overflights.

HISTORICAL RECORD

A content analysis was conducted of FS Annual Reports between 1979 and 1989, inclusive, to determine the historical record of aircraft in relation to wilderness safety. In preparing annual wilderness reports, Districts are not given specific direction to report accidents to people on the ground caused by aircraft overflights. Therefore, there is considerable variability in those reports regarding overflight-related accidents. However, these records provide the best available historical information on this subject.

Those FS Annual Reports show that between 1979 and 1989, three accidents were reported in which aircraft caused accidents to people on the ground. In each case, low-flying military jets spooked horses which in turn threw their riders. In one of these occasions, the jet spooked an entire string of horses, and two riders were seriously injured. These incidents occurred in 1988 and 1989. In one case in 1989, a low-flying military aircraft spooked an unmounted horse, who ran over an embankment, broke a leg, and had to be destroyed. No other aircraft-caused accidents of people on the ground were reported during this 10-yr period.

MANAGER SURVEY

To provide a systematic accounting of accidents reported to FS wilderness managers, a survey was conducted throughout calendar year 1990. Two hundred sixty-four FS wildernesses were included in a survey where managers were contacted twice at 6-mo intervals and asked to complete a survey concerning accidents during the previous 6 mo. A smaller sample of 69 wildernesses was contacted every month for 12 mo and given

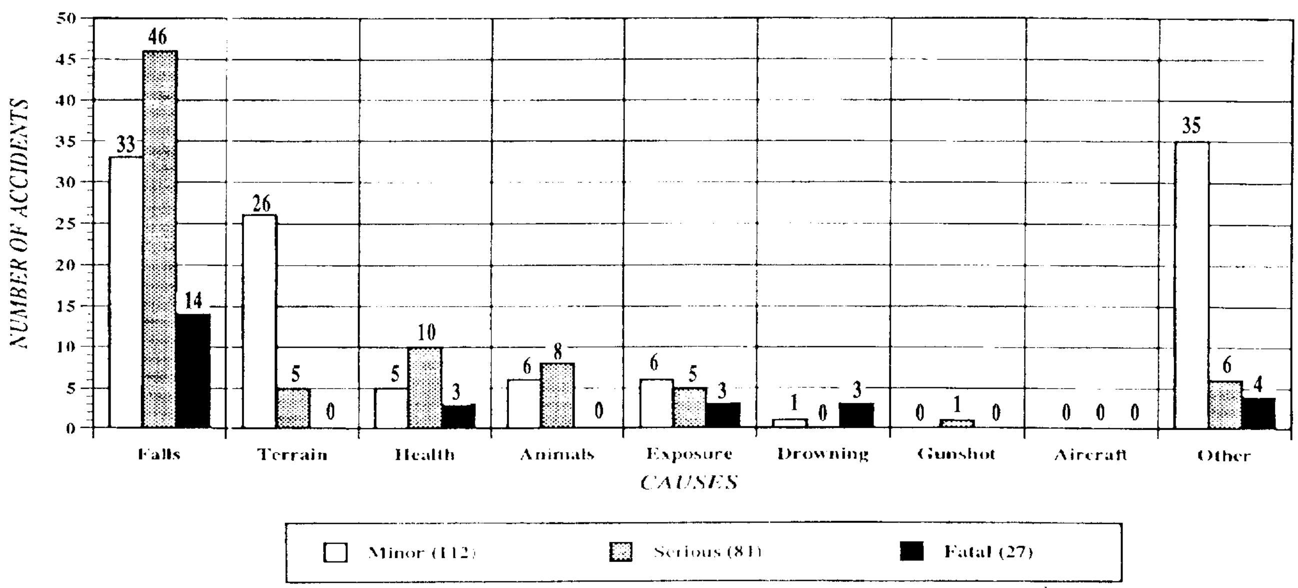


Figure 26. Causes/levels of severity of accidents to visitors and employees, Forest Service Wildernesses, 1990.

a similar questionnaire With this smaller sample, seasonal variation could be examined. A grand total of 843 returned questionnaires (a 62 percent response rate) comprised the data base for this study.

Figure 26 shows the major causes and level of severity of accidents in FS wildernesses in 1990. Falls constituted 41.5 percent of the incidents; terrain, 14.1 percent; health conditions, 8.2 percent; animals, 6.4 percent; exposure, 5.9 percent; drowning, 1.8 percent; gunshot, 0.5 percent; and a wide variety of other causes, 21.5 percent. No accidents were reported in calender year 1990 where aircraft flying overhead caused accidents to wilderness visitors or employees on the ground. Additionally, during calendar year 1990, wilderness managers reported no incidents where horses were spooked by overflights

VISITOR SURVEY

Information from the historical record and a survey of wilderness managers provides systematic information, but only on *reported* accidents. To obtain information directly from wilderness visitors, a survey of visitors to 12 FS wildernesses was conducted in 1990. Visitors were asked if they were involved in any accidents while they were in wilderness, the cause of the accident, severity of the injury, and if and to whom they reported the accident.

Of 1,180 visitors contacted in 12 wildernesses, 2.7 percent (32 visitors) reported involvement in an accident during their visit. Of the 32 reported accidents, none were related to aircraft overflights. The major causes of accidents were falls (37.5 percent), horse/stock accidents (21.9 percent), terrain-related injuries (12.5 percent), insect stings (9.4 percent), and other (18.8 percent). Of the accidents described by survey respondents, none were fatal, 9.4 percent were severe (broken bones), and 90.6 percent were minor. Only 6.3 percent of the accidents were reported to anyone, and none were reported to the FS.

Although the sample size of visitor accidents above is admittedly small, the trend is clear: visitors seldom report minor accidents to FS personnel, and in at least some cases do not report severe accidents. This finding implies that it is likely that the number of accidents reported in the managers survey described above almost certainly underestimates the number of visitor accidents actually occurring in FS wildernesses, especially for the less serious accidents. Although the methods used to identify accidents reported to wilderness managers were as thorough as possible, it is possible that minor aircraft-related accidents could have occurred that were not reported.

POSSIBLE SAFETY HAZARDS OF AIRCRAFT OVERFLIGHTS

There are two specific circumstances not illustrated by the data under which aircraft could possibly create a safety hazard. It is possible, though unlikely, that aircraft could create snow avalanches, or could create hazards for rock climbers.

Several controlled studies have shown that sonic booms with high overpressures are capable of triggering snow avalanches. However, no FS wildernesses are located within supersonic MOA's. There are high-altitude supersonic flight tracts over wildernesses, but the overpressures produced by supersonic flights at these altitudes are well below the overpressures shown to trigger avalanches. A pilot could violate policy and fly supersonic during a training exercise on a subsonic MTR, but the likelihood of this happening at a time and place which would trigger an injury-causing avalanche is very small. No injuries resulting from aircraft-caused avalanches were reported in this safety study. In the judgement of the authors, aircraft-caused snow avalanches are not a meaningful threat to visitor or employee safety in FS wildernesses.

Although the studies conducted for this section provided no data to indicate that rock climbers are at risk from aircraft overflights, some potential hazard exists under specific circumstances. Cliff faces provide some acoustical shielding from sound sources. Some respondents to the visitor surveys described a startle response to high onset rate aircraft noise. There is the potential for a safety hazard for rock climbers if they were in precarious positions on a cliff face, which provided some acoustical shielding, and they were exposed to a high onset rate aircraft overflight. The climbers' startle response could put them at extreme physical risk. It should be noted, however, that no such circumstances were described in either the 10 yr of historical data nor the surveys of wilderness managers in 1990 nor the visitor survey in 1990.

CONCLUSION

On the basis of the historical record, the 1990 survey of FS wilderness managers, and the 1990 survey of wilderness users, it appears that aircraft overflights are responsible for wilderness user accidents only under rare circumstances. The data from those studies indicated that the only circumstances under which aircraft posed a threat to visitor or employee safety was when visitors on horseback were startled by low-flying military aircraft.

CHAPTER 4

EFFECTS OF OVERFLIGHTS ON WILDLIFE

In this chapter the adverse effects of aircraft overflights on wildlife are assessed. This assessment is based upon a review of literature and no new studies were initiated. Known effects of aircraft overflights on wildlife are discussed.

NOTE: *This material is abstracted from Bolt Beranek and Newman Inc. Report No. 7500, "Review Of The Effects Of Aircraft Overflights On Wildlife".*

Existing wildlife literature is deficient in quantifying long-term consequences of aircraft overflights.

BACKGROUND

The goal of assessing overflight effects on wildlife was to draw inferences from the literature about potentially consequential impacts. This necessitated considerable analysis and interpretation of published information, since most studies of the effects of overflights on wildlife do not contain adequate information about overflight acoustic exposure and do not measure biologically meaningful effects. Since mitigation and regulation efforts have not established animal tolerances with useful precision, no framework exists for describing or predicting the effects of noise exposure on animals.

Studies of effects of human intrusions and habitat destruction on animals often find profound impacts of human activity. It is thus commonly assumed that aircraft overflights are equally damaging to wildlife. A study of existing literature covering the effects of overflights on animals concludes that animals' responses to overflights are only rarely consequential. This study produced a technical report which reviewed the literature on overflight effects on wildlife, addressed problems of measuring biologically meaningful impacts on animals, and developed a model to aid in predicting effects.

LITERATURE REVIEW

The literature reviewed included all pertinent literature from previous reviews, bibliographies, and publications; all identifiable literature in major electronic databases, including that of the Fish and Wildlife Reference Service; searches of the current contents of recent journals; correspondence with active researchers; and reports requested from Federal agencies. In all, over 400 references were used to compile the summary presented here.

Perhaps the greatest deficiencies of the existing literature are its lack of quantification of noise exposure and its focus on behavioral measures that are rarely, if ever, related to population impacts. These behavioral measures quantify animals' short-term aversive responses, but do not describe habituation or any long-term consequences of exposure to aircraft overflights. The results of the literature review conducted for purposes of PL 100-91 are presented categorically by major animal groups.

INVERTEBRATES

The effects of aircraft overflights on invertebrates, including all arthropods, have rarely been studied. Insects are not likely to be affected by aircraft overflights, however, and there is little reason to believe that further studies are needed.

FISH

The literature on the effects of noise on fish is confined almost exclusively to the effects of waterborne noise. Although fish are regarded as susceptible to noise effects, the evidence is weak. Anecdotes about the effects of airborne noise should be regarded very skeptically, since sound is greatly attenuated at the air-water interface. Since the displacement component of waterborne sound is an important determinant of noise impacts on larvae and eggs, the physical effects of aircraft noise are likely to be minor.

Fish do startle in response to aircraft noise and probably to the shadows of aircraft as well. None of the short-term studies reviewed has shown any adverse effects from these responses. Fish can habituate to sounds and learn to distinguish harmful from benign noise exposure.

REPTILES

The effects of overflights on reptiles have never been evaluated. Since reptiles do not exhibit a well-developed acoustic startle response, they are often regarded as nonsusceptible to noise impacts. Further, many reptiles (especially turtles and snakes) have very poor hearing. The species which may be most susceptible to noise of aircraft overflights are desert-dwelling lizards, which have sensitive low-frequency hearing (particularly Gambelia spp.). One study reports susceptibility to auditory damage in desert lizards. Future studies of reptiles should consider vibrations created by overflights as well as the noise.

AMPHIBIANS

The effects of aircraft overflights on amphibians have never been studied. It has been reported that Scaphiopus emerges prematurely from its burrow when exposed to motorcycle noise, leading to the suspicion that sonic booms and very low-altitude overflights might initiate a similar response. However, motorcycle noise differs in spectral composition from aircraft noise. Further, false cues have been reported to trigger emergence in Scaphiopus as well. Without additional evidence of impact, this effect cannot be considered a consequential one.

Since amphibians are sensitive to vibration, any study of aircraft overflights must consider ground vibration as well as acoustic and visual cues produced by overflights. Amphibians lack an acoustic startle response, but startle readily in response to vibration. Since amphibians depend on vocal cues for social communication, the impact of aircraft overflights (if any) is likely to be on audibility of conspecific animals.

BIRDS

All birds startle readily in response to close approach by aircraft. The literature on specific bird groups is summarized below.

Passerines

Reproductive losses have been reported in one study of small territorial passerines after exposure to low-altitude overflights. Studies of such effects are few and flawed. Natural mortalities of both adults and young are both high and variable in most passerines, making it difficult to measure impacts on productivity. In addition, little effort has been made in most studies to control for effects of human intrusions. An extensive body of literature derived from studies of pest species (e.g., many species of starlings and blackbirds) shows that passerines cannot be driven any great distance from a favored food by a nonspecific disturbance. Passerines avoid intermittent or unpredictable sources of disturbance more than predictable ones, but return rapidly to feed or roost once the disturbance ceases.

Waterbirds

The term "waterbirds" encompasses a large number of species. The bulk of the literature deals with wading birds, waterfowl, shorebirds, and marine birds. The large body of literature on the effects of human disturbance on waterbirds includes several studies of aircraft overflights. Effects on reproductive success have been most commonly studied, but there are also a few studies of habitat use and energy costs in migratory waterfowl.

Human intrusions can cause a decline of as much as a third of waterbird eggs laid. Nonspecific or nondirected disturbances (boats, vehicles, or aircraft) are not as clearly detrimental. The literature on aircraft overflights contains few studies that measure effects on reproductive success, so it is difficult to compare the bodies of work on human intrusions and aircraft disturbances directly. The literature may be characterized as follows:

- Concerns about losses of eggs or young due to overflight noise or startles are generally ill-founded.
- In certain predictable circumstances, losses can be measurable or even substantial. Cliff-dwelling colonial birds without nests can experience losses of eggs or young after adults are startled into flight.
- Colonial birds nesting in exposed areas may experience losses when predator densities are high. Estimates of the magnitudes of losses due to these causes are uncertain, but are on the order of a few percent of eggs laid.
- The few studies that have measured nesting success directly in the presence and absence of overflights have failed to find any measurable effect on reproduction. Differences as great as 50 percent may not have been detected by these studies, due to small samples of nests and the great variability of natural reproductive success.
- A few useful generalizations can be made about the responses of breeding birds to aircraft. Incubating or brooding birds are reluctant to leave their nests. When they fly, they stay off the nest for only 1 to 2 min. They also habituate rapidly to nonspecific stimuli. The nature of the stimuli needed to startle nesting adults into flight and the causes of losses of eggs or young are poorly understood.
- Migratory waterfowl respond to disturbances more readily than other species of waterbirds.
- Studies measuring changes in habitat use and energetic costs have not demonstrated meaningful effects.

Raptors

Effects of human disturbance, particularly aircraft overflights, on raptor breeding are relatively well understood. Naive and habituated behavioral responses of breeding birds have been documented in several species. Effects of overflights on reproduction and nesting populations have been examined over reasonably long periods. The potential effects may be summarized as follows:

- The literature on reproductive success suggests a small effect of close approach by aircraft on raptor nests. The impact is on the order of a few percent of eggs laid, far smaller than the natural variability in reproductive success of most populations.
- Small impacts on reproduction may not be detectable in cohorts that reach reproductive age due to density-dependent effects on juvenile survivorship. Since juvenile survivorship of exposed and unexposed cohorts have not been measured, the effects of reproductive loses are unknown.
- It is not clear how aircraft affect raptor reproductive success. Eggs and young are only rarely ejected from the nest after a startle. Panic responses are induced only after very close and abrupt approaches (e.g., an approach at 50 m over a cliff face). Adults are very reluctant to leave the nest, and generally remain away for 1 min or less as a rule. They habituate to overflights rapidly, sometimes tolerating aircraft approaches of 20 m or less.

- The effects of human intrusions near nests are, in contrast, readily detected and substantial. Studies of human intrusion show that differences of about 20 percent or more between experimental and control nests may occur.
- There is no evidence that raptors abandon favored breeding areas as a consequence of intense aircraft activity, although they may change nesting sites more often in the presence of aircraft. These changes do not have a large effect on reproductive success.
- Species-related differences are small by comparison with differences due to previous experience, stage in the breeding cycle, and stimulus characteristics.
- Raptor responses to aircraft disturbance tend to decline during the course of the breeding season, due either to energy conservation or habituation.

Although other aspects of raptor biology have not been studied as thoroughly, generalizations about habitat use can be suggested:

- Raptors respond flexibly to temporary disturbances in favored foraging territories. They leave when humans invade the area, but return as soon as the disturbance ends. They also take advantage of disturbances induced by human activity to increase their chances of capturing prey.
- Neither raptors nor any other bird can be driven from favored feeding areas by any nonspecific disturbance for longer than the time it takes to habituate to the disturbance. The only exception to this rule is the local area immediately around a very intense noise source. The amplitude and duration of such a source must be considerably greater than would be expected from aircraft overflights.
- The effects of intrusive (human) disturbances on a well-studied raptor (wintering bald eagles) have never been generalized to changes in use of critical habitat or to nonspecific (e.g., aircraft) disturbances.
- Eagles, like other large animals, respond less often when cold and food-stressed than at other times. They do not respond readily to aircraft overflights when the cost of such a response is high.

MAMMALS

Small

The literature on effects of aircraft on small mammals is too sparse to draw many conclusions. Studies of the effects of overflights on rodents have been motivated by a desire to remove these animals from the vicinity of airfields because they attract raptors and other animals hazardous to aircraft. Several studies of the abundance of rodents exposed to high levels of aircraft noise in the vicinity of airfields have failed to find any significant effect on populations.

Laboratory studies of noise-induced stress are only tangentially relevant to studies of aircraft noise, as they involve continuous exposures to very high noise levels. Although laboratory rodents exhibit physiological responses associated with stress when exposed to high noise levels, these responses do not necessarily create biologically important problems, such as reproductive effects. Long-term studies of animals exposed intermittently to high levels of noise demonstrate no changes in longevity. The physiological "fight-or-flight" response, while marked, does not appear to have any long-term health consequences.

The most useful laboratory studies document the startle response. Startles are induced by any rapid change in sound level. The degree of response and the rate of habituation both depend on sound level and other physical characteristics of the sound. Small mammals habituate with difficulty to high sound levels (>100 dBA).

Long-term effects of aircraft noise on mammalian hearing due to aircraft noise exposure are not consequential. Problems with predator avoidance or social communication due to masking or temporary threshold shifts have never been systematically considered, although hearing sometimes plays an important role in predator avoidance. Small desert-dwelling mammals (including Dipodomys) appear on *a priori* grounds to be most susceptible to these effects.

Carnivores

The literature on the effects of aircraft disturbance on mid- to large-sized carnivores is anecdotal at best. Most large carnivores are persecuted, making them potentially susceptible to disturbance. A few useful generalizations can be gleaned from the literature on other human disturbances.

- Large carnivores avoid humans and, as a rule, avoid noise associated with the presence of humans. The relevance of overflights to the animal is an important determinant of their responses.
- The behavior of carnivores in the presence of disturbances is flexible and intelligent. They learn to predict when intrusions are common, and return to disturbed areas when the intrusions end. (e.g. aerial hunting)
- Large carnivores cannot be deterred from a food source by loud sounds or by any other nonspecific disturbance. In fact, they rapidly habituate to such disturbances.

- Data on small domestic fur bearers suggest that carnivores will not consume their own young if startled by an aircraft. The effects on free-ranging carnivores during breeding are unknown, but published reports of parental cannibalism indicate that the response is stimulated by attack. More frequent changes of denning sites, changes in habitat use, and increased vigilance are the likely consequences of aircraft overflights that approach carnivores closely. The biological consequences of these changes are unknown.

Some concerns have been expressed about sleep interference in hibernating carnivores, but there is no evidence that such problems arise in any animal. The *a priori* expectation is that hibernating carnivores would learn rapidly to ignore the disturbance.

An extensive literature on the effects of human disturbance shows that habitat use is affected by intrusions. Some of this literature is relevant to the effects of aircraft noise. The important points are as follows:

- The relation between aircraft approach distance and flight (or other predator-avoidance responses) of large herbivores has been measured repeatedly and is understood to the extent that predictions can be made about proportions of animals responding. The most important predictors of response are prior experience with overflights, aircraft approach distance (or other measure of stimulus intensity), stage in the breeding cycle, activity or context, and herd age and sex composition. Previous experience with similar overflights is the most important of these.

Aircraft are often initially startling but animals generally adapt very well under most circumstances.

Large Herbivores

Extensive studies have been conducted on the behavioral and physiological responses of large herbivores to disturbances, including overflights. However, few studies have related herbivore responses to biologically important changes, such as changes in reproductive success or habitat use. Thus, while it is possible to predict behavioral responses, it is unknown whether large herbivores are seriously affected by overflights.

- Approaches within 50 to 100 m arouse strong or potentially dangerous responses in about 10 percent of habituated animals and up to 100 percent of naive animals. Evidence both from field studies of wild ungulates and laboratory studies of domestic stock indicate that the risks of damage are small, as animals take care not to damage themselves. If animals are simply overflown by aircraft at altitudes of 50 to 100 m, there is no evidence that mothers and young are separated, that animals collide with obstructions (unless confined), or that they traverse dangerous ground at too high a rate. Serious consequences, including death, can arise occasionally from lower overflights, especially if animals are pursued from aircraft.

- The proportion of strong responses to overflights declines rapidly with increasing distance and animal experience. Approaches of 300 to 500 m cause only a small proportion of strong responses. Approaches at ranges greater than 1000 m arouse no strong responses.
- The rate of habituation to aircraft overflights is not known but it is not a simple linear function of rate of approaches. Animals appear to habituate readily to exposure rates of 1 to 5 approaches per day. High rates of exposure (>10 per day at close range) can in some cases constitute harassment of large, free-ranging herbivores.
- Aircraft overflights within 200 to 500 m increase the heart rates and elevate cortisol levels of large herbivores. These short term physiological responses are mediated by the experience of the animal
- Physiological and behavioral responses of both domestic and wild ungulates suggest that very low-altitude overflights (15 to 50 m) are aversive to naive animals. This aversion declines with repeated exposure. Significant stimuli (predators, humans, etc.) arouse the response at much greater ranges. The distance at which the physiological "fight-or-flight" response disappears in habituated animals is unknown, because changes in heart rate often occur without any overt behavioral change. Since increased heart rate often indicates attention rather than fright, heart rate data require cautious interpretation.
- Increased heart rate and a transitory elevation of circulating cortisol are not evidence that an animal has been damaged physiologically, nor that it has been stressed, nor that its energy reserves have been taxed. Since animals must usually be handled to collect physiological measures, and since handling often is very stressful, any study involving physiological measures must be controlled very carefully.
- There is no evidence from studies of either wild or domestic stock that aircraft overflights compromise reproduction, either directly or indirectly. In wild animals, this absence of evidence may be related to effort, but in domestic animals it is not. Any effects found in wild animals would be the product of indirect effects, such as the results of using sub-optimal habitat.
- There is no evidence that low rates of aircraft exposure within 1 km (one to five times per day) can cause changes in habitat use.

SUMMARY

Studies of effects of human intrusions and habitat destruction on animals often find profound impacts of human activity. It is thus commonly assumed that aircraft overflights are equally damaging. The literature suggests that animals respond differently to aircraft overflights. Aircraft overflights are startling, but animals can adapt to them very well under most circumstances. Effects of overflights are subtle because animals adapt by habituating behaviorally and physiologically to the challenge.

More meaningful studies than those which comprise the bulk of the literature are required to determine consequences of habituation and of exceeding animals' capacity to adapt. Longitudinal studies with larger sample sizes and more sophisticated study designs are required to examine these issues.

CONCLUSION

In general, overflight effects appeared to be related more to prior aircraft experience and to general predator avoidance strategies (e.g., flight vs. concealment) than to species- or population-specific differences. In fact, the review of literature led to the conclusion that although overflights are often initially startling, animals generally adapt to them very well under most circumstances and generally pose negligible risks of consequential biological effects on wildlife. Effects of overflights (if any) are weak or subtle because animals adapt by habituating behaviorally and physiologically to the challenge.

However, the results of an informal survey of FS biologists contained in an internal report, "Wilderness Aircraft Overflights and Wildlife" (Roberts 1991) show that species-specific concerns about aircraft noise have been raised for the grizzly bear, mountain goat, caribou, bald eagle, peregrine and prairie falcon, sandhill crane, common loon, and bighorn sheep.

These situations have arisen, and will probably continue to, where individual species have entered a crisis condition; for example, during the years when the California condor was the subject of intense concern (1965-1987). At that time, extensive attempts were made to preserve it in the wild—in miniscule numbers and in a condition of severe ecological stress. FS managers voiced justifiable objections to low-level aircraft activity in the vicinity of the condor's habitat.

CHAPTER 5

EFFECTS OF OVERFLIGHTS ON CULTURAL RESOURCES

In this chapter the adverse effects of aircraft overflights on cultural resources in wilderness is assessed. This assessment is based upon a review of literature and no new studies were initiated. Known effects of aircraft overflights on cultural resources are discussed.

NOTE: *This material is abstracted from a report by Harris Miller Miller & Hanson Inc., Report No. 290940.04-1 "Aircraft Effects On Cultural Resources".*

Many wildernesses contain historic and cultural resources from past human occupation.

BACKGROUND

Although wilderness is generally thought of as an area in its natural condition without the imprint of man's activities, many designated areas were inhabited sometime in the past and contain historic and cultural resources. These resources are many and varied; e.g., fire lookouts, prehistoric artifact scatters, cliff dwellings, masonary and adobe ruins, etc.

Resonant vibrations of building elements may be experienced during some types of aircraft overflights, causing walls to vibrate, windows to shake and hanging bric-a-brac to rattle. Some may conclude that all this vibration must result in damage—maybe not immediately, but in the long term. When buildings are very old, they take on additional value; they become historical or cultural resources and are often irreplaceable.

Documented observations of aircraft noise effects on cultural resources are rare but there is still concern that aircraft noise may cause damage to these already fragile resources. Generally, concerns that aircraft noise causes damage are based on speculation. Aircraft noise is listed as a possible cause along with a list of other, better documented causes. Many cultural resources are remote and uninhabited, allowing much to be left to speculation with regard to damage.

Most of the available literature stems from research on the effects of sonic booms conducted by the U.S. Air Force, NASA, and the FAA. Methods of estimating probabilities of damage to historical and cultural resources have been developed. In contrast, very limited information has been obtained on the response of structures to subsonic aircraft and helicopters.

RESULTS OF LITERATURE REVIEW

Airborne noise is a pressure wave in the atmosphere. When a pressure wave encounters a solid structure, it acts as a force over the area of the surface. Depending on the compliance of the structure to such forces, it will respond by deflecting and distributing the resultant stresses throughout the structure.

Thus, aircraft noise impinging on a building or other structure or artifact may result in any of a number of observable physical effects. In descending order of amplitude they are: Permanent displacement, visible motion, feelable vibration, and audible re-radiated sound. Of the foregoing physical effects, the only lasting one is permanent displacement—a failure of a structural element that occurs whenever the peak stress induced by the pressure loading exceeds the material strength. Cosmetic damage, such as visible cracks in nonstructural members, may have an entirely different connotation than structural damage (such as large cracks in structural members, which may result in reduction of load-carrying capacity). However, neither can be neglected since, in some ancient structures, the incidence of cosmetic damage may have more serious effects in the long term. This apparent insignificant event can be the first step to further damage caused in the long term by the forces of nature. Most authors refer to the threshold of effect as "damage," even though the occurrence of damage may simply be hairline cracks that may be indistinguishable from cracks generated by other causes.

An obvious short-term effect is when a building element suffers immediate displacement, with broken surface or increased crack length. For noise to be the source of immediate damage, the pressure levels must be extremely high, such as in a sonic boom, or the frequency must coincide with one or more of the natural frequencies of the structure. Cumulative effects of repeated noise exposure are not as easy to document as short-term effects, for the reason that some of the damage observed in a structure will be due to naturally occurring forces. Cracks develop in houses, buildings, and all structures as they age. Materials and structures expand and contract due to changes in temperature, humidity, wind loads, foundation settlement, and human activity.

There is some current evidence that long-term effects of noise exposure could result in damage by initiating or accelerating the deterioration process. The evidence of potential damage risk is more theoretical than empirical. The long-term effects appear as (1) fatigue effects in walls and other structural elements after extensive exposure, (2) moisture damage initiated by cosmetic cracks in exterior surfaces, and (3) gradual erosion of surface materials from repeated events.

Structural elements may experience as many as 80-million cycles of loading at their resonance frequencies from exposure to aircraft operations along defined military training routes over a 50-yr period. This large number could lead to significant reduction in material strength through fatigue. Moisture damage can be the second phase of a deterioration process initiated by surface cracking. Though initially cosmetic, surface cracks admit moisture which may weaken the underlying structure, thus setting in motion a natural chain of events leading to premature structural damage.

Erosion damage can occur once the exterior surface has been compromised. For many adobe mud-plastered walls, the loss of the exterior surface also results in invasion of additional moisture into the interior, thereby weakening the structural core. Once the core is weakened, wind or additional acoustic loadings (e.g., high-pressure sonic booms) can compromise the integrity of the structure. Because it has the potential of initiating some of these long-term effects, aircraft noise exposure may, over time, be a contributor to the degradation of historical structures.

Threshold damage criteria have been proposed by various researchers in the field. The general conclusion is that in establishing thresholds for effect related to historical structures and cultural resources, the criteria must be specifically oriented to the frequency range below 30 Hz.

The designs of many historical structures lend themselves to potential damage from airborne pressure waves. For the frequency range of 10 to 20 Hz corresponding to a helicopter fundamental rotor frequency, the quarter wavelength (the property associated with a sound which predicts its damage potential to a structure) ranges from 28 to 14 ft. This length is comparable to the dimensions of roof elements of old Pueblo dwellings.

The noise characteristics of helicopters are such that they tend to excite nearby structural elements at their resonant frequency, causing low frequency vibrations, rattle, and in some cases, damage. Structures on the ground are not normally exposed to the highest noise levels generated by a helicopter. The sound pressure is greatest at structures in the plane of the main rotor, such as could be the case for a helicopter approaching a cliff dwelling. Nevertheless, noise levels beneath a helicopter can also have an effect. There is potentially a very high risk of damage to prehistoric sites from overflights of heavy helicopters on military training routes. This risk is associated with the very high sound levels in the same low-frequency range at which structural fundamental resonance frequencies occur.

Mitigation measures for the effects of low-flying subsonic aircraft, including helicopters, are related to operational restrictions to maintain a sufficient distance between the noise source and sensitive structure. Although a specific set of mitigation measures does not emerge from the limited number of cases reported, it is clear that researchers have recognized the possible advisability for maintaining some kind of clear zone between identified sensitive structures and aircraft operations.

CONCLUSIONS

Cultural resources in National Forest wildernesses are not currently threatened by sonic booms. Although studies conclude that sonic booms can present very substantial risks to structures within the area of their influence, no National Forest wildernesses are located within supersonic MOA's. There are high-altitude supersonic flight tracks which cross wildernesses, but the overpressures produced at these altitudes are very low, and well below the threshold of risk to cultural resources. It is still possible for a military pilot to violate policy and to go supersonic during a training exercise on a subsonic MTR, but the likelihood of such an event occurring in a manner and location to cause damage is remote at best. The potential impacts to cultural resources would have to be evaluated on a case-by-case basis if supersonic MOA's or MTR's are proposed over National Forest wildernesses in the future.

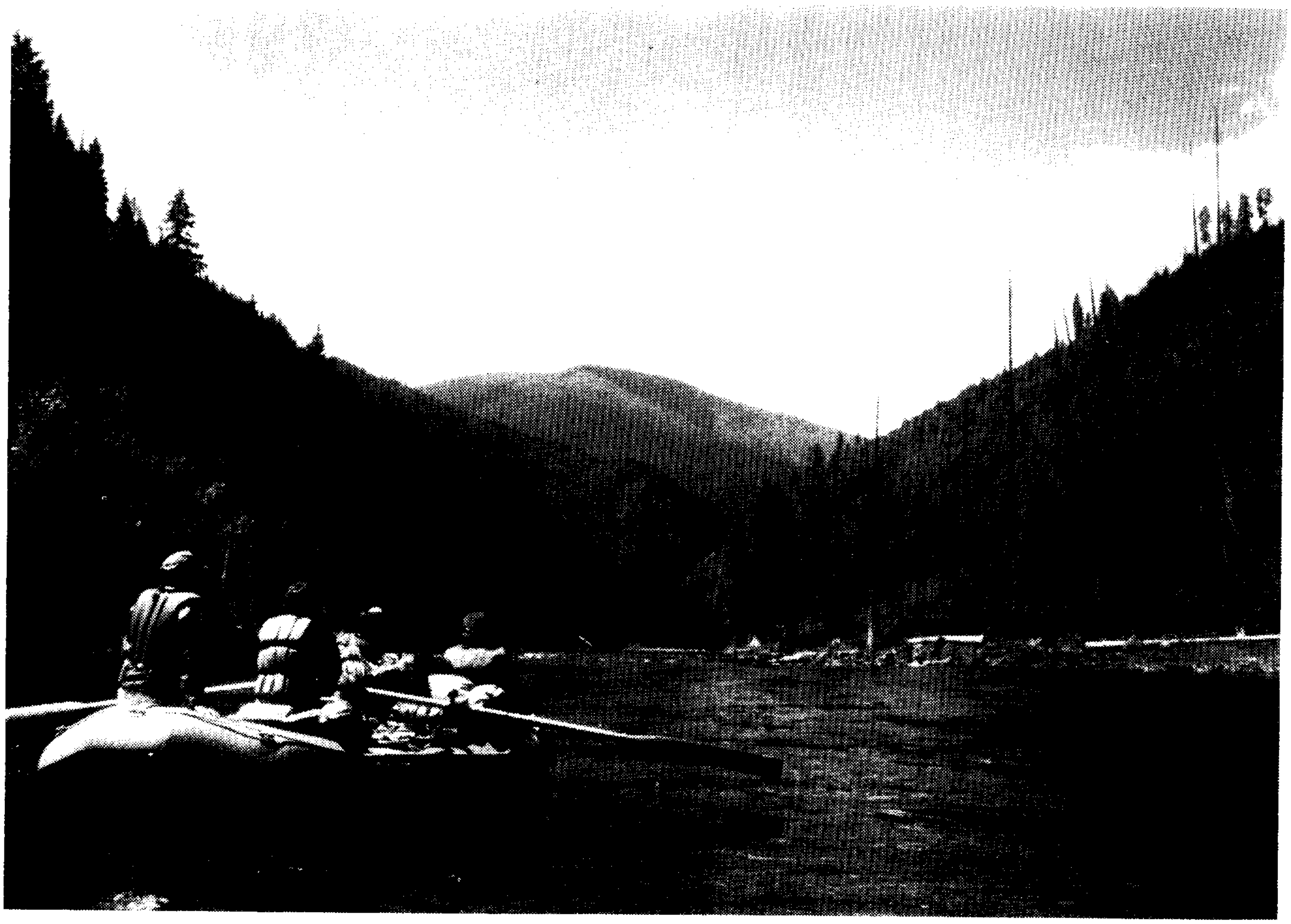
Very limited information has been obtained on the response of structures to subsonic aircraft and helicopters. Measurement programs have been conducted which conclude there is normally a minimal risk of damage to structures from light, low-flying, subsonic jet aircraft and light helicopters. However, in special situations, such as a tour helicopter approaching a cliff dwelling, there is evidence of a potential damage risk from these aircraft. Moreover, a recently developed prediction method places a definite risk of damage to prehistoric structures from low overflights of heavy bombers and a significant risk of damage to these resources from heavy helicopters.

CHAPTER 6

ALTITUDE RESTRICTIONS AS A MITIGATION MEASURE

This chapter examines the effect at ground level of changes in altitude of the aircraft above ground and the shortcomings of altitude-based restrictions.

NOTE: *This material is abstracted from Harris Miller Miller & Hanson Inc. Report No. 290940.2A, "Effects Of Aircraft Altitude Upon Sound Levels On The Ground".*



The FAA has issued a 2000 ft AGL advisory over noise sensitive areas including wilderness.

BACKGROUND

It is commonly known that sound levels decrease with distance from a source of sound. The rate at which sound levels decrease as distance increases is not constant, as it depends on many complicating factors. The most basic cause of sound levels decreasing with distance is "spherical divergence." Spherical divergence is the spreading of sound energy over an increasingly large area as it propagates away from its source. For short distances, spherical divergence is the most important source of sound attentuation as a function of increasing distance. However, other physical effects are also important. The most important of these are:

- Atmospheric absorption, which depends upon humidity, temperature, and atmospheric pressure—as well as upon the aircraft's sound spectrum (frequency content)
- Ground attenuation, which depends upon the type of vegetation, the structure of the soil, and the ground's proximity to the sound path—as well as the aircraft's sound spectrum
- Shadow effects, which depend on wind direction and speed, temperature, and other atmospheric parameters
- Attenuation due to intervening hills and heavily wooded areas
- The particular acoustical metric being used to describe the overflight.

This last factor is often overlooked but is of critical importance in that there are many ways to measure aircraft sound. As an aircraft flies by, its sound level first increases as it approaches, then reaches a maximum, and then decreases as the aircraft recedes into the distance.

Several acoustical descriptors are commonly used to describe this flyby's entire sound-level history. One is the maximum sound level during the flyby. Another is a measure of the total sound exposure during the flyby, which accounts for the flyby's maximum sound level and its duration, as well. Another descriptor is the audibility of the aircraft during its flyby; another is its audible duration There are many more ways to describe aircraft sound. Each of these represents a different way to measure the aircraft's sound during the flyby. Each can serve a different purpose in assessing the effects of the flyby, and each depends somewhat differently upon distance. Six of these acoustical descriptors will be discussed here.

- **Maximum A-weighted Sound Level, in dBA**—Maximum sound level during an air craft flyover
- **Onset Rate, in decibels per second (dB/s)**—Maximum rate of increase in the A-weighted sound level as the aircraft approaches
- **Sound Exposure, in dB**—Total accumulated sound exposure during the flyover
- **Audible Sound Exposure, in dB**—Audible portion of the total sound exposure; this quantity is related to the detectability of the flyby.
- **Chance of Detection, in percent**—Chance that the aircraft can be detected by attentive listeners on the ground
- **Audible Duration, in seconds**—Audible duration of the flyover.

EFFECT OF HEIGHT ON SOUND LEVELS

The effect of aircraft height on sound levels at the ground depends upon the location of the flight path relative to the listener. Two situations are of importance:

1. When the flight path is directly overhead, or nearly so.
2. When the flight path is to the side, laterally displaced from the listener. In this case, the distance from the aircraft to the listener is described as "slant distance."

Flight Path Overhead

When the flight path is directly overhead, or nearly so, then the sound levels at the listener reduce in value as aircraft height above ground level (AGL) increases. This reduction in sound levels is mainly due to divergence and atmospheric absorption, which both cause sound levels to decrease with distance from the sound source. Table 9 shows the effect of these reduced sound levels upon the six acoustical descriptors listed above.

The first column in table 9 shows several height increases, each of 1,000 ft except for the first, which is smaller. The remaining columns show the effect of these height increases on the six acoustical descriptors. For the first three acoustical descriptors in the table, 1,000-ft increases in aircraft height reduce the acoustical descriptor's values. For example a 1,000-ft height increase from 5,000 to 6,000 ft (1) reduces the maximum A-weighted sound level by 3 dB, (2) reduces the onset rate by 1 dB/sec, and (3) reduces the total sound exposure by 2 dB. For these three acoustical descriptors, the sound-level steps converge at large distances to small values for each 1,000-ft increase in distance. In other words, stepped increases of 1,000 ft in aircraft height reduce the acoustical descriptors in steps, as well, but with diminishing returns. The sound-level steps become ever smaller with increasing height.

For the last three acoustical descriptors in the table, the situation is more complex because these descrip-

SUMMARY OF CHANGES DUE TO 1,000 FT INCREASES IN AGL

Increase in AGL (ft)	*Decrease in Maximum (dBA)*	*Decrease in Onrate (dB/s)*	*Decrease in Exposure (dBA)*	*Decrease in Audible Exposure (dBA*	*Decrease in Change of Detect (%)*	*Change in Audible Duration (sec)*
from 125 to 1,000	**24**	**28**	**14**	**14**	**0**	**+10**
from 1,000 to 2,000	**12**	**3**	**6**	**6**	**0**	**+7**
from 5,000 to 6,000	**3**	**1**	**2**	**2**	**0**	**0**
from 10,000 to 11,000	**2**	**1**	**2**	**2**	**19**	**-2**
from 15,000 to 16,000	**2**	**1**	**1**	**25**	**1**	**-22**

NOTE: Turbofan Jet Aircraft, 400 Miles Per Hour, "Moderate" Background Sound Levels

tors depend on background sound levels. For the audible sound exposure, the steps first decrease in the normal manner, but then they become quite large at the bottom of the table. This occurs as the aircraft becomes inaudible due to the natural sounds in the environment. The transition to inaudibility also causes the tabulated pattern for the chance of detection and the audible duration. All three of these acoustical descriptors reduce abruptly as the aircraft rises and becomes inaudible. In the table, inaudibility begins at a distance of approximately 10,000-15,000 ft. This distance differs for other background sound levels, other aircraft speeds, and other aircraft types.

This table assumes a "moderate" amount of background sound, produced by a 10- to 20-mph wind. This same abrupt reduction of these three acoustical descriptors would also occur for other amounts of background sound, but at some other aircraft height. To a first approximation, it would occur around an aircraft height of approximately 4,000- to 5,000-ft in the presence of surf sound, and at a height of approximately 20,000- to 30,000-ft in areas with background sound levels close to the threshold (lower limit) of human hearing.

Even in a single location within a wilderness, background sound levels often vary from moment to moment, and vary between day and night, and vary from day to day—often depending upon wind speed. For this reason—as well as sound fluctuations due to atmospheric turbulence—the distance at which audible sound exposure begins its abrupt reduction is highly variable.

One additional important point in interpreting the table: The specific transition to audibility shown in the table is only for turbofan jet aircraft travelling at approximately 400 mph. It will differ for jets at other speeds, as well as for other aircraft, as a function of speed. In essence, different aircraft cause different sound levels at the ground, as a function of their speed, and therefore they will become inaudible at different distances.

Flight Path to the Side

When the flight path is to the side, laterally displaced from the listener, the situation is more complex. At low elevation angles, acoustically soft ground may attenuate the aircraft sound. The sound also may be attenuated by intervening hills and heavily wooded areas.

In this situation, the amount of extra attenuation depends upon the elevation angle of the aircraft above the soft ground, or upon the blockage in the sound path by the hills and heavily wooded areas. In turn, these depend upon the aircraft's height above the ground.

Increasing the aircraft height in this situation causes an increase in sound level—as the aircraft rises above the ground's influence, or the hill's influence, or the wooded-area's influence Once the aircraft rises high enough, however, this effect is finished and the sound level then decreases as usual with increasing aircraft height.

Altitude As Mitigation Measure

The table above shows that sound-level reductions converge at large distances to small values for each 1,000-ft increase in distance. In other words, 1,000-ft stepped increases in aircraft height generally reduce sound levels in steps, as well, but with "diminishing returns." The sound-level steps become ever smaller with increasing height.

For this reason, asking aircraft to maintain a minimum altitude above units of the FS Wilderness System has potential acoustical effectiveness only when the aircraft presently fly very low above these units. Height increases from 100 to 1,000 ft, for example, would produce very large reductions in sound level. Increases from 1,000 to 2,000 ft would produce smaller reductions. Increases above the currently suggested 2,000 ft, on the other hand, would produce only very small reductions in sound level, and so would have little potential for effective mitigation.

In general, moderate-to-large benefits (4 to 10 dB, or so) require an approximate doubling of the distance between the aircraft and the sound-sensitive area on the ground. Where existing distances are small, their doubling may come easily. On the other hand, where existing distances are large, their doubling is essentially impossible. Where existing slant distances are intermediate, their doubling becomes more and more difficult the greater their initial value. Doubling them may not be practical.

Note that aircraft sound also reduces with increased horizontal range. In addition for aircraft at low altitude, as horizontal range increases, the chance of obtaining even further sound reductions improves, due to grazing over soft ground or interruption in the sound paths by hills and heavily wooded areas.

CONCLUSION

Only when current aircraft overflights are at very low altitude (1,000 ft or below) will significant reductions in sound be realized by increasing altitude. Conversely, for most flights, practical increases in altitude will not greatly change the impact of sound at ground level.

CHAPTER 7

POSITIVE VALUES OF AIRCRAFT OVERFLIGHTS

This chapter examines the positive values of aircraft overflights of wilderness for the protection and management of the National Forest System wildernesses, including values to lands adjacent to the National Forest System. The effect of these overflights are analyzed in terms of their benefit to wilderness resources and users, and in terms of their effect on adjacent National Forest resources and management. Aircraft overflight values to other governmental agencies and private interests such as the Department of Defense, commercial airlines, utilities, etc. are not assessed.


Aircraft are often necessary for fire detection and suppression in wilderness.

BACKGROUND

It is FS policy to discourage flights over wildernesses below 2,000 ft above ground level (AGL), except for emergencies and certain special situations [see Forest Service Manual (FSM) 2326.03]. The presence and use of airstrips is explicitly restricted (FSM 2324.33). These policies protect and enhance the values for which wildernesses were established.

Wildernesses are, however, part of the National Forest System, and are managed accordingly. National Forest management often requires the use of aircraft, and some overflying of a wilderness is necessary. The policy, therefore, allows line officers to approve certain types of administrative aircraft operations at lower altitudes.

A review[1] of aviation operations on National Forests having wildernesses (excluding Alaska) indicates that approximately 6,000 hr of flying over wilderness is done annually in support of forest management objectives (see table 10). This represents less than 10 percent of total FS flying in a typical year[2].

This review discusses and describes the types of work performed by aircraft flying over wilderness, and the benefits the wilderness and its visitors derive.

SUMMARY OF AIRCRAFT OVERFLIGHT HOURS

Use Category	*Hours*	*Percent*
Fire Management	3,743	63
Resource Management	1,174	20
Public Safety	992	17
Total	**5,909**	**100**

Table 10

FIRE MANAGEMENT

Fire Management in the wilderness has both emergency and non-emergency aspects; both often involve support by aircraft. Fire detection and suppression account for over 60 percent of FS flying over wildernesses.

Detection, often called fire patrol or reconnaissance, begins as a routine activity. It is normally accomplished in a light airplane, usually single engine, at altitudes of 1,000 to 2,000 ft AGL. In mountainous terrain, it is often necessary to descend below 1,000 ft AGL in order to observe certain canyon areas. Short term operations at lower altitude are also necessary once a fire is discovered, because a precise description of the location, size and behavior, fuels, and topography must be relayed to the Forest immediately to allow timely, appropriate management action.

Determining the appropriate action is more complex than it might seem. If the located fire can be treated as a prescribed natural fire (a naturally caused fire burning in predetermined prescribed conditions), positive long and short term benefits to the wilderness values of the area can be realized. Prescribed natural fires allow fire to play its natural ecological role within the wilderness and reduce the fuel load on the forest floor, thus preventing catastrophic wildfires. They may also provide secondary benefits for wildlife and plants. These fires must be monitored regularly, most likely from aircraft, and these aircraft will need to operate below 2,000 AGL from time to time.

If the detected fire is determined to be a wildfire, FS policy requires that it be suppressed. All wildfire suppression is regarded as an emergency activity. Various suppression strategies are possible, depending on the situation, and the role of aircraft will vary accordingly from a monitoring use similar to that described for prescribed natural fire to extensive use of airtankers, helicopters, and leadplane/air attack aircraft. Occasionally, because of the geographic location of support bases, suppression aircraft must overfly a wilderness to attack a fire that is not burning in the wilderness itself. These operations are critical to management of the forest and are kept to a minimum.

The other routine use of aircraft for fire management is to support prescribed fire that is purposefully ignited by qualified FS personnel. Consideration of terrain, fuels, and an objective of minimizing intrusion sometimes identifies aircraft as the safest and most cost effective means of igniting and monitoring such fires. This activity results in relatively few overflights because management ignited prescribed fire is of limited scope and is accomplished by nonmechanized means whenever possible.

RESOURCE MANAGEMENT

Aircraft are used to enable FS Pest Management personnel to survey both wilderness and non-wilderness for infestations of tree disease or insects. These survey flights must operate below 2,000 ft AGL to allow observers to precisely identify the location and nature of the pest or disease involved. Not only the wil-

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[1]*Forests with designated wilderness within their boundaries were asked for a professional estimate of the amount of flying done over these areas at or below 2,000 ft AGL. The type of flying considered was only that done in support of forest management objectives by FS-operated or contracted aircraft, or those of FS cooperators.*

[2]*Based on aircraft use reports submitted by the FS to the General Services Administration (GSA) for fiscal years (FYs) 1987 through 1989.*

derness itself but surrounding Federal, State, and privately owned lands benefit from the information obtained on these surveys. Although direct intervention against pests in wilderness is rare, control may be required when there is an immediate threat of unacceptable damage to resources outside the wilderness boundary or of unnatural loss of the wilderness resource because of exotic pests. The usual means of applying such control is aerial spraying.

Aerial photography is also an important resource management tool. While most kinds of aerial photos are taken well above 2,000 ft AGL, some specialized work is done below that altitude. The low-altitude work, often involving areas that affect wilderness visitor exposure to rock, mud, or snow slides, flash floods, and trail hazards, is important to overall wilderness management. Recent advances in electronic navigation and video tape technology have allowed the FS to develop an airborne, geographically referenced video-imaging system whose capabilities will dramatically supplement high-altitude photography, but will require some low-level flying.

Some special projects in wildernesses may be done with aircraft. These are projects that are impossible or not feasible by nonmechanized means, and are particularly suited to the speed and performance characteristics of aircraft. For example, aircraft are often the most effective and least intrusive means of removing debris from human activities. Airplane wreckage is an example where removal by aircraft may be approved by the appropriate line officer, but only after other nonmotorized alternatives have been considered and found to be unsuitable and the use of aircraft will have the least lasting impact to the wilderness resource.

Transport of fish or wild animals to or within wildernesses is often done to reintroduce or invigorate native populations or relocate individual animals; use of aircraft shortens the animals' time in captivity and thus increases their chance of survival after release. Accurate herd or wildfowl counts and tracking of collared animals are very difficult without aircraft. Aircraft are also used to survey the depth and condition of the snowpack in some areas where other means are not feasible and where this use was established before the area was designated wilderness.

PUBLIC SAFETY

Wilderness is, of course, naturally wild and remote. When life-threatening situations involving visitors or Government employees occur, aircraft are frequently the only effective means to respond. Search for and rescue of lost persons and medical evacuation of the sick or injured accounts for almost 13 percent of wilderness flying. Of 3,159 search and rescue operations reported in the FS Annual Wilderness Reports between 1979 and 1989, inclusive, over 47 percent (1,500) utilized aircraft to assist with the search and rescue operation. Although the Annual Wilderness Reports do not consistently specify the number of aircraft used in each search and rescue operation, the range was from one to 30 aircraft. Those search and rescue operations were concentrated in the western portion of the United States. This western concentration could be related to the larger number and size of wildernesses in the West.

Since the lack of roads for rapid land access is a desirable wilderness feature, using aircraft for such emergency work allows maintaining the character of wilderness while protecting the lives of individuals and providing an important sense of security for all wilderness visitors. Both airplanes and helicopters are used for these emergency response operations; helicopters are more common because the few wilderness airstrips are seldom handy for sick or injured persons.

In recent years, the National Forests have become sites for marijuana cultivation and other drug production activities. This development results primarily from the asset seizure laws applicable to private land and the vast, relatively remote acreage of the National Forest System. The FS has responded by cooperating with State, local, and other Federal law enforcement agencies in an aggressive program focused on detection and eradication of cultivation and other drug production sites and apprehension of those responsible. Aircraft have been a primary tool in this program.

The success of this program has prompted marijuana growers and others to seek even more inaccessible and remote sites for their activities, unfortunately including wilderness. The hazards to wilderness users and resources alike from such activity include hostile armed growers, booby traps, and the indiscriminate discharge of herbicides, pesticides, and the toxic chemical by-products of drug production into the environment.

Such hazards are not tolerable, and control efforts when authorized must involve aircraft to be effective. Cultivation sites are usually detected using small, fixed-wing aircraft. Helicopters are then employed to land or rapel eradication personnel into the sites and to haul marijuana to disposal areas by slingload. All operations require most flying to be below 2,000 ft AGL. Fortunately, the need for this type of activity has been light, except in a few areas; law enforcement represents about 4 percent of wilderness flying.

Use of helicopters for search and rescue operations is common for life threatening situations, particularly in the mountainous regions of the west.

RECREATION

Many Americans, who cannot travel on foot or horseback, value and wish to see the beauties of wilderness. Elderly or persons with disabilities, or persons restricted by time, economic, or family constraints are some examples. For such persons, scenic overflights may be the only wilderness experience available to them. Most overflights are accomplished above 2,000 ft AGL, but in some areas, portions of a scenic route may be lower for special sights or vistas.

Some wildernesses contain landing strips; in most cases, these are recognized and authorized by the legislation that established the wildernesses. Private aircraft operators and their guests use these strips to combine a flight experience with some hands-on wilderness living. These strips are used by commercial guides and outfitters, thus allowing more people to use their services to enjoy the wilderness than would otherwise be possible. Finally, these airstrips provide quicker wilderness access for firefighters and other emergency service personnel.

SUMMARY

The FS discourages flight operations over wildernesses below 2,000 ft AGL. The agency also fully recognizes that there are situations where use of aircraft provides the most effective method of performing a task that is critical to sound management of a National Forest that includes wilderness. The policy, therefore, requires line officer approval of any management use of aircraft in wildernesses, except for takeoff and landing from approved airstrips. Non-emergency uses are generally approved only when a nonmotorized means is impractical or unavailable.

This policy appears to strike a good balance for the wilderness user. It minimizes the intrusions of aircraft into the environment, but allows aircraft to be used to help preserve or enhance the character and viability of wilderness and the quality of the visitor's experience.

APPENDIXES

Appendix A
GLOSSARY

The terms in this glossary are defined in the sense in which they are used in the body and appendixes of this report, not necessarily in their broadest sense. Also listed are acronyms, and their meanings, that appear more than once in this report.

AGL: Abbreviation for "above ground level", one of two common references for specification of aircraft altitude (see also MSL).

Ambient sound: That sound which exists at a particular location due to indigenous sources (also called "background" sound, see appendix B).

Audibility: Bandwidth-adjusted signal-to-noise ratio.

A-weighted sound level: A single number index of a broadband sound that has been subjected to the A-weighting network.

A-weighting network: A frequency-equalizing function intended to approximate the sensitivity of human hearing to sounds of moderate sound pressure level.

d': The unit (pronounced "d-prime") of the audibility of a sound in a particular background noise environment.

D*: A L_{dn} value above which respondents describe themselves as highly annoyed.

dB: Abbreviation for decibel.

dBA: Abbreviation for A-weighted sound level; use of alternative symbol, dB(A), is deprecated.

dB/s: Abbreviation for decibels per second.

Decibel: The unit used to express the amplitude of a sound; as used in this report, 20 times the logarithm (base 10) of the ratio of a sound pressure of interest to a reference sound pressure.

Detectability: Bandwidth-adjusted ratio of signal-plus-noise to noise.

Dosage-response relationship: A plot of the relationship between some measure of exposure (dose) plotted on the abscissa (horizontal axis) and some measure of behavior, attitude, or disease state (response) plotted on the ordinate (vertical axis).

Eight-position array: An arrangement of eight microphones used in field studies of ambient noise sources.

Equivalent level: The averaged sound pressure level for a specified duration (see L_{eq}).

FAA: Federal Aviation Administration.

FS: U.S. Department of Agriculture Forest Service.

IFR: Instrument flight rules.

Intervening variable: A variable that mediates (accentuates or minimizes) the impacts of aircraft overflights on outdoor recreationists.

L_{dn}: Symbol for day-night average sound level; a 24-hr energy average A-weighted sound level with a 10-dB adjustment for nighttime (10 pm to 7 am).

L_{dnmr}: Symbol for onset rate adjusted monthly day-night average sound level.

L_{eq}: Symbolic representation of equivalent level; the logarithmic sum over a specified time period of sound exposure levels (SEL's).

μPa: Abbreviation for microPascal, a millionth of a Newton per square meter.

MOA: Military operating area.

MSL: Abbreviation for "mean sea level", one of two common references for specification of aircraft altitude (see also AGL).

MTR: Military training route.

NASA: National Aeronautics and Space Administration.

NPOA: National Park Overflight Act.

NPS: U.S. Department of the Interior National Park Service.

Onset rate: The slope of increase in sound level with time, expressed as dB/s.

PL: Public Law.

Purposive sample: A sample selection made in a non-random manner. Usually employed when *apriori* knowledge of the attributes of the sampled population exists.

Response bias: The willingness to report the presence or absence of a condition independently of any substantive information on which to base a decision.

RVD's: Recreation visitor days, calculated by dividing RVH's by 12.

RVH's: Recreation visitor hours.

SEL: Sound exposure level.

Self-noise: Noise generated by activities of a wilderness visitor that affects the background noise of the location.

Signal-to-Noise Ratio: The relative level (in dB) of some characteristic of a signal; e.g., its root mean square (rms) value; and the corresponding characteristic of a distribution of noise (see appendix B for technical discussion).

Sound pressure: A fluctuating pressure superimposed on the static pressure by the presence of sound.

Sound pressure level: In decibels, 20 times the logarithm to the base 10 of the ratio of the time-period, root-mean-square sound pressure, in a stated frequency band, to the standard reference sound pressure—20 microPascals (20 µPa).

Stratified sample: A sample selection made to eliminate populations of little interest.

Temporary threshold shifts: A loss in hearing acuity due to noise exposure most of which is recovered without treatment through the passage of time.

VFR: Visual flight rules.

Appendix B
TECHNICAL TERMS AND ISSUES

A number of terms used in this report have both colloquial and technical meanings. Technical uses of these terms are provided in this appendix to minimize confusion between technical and colloquial, and to avoid imputation of nontechnical motives to uses of these terms.

The term *"signal"* is applied to any physically describable, information-bearing event. A meaningful sound, for example, can be considered as an acoustic signal. The term *"stimulus"* is sometimes used loosely as a synonym for *"signal"*. The effective *"stimulus"* produced by a signal can only rarely be described in physical terms.

"Sound" is a term used colloquially to describe any audible signal. The technical definition of sound which corresponds most closely to this colloquial use is "a propagating fluctuation in atmospheric pressure". The latter definition intentionally omits any reference to the origin of the pressure fluctuation, its audibility by any observer, anyone's opinions about the pressure fluctuation, any political or economic consequences of the existence of the pressure fluctuation, etc.

"Noise" is a term used colloquially to characterize "unwanted" sound. This characterization obscures by whom and for what reasons a sound is unwanted. A more forthright definition of the term as it is used colloquially is sound having amplitude, frequency content, situational, or temporal qualities that are inappropriate to the particular setting. The non-evaluative and neutral technical definition of noise is "a signal lacking information of interest."

The terms *"ambient noise"* and *"background noise"* are used to characterize sound created by ongoing continuous processes in any measurement environment, in order to distinguish such sound from that produced by specifiable sources of interest. The word *"noise"* is used in its non-evaluative, technical sense in the terms *"ambient noise"* and *"background noise."* Inclusion of the word *"noise"* in the phrase *"ambient noise"* carries no implications about the desirability or undesirability of sound energy. The technical terms ambient noise and background noise are sometimes used roughly synonymously with the legislative term *"natural quiet"* when applied to sounds of indigenous origin in unpopulated areas.

In colloquial use, *"audibility"* is the ability of a human observer to hear a sound, either in the presence or absence of other sounds. In acoustic terms, audibility is a continuous scalar quantity calculated as the bandwidth-corrected quotient of the means of two distributions of sound levels: one referred to as the distribution of noise alone, and one referred to as the distribution of signal plus noise. Audibility is conventionally expressed in the unit d'.

Appendix C
TECHNICAL REVIEW GROUP MEMBERS

Membership (in alphabetical order, with dates for persons who were not members for the entire study period) on the Technical Review Group for the interagency Wilderness Aircraft Overflight Sound Study is as follows:

- Dr. James A. Ballas, Ph.D. - Department of Psychology, George Mason University, Fairfax, VA
- Harold Becker - Federal Aviation Administration, Washington, DC
- James M. Fields, Ph.D. - Consultant, Silver Springs, MD

- Lawrence S. Finegold - NSBIT Program Office, Wright-Patterson AFB, OH
- LTC James R. Hegland - U.S. Air Force Hdqtrs for Environment, Washington, DC
- Susan Henley - Executive Director, American Hiking Society, Washington, DC
- Michael Herth (1990-Present) - Forest Service, Monongahela National Forest, Elkins, WV
- Janet F. Hurley (1989-1990) - Forest Service, Gila Wilderness District, NM
- LTC Charles R. Linn - U.S. Air Force Hdqtrs for Operations, Washington, DC
- Jack Morehead (1989) - Superintendent Yosemite National Park, CA
- Dr. Clemans A. Powell, D.Sc. - National Aeronautics & Space Administration, Hampton, VA
- Edward J. Rickley - Transportation Systems Center, Department of Transportation, Cambridge, MA
- Tom Ritter (1989-present) - Superintendent, Sequoia-Kings Canyon National Park, CA
- John Seibold (1990-present) - Scenic Airlines, Las Vegas, NV
- Martin W. Shuey (1990-present) - Aircraft Owners & Pilot Association, Fredrick, MD
- H. Martin Sorensen Jr.- Chairman, Sierra Club's Wilderness Management Committee, Golden, CO
- Michael Stephens (1989) Aircraft Owners & Pilots Association, Fredrick, MD
- Amy Wallop - American Horse Council, Washington DC
- Ronald L.Warren (1989) - Grand Canyon Airlines, Grand Canyon, AZ

Appendix D

DEFINING AIRCRAFT OVERFLIGHTS

Several issues affec definition of the term "aircraft overflight" for purposes of PL 100-91. These include definition of flights associated with landing fields, distinction between en route flights and those associated with airfields, and distinction between flights which are "over" and "adjacent to" wildernesses.

DEFINITION OF "OVERFLIGHT" ADOPTED FOR CURRENT STUDY

For purposes of this study, an overflight is defined as an aircraft operation occurring:

1. Within the boundaries of a National Forest wilderness, with the exception of operations associated with landing fields within or adjacent to those boundaries. For current purposes, an aircraft opera tion will be assumed to be associated with landing fields within or adjacent to those boundaries, unless there is substantial evidence to the contrary, if it occurs within a cylindrical airspace volume ten nautical miles in diameter and whose top is 3,000 ft above ground level centered on an airfield within or adjacent to those boundaries; or

2. Adjacent to the boundaries of a National Forest wilderness for aircraft operations on defined routes or within otherwise defined airspace. With the exception of operations associated with landing fields as defined above, such "adjacent" operations will be defined for current purposes as aircraft operations occurring on one of the following:

- A J-route (high-altitude jet route) with centerline within four nautical miles of a wilderness boundary
- A narrowly defined low-altitude route with a centerline within a distance from a wilderness boundary equal to half the maximum altitude for the route
- A flight corridor, MTR, MOA, or RA whose boundaries lie within a distance from a wilderness boundary equal to half the maximum authorized altitude
- A Victor route with a centerline within 4.5 nautical miles of a wilderness boundary.

ISSUES ASSOCIATED WITH DEFINING AIRCRAFT OVERFLIGHTS

The following issues were addressed before the term "aircraft overflight" was defined for purposes of PL 100-91. One issue is the distinction between en route flight operations and those associated with landing fields in or adjacent to wildernesses. This distinction requires definitions of both types of flight operations, as well as interpretation of the meaning of "adjacent to." A second issue is the distinction between flights "over" and "adjacent to" wildernesses. This distinction requires interpretation of the meaning of "adjacent to" for several classes of overflights.

Definition of Airfield-related Airspace

The distinction in PL 100-91 between flight operations associated with landing fields and other flight operations is most directly treated as a distinction between en route and approach/departure aircraft operation. The most straightforward way of differentiating en route from approach/departure operations is with respect to a volume of airspace in the vicinity of airfields in which approach and departure activity generally occurs. Operations within the defined airspace could then be considered airfield-related (and hence excluded from analyses related to PL 100-91), while all other flight could be considered en route overflights, subject to a further qualification described below.

> Airspace associated with airfield operations is defined as a circular area with a radius of 5 nautical miles from the centroid of an airfield.

Federal Aviation Regulation (FAR) 1.1 defines an airport traffic area as "...that airspace within a horizontal radius of five statute miles from the geographical center of any airport at which a control tower is operating..."[1]. Although Federal Aviation Regulations provide no specific definition of an airport traffic area for an airfield without a control tower, there is little practical reason to adopt a different definition for such airfields.

Definition of "Adjacent" Airfields

PL 100-91 excludes from consideration overflights associated with landing fields adjacent to FS-managed wildernesses. Although the term "within" can be interpreted unambiguously as "completely contained inside of", the phrase "adjacent to" can plausibly imply any of several distances: from actual congruence of an airport boundary with a wilderness boundary, to variously defined distances from a wilderness boundary to an airfield.

These distances could in principle be defined in terms of standard approach and departure patterns for individual airports, in terms of noise contours, in terms of flying time, etc. However, for the sake of consistency with the definition adopted above for airspace associated with airfield operations the following definition is adopted:

An airfield adjacent to a wilderness is one within 5 nautical miles of a wilderness boundary.

Definiton of "Adjacent" Airspace

Because geometric spreading of aircraft noise emissions does not respect wilderness boundaries, aircraft operations flying adjacent to their boundaries may affect them. This condition requires a definition of "adjacent airspace" to account for the physical realities of aircraft noise exposure.

[1]*Nautical miles are preferred for present as the metric for consistency with other measurements.*

En route flight operations capable of producing noise emissions audible within wildernesses occur not only in defined airspaces ranging from narrow low-altitude corridors to very large high-altitude reserved volumes, but also in completely uncontrolled airspace. Distances defining "adjacent" overflights in these different airspaces differ for simple acoustic reasons. As a rule of thumb, the distance orthogonal to the ground track of an overflight within which aircraft noise emissions are within 3 dB of those along the centerline of the ground track is equal to approximately half of the overflight altitude. The definitions of "adjacent" suggested for the following types of flight operations reflect the common practice of defining acoustic quantities by means of half-power (3 dB-down) points.

1. En route altitudes of jet transports flying on narrowly defined high-altitude (above 18,000 ft) J-routes typically occur between 30,000 to 33,000 ft MSL. Therefore, *A J-route adjacent to a wilderness is one with a centerline within four nautical miles of a wilderness boundary.*
2. Low-altitude routes, such as those prescribed in some places for sightseeing tours, may be defined in similar terms: *A narrowly defined low-altitude route adjacent to a wilderness is one with a centerline within a distance from a wilderness boundary equal to half the maximum altitude of the route.*
3. "Adjacent" airspace may also be similarly defined for flight corridors and areas of varying width and altitude limits, such as military airspace (Military Training Routes, Military Operating Areas, and Restricted Areas): *A flight corridor, MTR, MOA, or RA adjacent to a wilderness is one whose boundaries lie within a distance from a wilderness boundary equal to half the maximum authorized altitude.*
4. "Adjacent to" a Victor route (along which much long distance general aviation operations occurs) may be defined as follows: *A Victor route adjacent to a wilderness is one with a centerline within 4.5 nautical miles of a wilderness boundary.*

Appendix E

QUANTIFICATION OF AIRCRAFT NOISE EXPOSURE

The most widely accepted method of quantifying aircraft noise for purposes related to environmental impact analyses is in terms of cumulative exposure. The conventional metric of exposure and a suggested modification of it currently under evaluation are described below.

DAY-NIGHT AVERAGE SOUND LEVEL (L_{dn})

Aircraft and other sources of environmental noise exposure have been intensively studied for more than four decades. Much of this work was summarized

17 yr ago by the Office of Noise Abatement and Control of the Federal Environmental Protection Agency in a report to Congress required by the Noise Control Act of 1972, usually referred to as the "Levels Document". Among the accomplishments of this report were (1) establishment of a consensus among Federal agencies on the use of a family of cumulative metrics of noise exposure for prediction of noise-induced annoyance, and (2) identification in terms of these metrics of levels of noise exposure adequate to protect public health and welfare with an adequate margin of safety.

The metric developed by EPA for describing environmental noise exposure, day-night average sound level (L_{dn}), is a cumulative rather than an instantaneous measure; it is one of a family of noise metrics developed principally for regulatory purposes. It embodies a set of decisions about (1) how to deal with the spectral content of noise intrusions (i.e., the distribution of sound energy over frequency); and (2) how to represent the duration and number of noise intrusions over a specified period of time.

MONTHLY ONSET RATE ADJUSTED DAY-NIGHT LEVEL (L_{dnmr})

L_{dnmr} is a variant of L_{dn} intended to characterize noise exposure produced by rapid onset rate signals such as those of low-altitude, high-speed aircraft flyovers. Although atypical of airport environs, such noise exposure may occur in proximity to some MTR's and MOA's, which tend to be sited in sparsely settled areas. Some wildernesses managed by FS lie near or underneath MTR's and MOA's. L_{dnmr} was intended as an "interim" measure supported only circumstantially, "or by the argument that there are no data to show that anything else is better." Adoption of L_{dnmr} to predict the annoyance of aircraft noise exposure in recreational settings implies acceptance of a number of assumptions, including the following:

1. Long-term annoyance of intermittent exposure to the noise of potentially small numbers of sporadic flight operations is predictable from a cumulation of exposure to individual events over the course of a specific time period: the month in which the greatest number of operations occurs over the course of a year
2. Rapidity of onset has no effect on annoyance until the maximum A-weighted fast sound level of a flyover exceeds a loosely defined ambient noise level by 15 dB
3. All other things being equal, people are as annoyed by steady-state noises as by those with onset rates as great as 15 dB/s
4. The increment in annoyance attributable to rapidity of onset per se reaches a limit of 5 dB in equivalent signal level when an onset rate of 30 dB/s is reached.

L_{dnmr} has a common heritage with several other proposed methods for predicting aircraft noise annoyance. It is similar in certain formal respects to a number of noise metrics proposed (and subsequently fallen into disuse) to account for the "impulsiveness" of aircraft noise signatures (e.g., helicopter blade slap) and for temporal variance in noise exposure (e.g., noise pollution level). The merit of predicting the prevalence of annoyance due to the noise of low-altitude, high-speed aircraft operations via L_{dnmr} is not argued from first principles. It is based instead on ad hoc analyses of available information, of which little is directly applicable to predicting the annoyance of aircraft operations in very low population density areas.

L_{dnmr} is not a mature noise metric, in that its utility for predictive purposes has not advanced beyond preliminary laboratory testing. It has yet to be applied in any formal environmental impact analysis, and no dosage-response relationship has been developed using L_{dnmr} explicitly as an independent variable.

MODELING AIRCRAFT NOISE EXPOSURE

Elaborate computer software exists for predicting the spatial distribution of noise exposure created by aircraft operations. The basic question this source-oriented, emission contouring software answers is "How much noise exposure is created here by aircraft flying there?" Aircraft noise contouring software is most highly developed for predicting aircraft noise exposure associated with standardized approach and departure flight tracks in airport environs. Programs which predict en route noise exposure are less highly developed.

Some of the limitations of existing aircraft noise contouring software for purposes of PL 100-91 analyses include the following:

1. Existing aircraft noise contouring software requires large amounts of detailed information about aircraft operational characteristics which is expensive to obtain, difficult to verify, subject to frequent change, and is unlikely to be available except in airport environs or from sophisticated instrumentation systems
2. Routine interpretations of contours developed for residential cases cannot be readily transferred to outdoor recreational settings
3. None of the noise exposure contouring programs can deal effectively with en route noise produced by unscheduled helicopter operations, nor with exposure produced by VFR operations by light aircraft on essentially random flight tracks, nor with noise produced by high-altitude transport aircraft
4. The numerous simplifying assumptions (e.g., that the world is flat, that the atmosphere is stable, that ambient noise is irrelevant, that lines of sight exist from aircraft to observers, etc.) are tailored to

a limited range of conditions that do not hold in wildernesses

5. Noise exposure predictions produced at large slant ranges tend to be very uncertain

6. Conventional aircraft noise contouring programs lack a geo-information system orientation and capability. Designed as stand-alone programs, their graphic outputs cannot be conveniently manipulated for purposes such as intersection or superimposition with other map layers or imagery, or for other automated analyses (e.g., rescaling, automatic computation of areas meeting arbitrary criteria, etc.) of cartographically referenced information

7. Contouring software alone provides no solutions to problems of exercising computationally complex models of acoustic propagation, population-weighted point and area exposure estimates, and so forth.

Appendix F

NATURAL QUIET

Natural quiet is not an absolute quantity, in that it does not universally prevail in constant and equal measure throughout all portions of all wildernesses. The concept of natural quiet is instead a relative one applicable not only to the stillness of arid environments, but also to diverse areas of wildernesses replete with sounds of surf and waterfalls, insects and other animals, wind and thunder, etc.

An ideal definition of natural quiet would be simple, unambiguous, amenable to inexpensive verification, and capable of leading directly to a metric useful for managing aircraft overflights and other noise-related land use conflicts in wildernesses. An ideal definition is also an elusive one for reasons noted below.

RESOURCE-BASED DEFINITION OF NATURAL QUIET

The natural quiet of a wilderness may be defined as the presence of only indigenous sounds measurable for a specified period of time at a particular place. While this definition appears simple and noncontroversial, many would define natural quiet in terms of human perception. If no non-indigenous sounds were able to be heard, natural quiet would be present at the site.

The following discussion presents several alternative definitions of the phrase natural quiet in terms of human perception.

AUDIBILITY-BASED DEFINITION(S) OF NATURAL QUIET

> Definition: The natural quiet of a wilderness is defined as the absence of non-indigenous sounds of a specified degree of audibility from the ambient sound environment measurable for a specified period of time at a particular place.

A point or an area within a wilderness in which the probability of hearing sounds of non-indigenous origin is negligibly small (say, d' values less than 10) could be said to be one in which natural quiet is unimpaired. Since audibility is a continuous quantity which can be calculated and expressed in decibel-like units of 10 log d', audibility offers a consistent scale of measurement even for noise intrusions of high absolute sound pressure level. Thus, a wilderness in which aircraft noise intrusions were highly audible (say, 10 log d' values on the order of 60) might be characterized as one in which natural quiet is severely compromised.

Audibility-based interpretations of the degree of impact of noise intrusions of any given origin on natural quiet require a quantitative dosage-response relationship between physical measurements of ambient and intruding sound levels in d' units and one or more measures of human response to the noise intrusions in outdoor recreational circumstances.

Characterizing natural quiet in terms of audibility of noise intrusions is not a panacea for all of the complexities noted previously, since decisions are still required about details of specification and measurement of two distributions of sound levels. Consider, for example, the following two variants on an audibility-based definition of natural quiet; the first is place-oriented, while the second is observer-oriented:

Variant 1: The natural quiet of a wilderness is defined as the absence of non-indigenous sounds of an audibility in excess of a d' value of (...) from the ambient sound environment measurable for a specified period of time at a particular place.

Variant 2: The natural quiet of a wilderness is defined as the absence of non-indigenous sounds of an audibility in excess of a d' value of (...) at the ear of an observer engaged in a sanctioned outdoor recreational activity.

Defining natural quiet in audibility-related terms also makes available a complete system of units that is:

1. Relativistic, and hence applicable to the entire range of natural quiet encountered in diverse wilderness locations
2. Sensitive and quantitatively relatable to human response by empirical means
3. Rigorously definable and mathematically adaptable to specialized analyses of various aspects of natural quiet
4. Capable of adaptation for use as a metric for making and expressing overflight management policy decisions.

An audibility-based system of units may be constructed in a fashion analogous to the family of integrated energy metrics (e.g., SEL, L_{eq}, L_{dn}) developed by the Environmental Protection Agency (EPA) for quantifying high level community noise exposure. Although conventional measurement units developed for urban settings are insensitive to indigenous sound environments, an audibility-based system of units could systematically account both for the spectral content and amplitude distribution of natural quiet, and for its ability to mask noise intrusions.

*U.S. GOVERNMENT PRINTING OFFICE 199[illegible]

Mt. Lemmon Highway

EXAMPLE OF PARTIAL VPP THROUGH CONSTRUCTION PHASE

INTRODUCTION

The Mt. Lemmon Highway, a part of the Arizona Federal-aid secondary highway system, crosses the Coronado National Forest. The Forest Service manages national forests for natural, social, cultural, and visual resources. Maintenance of this highway is provided by the Pima County Department of Transportation and Flood Control District. Reconstruction of the existing two-lane roadway began with a 3-mile (4.83 km) project in late 1987. A second 3-mile (4.83 km) project was completed in mid-1991. Improvements included widening the two traffic lanes from 9 feet (2.7 m) to a standard 12-foot (3.7m) width, adding paved shoulders, and realigning the highway to a 30-mph (48.3 km/h) design speed.

The visual prioritization process (VPP) was first developed and applied to this project. This application of the VPP is presented as a "partial" VPP version. This streamlined example of the process considers only new visual elements of cuts and fills. Other visual factors—such as the loss of significant visual resources and other proposed visual elements—were inventoried separately.

PHASE I— EXISTING VISUAL RESOURCES

Character Zone

Mt. Lemmon Highway is a 25-mile (40.3 km) long highway between the desert city of Tucson, Arizona and the top of the Catalina Mountain Range. The highway crosses nine plant zones, from the Sonoran Desert Upland zone—2,250 feet (685.8 m) at the base of the mountains, to the Subalpine Zone—9,000+ feet (2,743.2+m) at the top of the range.

The highway scenery is characterized by steep, mountainous terrain; rough canyons; panoramic ridge and valley views; unique vegetation which changes with elevation and exposure; clear, cold-water streams enclosed by dense riparian zones; diverse wildlife; and spectacular rock formations—

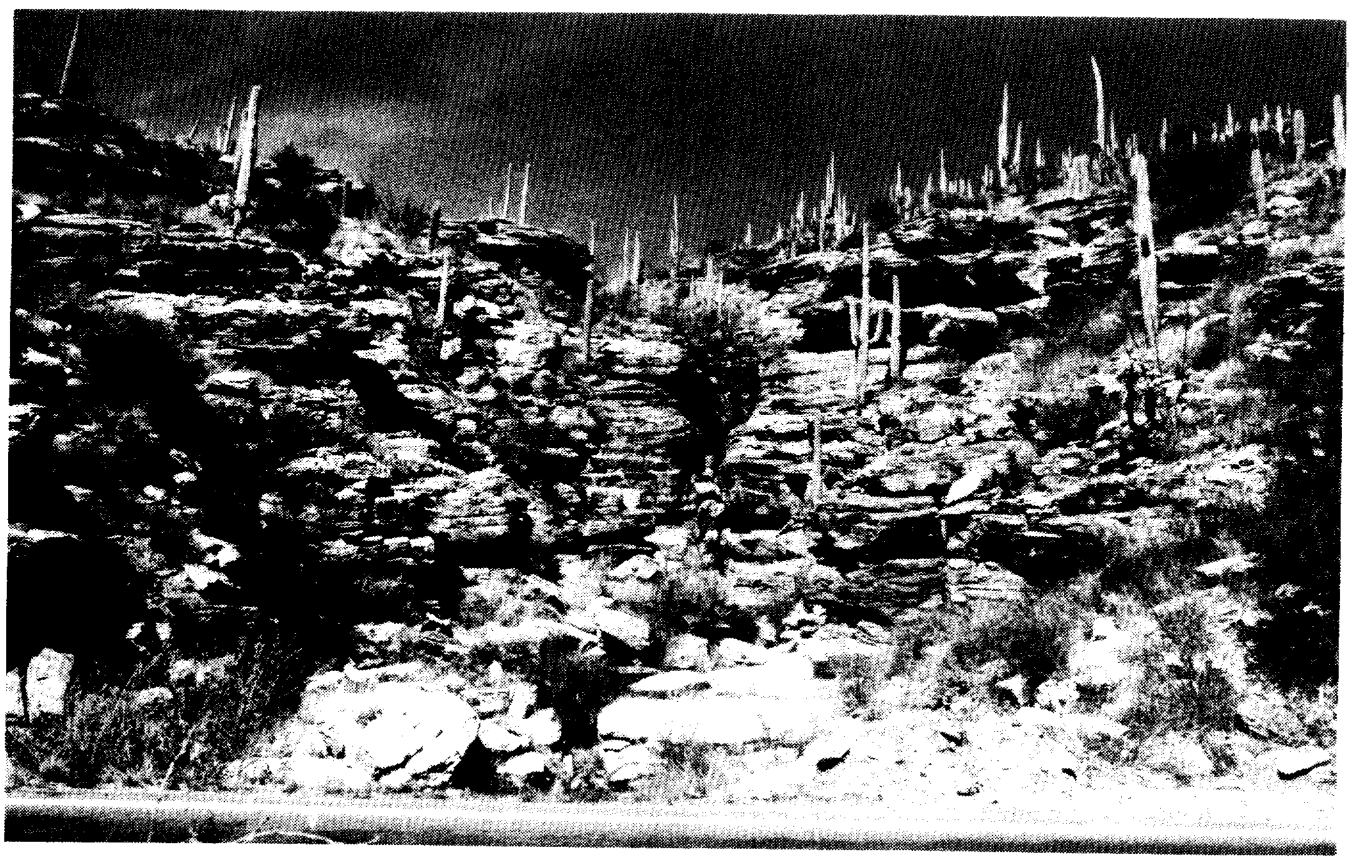


Figure B-1. Characteristic view from Mt. Lemmon highway.

resulting in some of the most attractive scenery and recreational opportunities in the typically flat, arid southwestern United States. Mt. Lemmon Highway is a designated scenic highway in Pima County (figure B-1).

The Catalinas are an important visual backdrop for Tucson. The first two projects of reconstruction are along the lower 6 miles (9.7 km) of the highway. The first 4 miles (6.4 km) cross the front face of the Catalinas, facing Tucson (figure B-2).

Visual Quality/Variety

Visual resources along the highway are managed under the Visual Management System (VMS) (reference 18) of the USDA Forest Service. Under this system, the variety of the physical features of the landscape are measured to determine visual quality. The variety of landscape features viewed from the Mt. Lemmon Highway are categorized as being *distinctive*, falling into *Class A*. This rating is assigned because of the spectacular views of changing landform, rock form, vegetation, and riparian areas along the highway.

Visual Concern

The Sensitivity Level of the route measures people's concern for scenic quality, under VMS (reference 18). Mt. Lemmon Highway has a Sensitivity Level 1 rating, as it is a primary travel route, where at least one-fourth of the Forest visitors have a major concern for the scenic qualities. Many tourists drive the entire 25-mile (40.3 km) length just to view the scenery.

Visual Goals

Under the VMS, areas with Variety Class A and Sensitivity Level 1 are within the Retention Visual Quality Objective. The goal of retention is for construction activities to be unnoticeable to a forest visitor upon completion of the project. To achieve this, design elements should repeat the existing patterns of form, line, color, and texture in the landscape.

Because the project is located in the fragile, biological environment of the Sonoran Desert, and with the budget available, the Forest Service recognized initially that the retention objective could

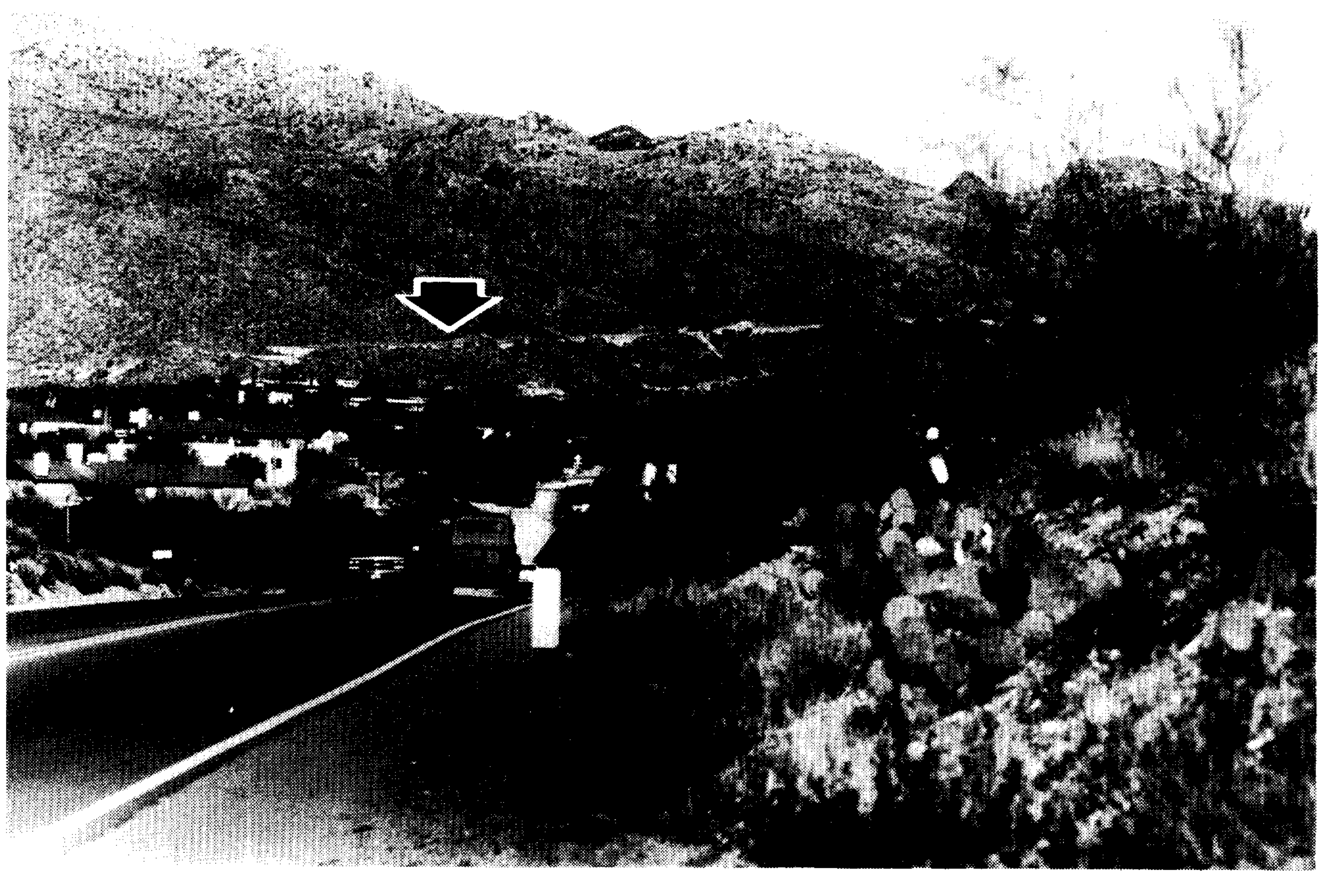


Figure B-2. Background view of Mt. Lemmon highway from urban area.

not be met upon completion of the project. A modified visual goal was adopted for this project, to meet the *retention* objective within 3 years of completion of construction.

PHASE II—VISUAL IMPACTS
Conceptual/Preliminary Design

Federal Highway Administration (FHWA), Central Federal Lands Highway Division engineers were responsible for the highway design. An early design decision was made, based on the preliminary visual resource assessment, to consolidate fill/waste areas in low-visibility areas, rather than a more traditional approach of minimizing the haul by side casting fill material along the entire route. The alignment, as a result, shifted toward the cut side in high-visibility areas. This decision was based on the high visibility from Tucson of large sections of the lower 4 miles (6.4 km) of the highway, and the probability of greater success with mitigation on cuts. Concentrated areas of fill disposal were identified, where slopes could be flattened for better revegetation.

Preliminary Visual Prioritization Process (VPP) Inventory

On this project, cuts and fills were identified as the primary visual elements requiring mitigation. The VPP was used to inventory each proposed cut and fill as identified on the preliminary roadway design provided by FHWA, in order to determine the visual sensitivity level of each area. The mitigation measures would be concentrated on areas with greater sensitivity, and a higher visual priority level (VPL).

Conduct Detailed Visual Inventory

In addition to the VMS mapping, a visual resource assessment was initially completed in 1986 as part of the environmental assessment for the reconstruction of the Mt. Lemmon Highway. Distance zones fo˂ the visual inventory along the highway, guided by VMS recommendations, are shown in figure B-3. While the entire highway requires special attention to visual resources, the lower 4 miles (6.4 km) are especially critical visually, as long stretches are visible in the background from Tucson.

Determine Values of Inventory Variables

Six visual criteria were identified to inventory the visual sensitivity of each proposed cut and fill: (1) Distance from the viewer, (2) magnitude or scale, (3) angle of the view, (4) duration of the view at the design speed of 30 mph (48.3 km/h), (5) silhouette condition, (figure B-7) and (6) aspect. Following are

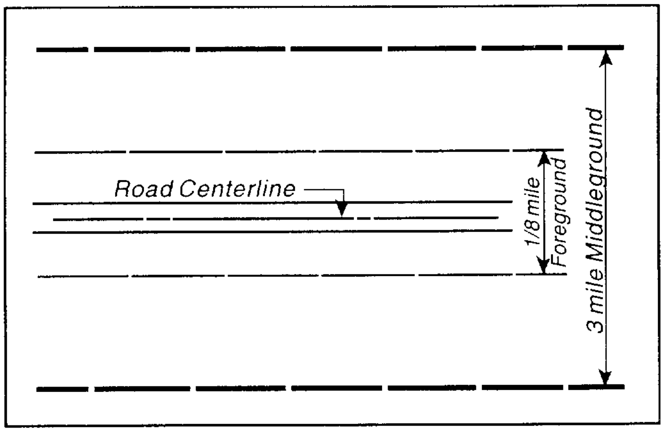


Figure B-3. Distance zones for visual inventory of Mt. Lemmon highway.

the inventory variables, their values, and the numerical scores used on this project. (Note: In this case study, "immediate foreground" was not used as a distance zone)

Inventory variables	Numerical score
1. Distance from the viewer:	N/A
Foreground: up to 1/8 mi (201.2 m)	
Middleground: 1/8 to 3 mi (201.2 km to 4.83 km)	
Background: 3+ mi (4.83+ km)	
2. Magnitude:	
0 to 600 sq ft (0 to 55.8 sq m)	1
600 to 4,000 sq ft (55.8 sq m to 371.6 sq m)	2
4,000+ sq ft (371.6+ sq m)	3
3. Angle of the view:	
46 to 90 deg (peripheral)	1
16 to 45 deg	2
0 to 15 deg (direct)	3
4. Duration of the view:	
0 to 7 sec—up to 300 ft (91.4 m)	1
7 to 12 sec—300 to 500 ft (91.4 m to 152.4 m)	2
12+ sec—500+ ft (152.4 +m)	3
5. Silhouette condition:	
No silhouette	0
Background is vegetation	1
Background is sky	2
6. Aspect:	
Angles flat, or slopes away from, viewer	1
Angles 45 deg to flat	2
Angles vertical to 45 deg	3

MT. LEMMON HIGHWAY

VPP INVENTORY-NEW VISUAL ELEMENTS

	STATION	MAGNITUDE				ANGLE				DURATION/ VISIBILITY				SILHOUETTE				ASPECT				SUB TOTAL	VPL
		I	F	M	B	I	F	M	B	I	F	M	B	I	F	M	B	I	F	M	B		
	CUTS, PHASE I																						
10	L 54+50 - 57+00		3	3			1	3			1	3							3	3		20	2
11	L 57+00 - 62+50		3	3	2		1	2	3		3	3	3		1	2			2	3	3	34	1
12	L 65+50 - 69+50, R 67+00 - 69+00		3	3	3		1	3	2		2	2	3						3	3	2	30	1
	CUTS, PHASE II																						
24	R 126+50 - 127+50		1				2				1				1				3			8	3
	FILLS, PHASE I																						
1	R 12+00 - 17+00			3				2				1								1		7	3
2	R 18+00 - 23+50			3				2				1								1		7	3
3	L 26+50 - 27+50, R 25+50 - 27+00			2				2				3								2		9	3
4	R 27+75 - 28+25			1				2				3								1		6	3
5	L 33+50, R 29+50 - 30+50			2				2				2								1		7	3
6	L 43+50 - 45+00, R 38+00 - 45+50		3	3			3	3			3	3								2		25	1
7	L 62+50 - 65+50		1	2			1	2			1	1								1		9	3
8	L 69+50 - 73+50, R 69+00 - 73+50		3	3	3		2	3	3		3	2	3						1	2	3	31	1
9	L 93+00, R 91+25 - 93+00		2	2	2		3	3	3		3	2	3						1	2	3	29	1
10	L 94+50 - 95+50		1	1			2	3			2	2							1	1		13	2
	FILLS, PHASE II																						
7	R 214+00 - 216+00		3	3			2	3			1	3							1	2		18	2

Figure B-4. VPP field inventory form—New Visual Elements

The following assumptions were made for the VPP inventory of this project: (1) When more than one angle of view was possible, the most sensitive angle was selected, and (2) when more than one duration of view variable applied, the most sensitive was selected.

Setup Unit VPP Inventory Forms

The inventory form was set up to include all cuts and fills on the project, with each of the variables listed, representing the values (see figure B-4). Forms list numerical scores assigned for each variable on all cuts and fills.

Perform Inventory

Each new cut and fill was inventoried, based on the preliminary cross sections, plans, and field reconnaissance. The VPP numerical scores are recorded on field inventory forms. Three cuts and three fills, with VPL ratings of 1, 2, and 3, shown in the form in figure B-4, are presented as examples of this process. A photo and description of each numerical rating assigned for the cuts and fills follows.

a) Example 1: Cut 11, Project 1, Station 57+00 - 62+50 L—VPL 1

Cut 11 on project 1 of the Mt. Lemmon Highway reconstruction is a 55-ft (16.8 m) cut, the highest cut on the first project. Approximately 19,000 sq ft (1,765.1 sq m) of cut surface is proposed. Under magnitude variable, 19,000 sq ft (1,765.1 sq m) is in the value range with a numerical score of 3 (see figure B-5).

The angle of view from the foreground (in a vehicle) is peripheral, and is scored 1. The duration of view while traveling at the design speed of 35 mph (56.4 km/h), is 15 sec, and is scored 3.

The cut is silhouetted against vegetation from the foreground view, and is scored 1. The aspect of the cut view from the foreground is nearly vertical, scored 3. The middleground view of the cut is shown as viewed from a lower section of the highway (see figure B-6). Although the entire cut is not visible, over 5,000 sq ft (464.5 sq m) of the proposed new cut can be seen from this area, and the cut receives a 3 scoring for magnitude.

The angle of view from the middleground ranges between 16 and 45 deg, and is scored 2. The duration of view from this area is over 12 sec and is scored 3. The aspect of the cut viewed from the middleground is nearly vertical, scored 3.

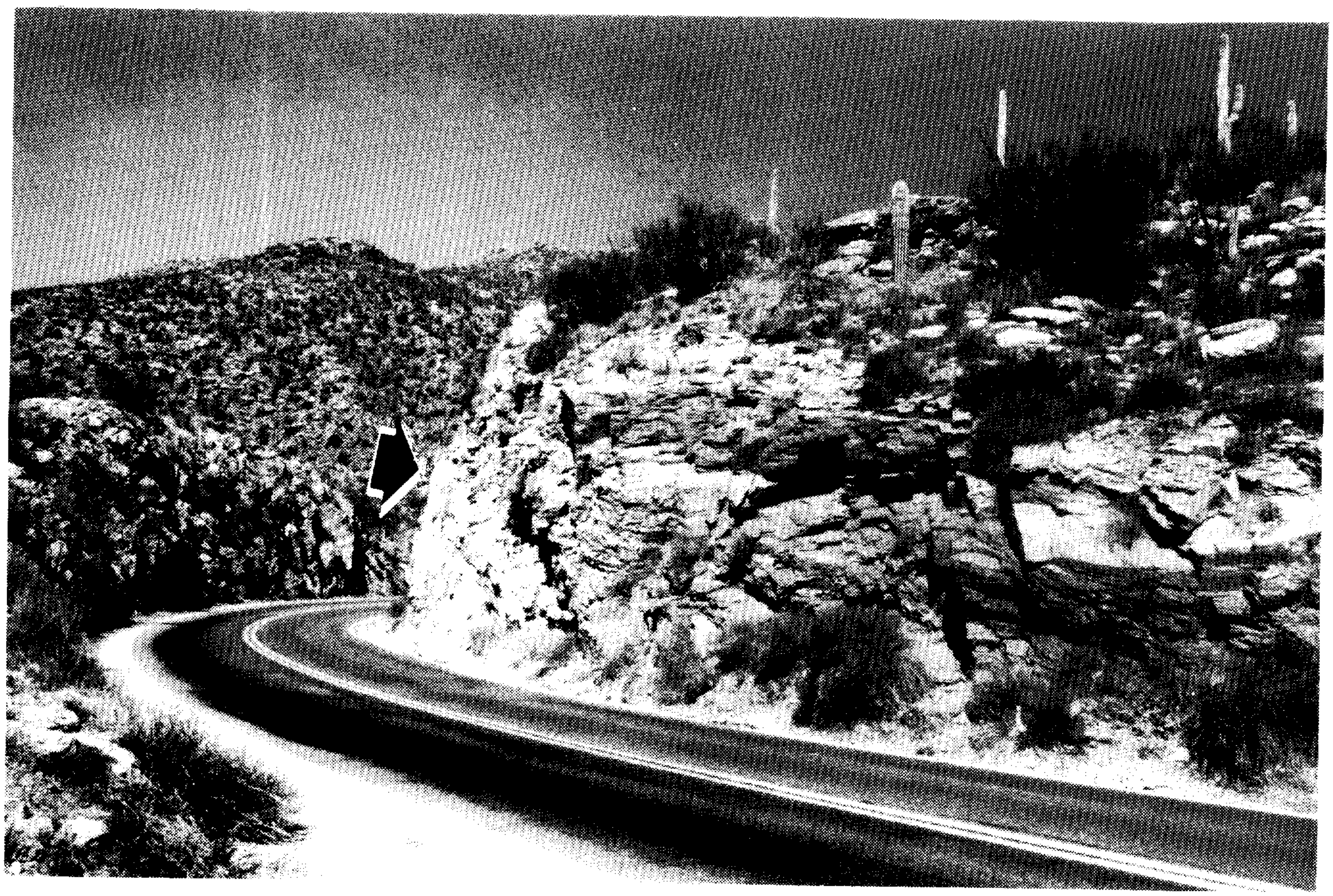


Figure B-5. Cut 11, VPL 1—Foreground view from the highway, before reconstruction.

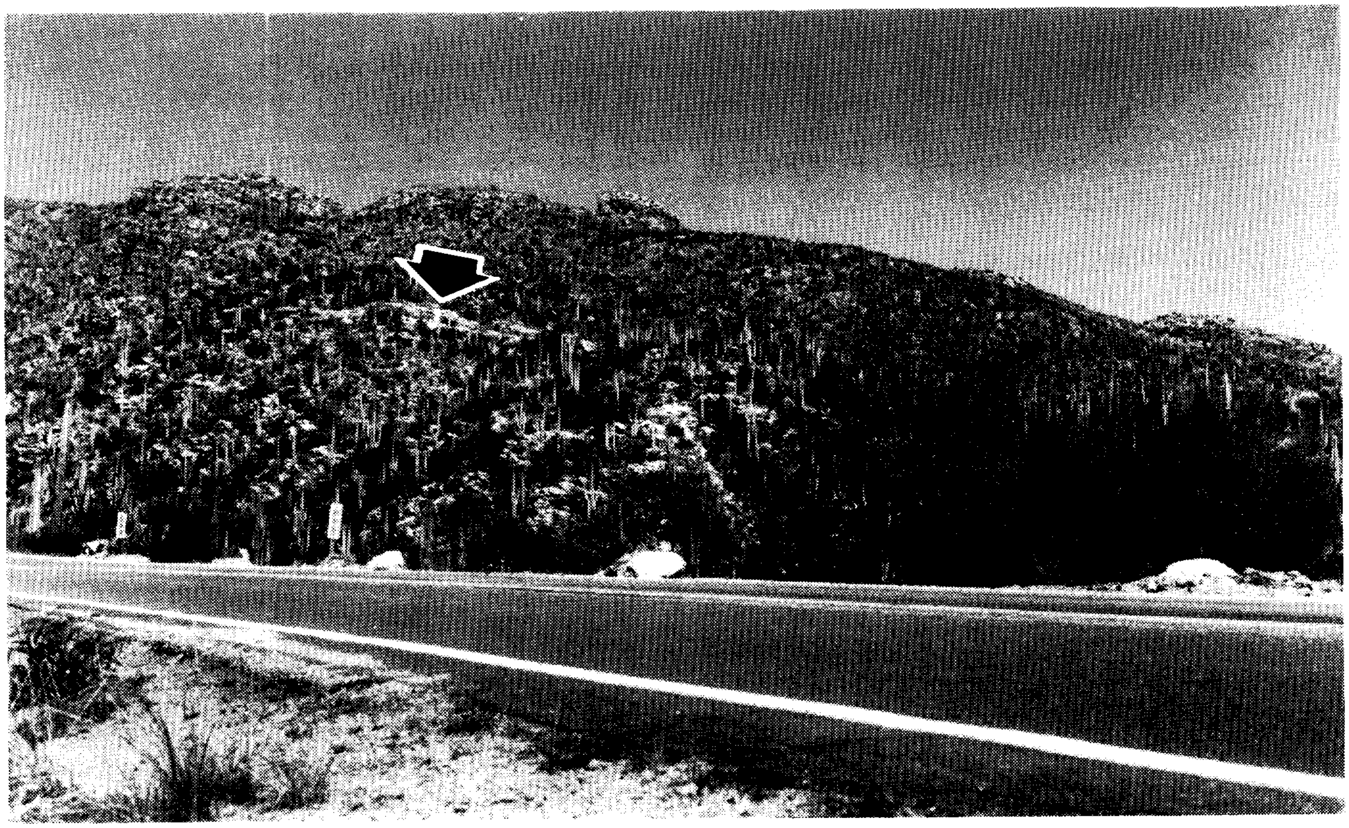


Figure B-6. Cut, VPL 1—Middleground view from lower section of highway.

Figure B-7. Cut 11, VPL 1—Silhouette against sky, viewed from lower section of highway.

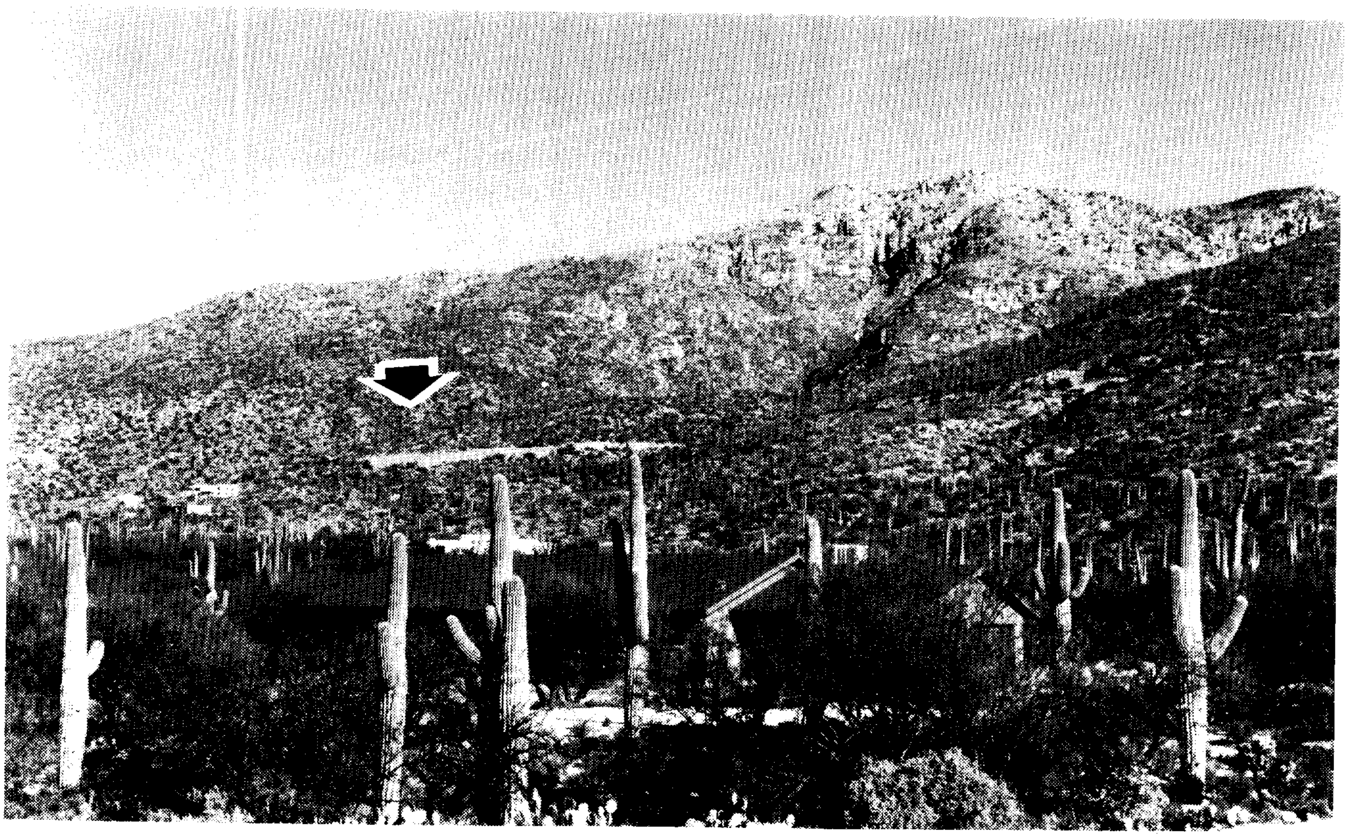


Figure B-8. Cut 11, VPL 1—Background view of the cut from residential area.

Figure B-9. Cut 10, VPL 2—Middleground view from lower section of highway.

A different middleground view, also from a lower section of the highway, shows a sharp silhouette against the sky, resulting in a 2 score (see figure B-7). Only a portion of Cut 11 is visible from the background view in Tucson, resulting in a 2 score for magnitude (see figure B-8). The angle of view from the background is direct, scored 3.

The duration of view from the background is continuous and is scored 3. There is no silhouette view from the background. The aspect of the cut from the background is nearly vertical, scored 3 (see figure B-8).

b) Example 2: Cut 10, Project 1, Station 54+50 - 57+00 L —VPL 2

This cut is visible from the foreground and middleground distance zones, but is not visible from the background. The magnitude of this proposed cut, viewed from the middleground, is 6,000 sq ft (557.4 sq m), scored 3 (see figures B-5 and B-9).

The angle of view from the middleground is direct, scored 3. The duration of view from the middleground is approximately 1-1/2 min at the design speed of 35 mph (56.4 km/h), and is scored 3. The aspect of the cut viewed from the middleground is nearly vertical, scored 3.

There is not a silhouette view from the middleground or the foreground.

The entire proposed cut of 6,000 ft (1,828.8 m) is visible from the foreground, and is scored 3 for magnitude (see figure B-10).

The angle of view from the foreground is peripheral, and is scored 1. The duration of view from the foreground is slightly under 7 sec, scored 1. The aspect of the cut viewed from the foreground is nearly vertical, scored 3.

c) Example 3: Cut 24, Project 1, Station 126+50 - 127+25 R—VPL 3

Cut 24, Project 1, located on the inside of a curve, is visible from only the foreground view (see figure B-11).

The magnitude is scored 1 with a proposed cut face surface of 575 sq ft (53.4 sq m). The angle of view is an average of 30 deg, and is scored 2.

Figure B-10. Cut 10, VPL 2—Foreground view.

Figure B-11. Cut 24, VPL 3—Foreground view.

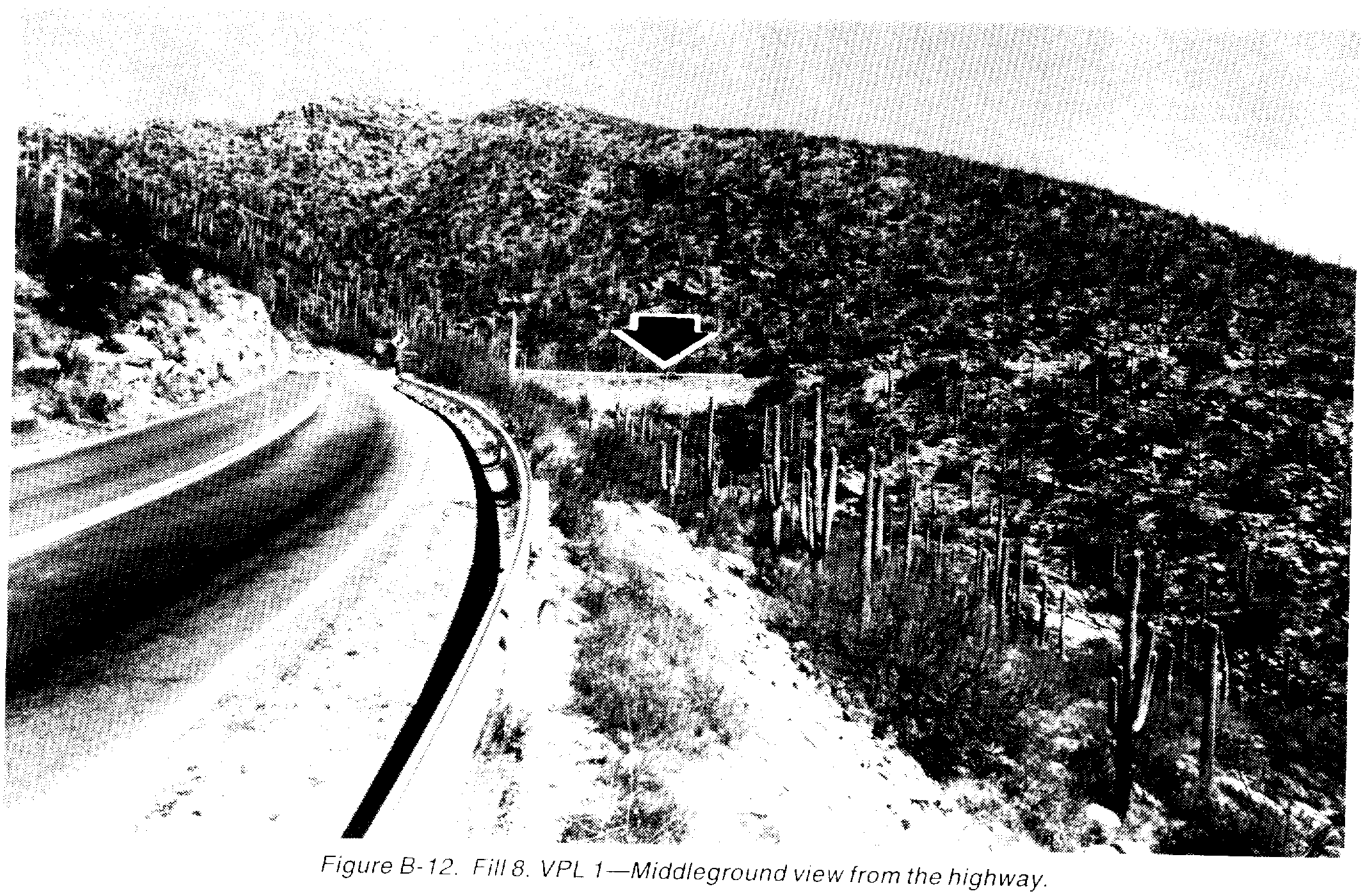


Figure B-12. Fill 8. VPL 1—Middleground view from the highway.

The silhouette condition is against vegetation, and is scored 1. The duration of view is less than 2 sec, scored 1.

d) Example 4: Fill 8, Project 1, Station 69+50 - 73+50 R—VPL 1

The large fill at Station 69+50 to 73+50 is one of the designated waste areas and is visible from the foreground, middleground, and background (see figure B-12).

The magnitude at all distance zones is scored 3, as the new fill is approximately 20,000 sq ft (1,860 sq m).

The angle of view is approximately 30 deg at the foreground view, scored 2. The middleground and background views are direct, scored 3.

The duration of view for Fill 8, from the foreground, is approximately 20 sec, scored 3. From the middleground, the duration of view is slightly over 7 sec, scored 2 (see figure B-12).

The continuous background view, where the fill is visible from a residential area, results in a 3 score for duration of view.

There is not a silhouette condition for this fill area (see VPP inventory form, figure B-4).

e) Example 5: Fill 7, Project 2, Station 214+00 - 216+00 R —VPL 2

Fill 7 on project 2 of the Mt. Lemmon Highway reconstruction is visible from a foreground and middleground view (see figure B-13). The magnitude is scored 3 from both distance zones, with approximately 20,000 sq ft (1,858 sq m) proposed in the fill.

The foreground angle of view is approximately 30 deg, scored 2. When viewed from the middleground, the view ranges from 30 deg to direct and is scored a 3, selecting the most sensitive viewing angle (see figure B-13).

Figure B-13. Fill 7, Project 2, VPL 2—Middleground view from upper section of highway.

The duration of the foreground view is 6 seconds, and scored 1. The middleground view duration can be considered constant (at the scenic overlook) and is scored 3.

The aspect is scored 1 at the foreground distance zone, as the slope drops away from the viewer. It is scored 2 at the middleground distance zone, as the slope is less than 45 deg from the observer when viewed from this area.

There is no silhouette condition.

f) Example 6: Fill 3, Project 1, Station 25+50 - 27+50 R—VPL 3

Fill 3 on project 1 of the Mt. Lemmon Highway project is visible only from the middleground view (see figure B-14). With a proposed size of 3,500 sq ft (325.6 sq m), the fill was scored 2 for magnitude.

The angle of view ranges from approximately 20 to 40 deg, and is scored 2. The duration of the middleground view is approximately 31 sec, scored 3.

The aspect of the middleground view is less than 45 deg, and is scored 2. There is no silhouette condition (see figure B-15).

Tally Total Value

After the preliminary inventory, the totals of the scores for each cut and fill were added, which resulted in the VPL ratings. For the Mt. Lemmon Highway project, the VPL ratings were:

VPL 1: scores of 21+
VPL 2: scores of 11 to 20
VPL 3: scores of 1 to 10.

PHASE III—IMPLEMENTATION

Intermediate Design

Based on the preliminary VPP and field review during project 2 of the Mt. Lemmon Highway project, an alignment shift was incorporated into the design. A unique rock structure, which was a strong visual feature in the area, was identified at Station 230+00 (R) (see figure B-16).

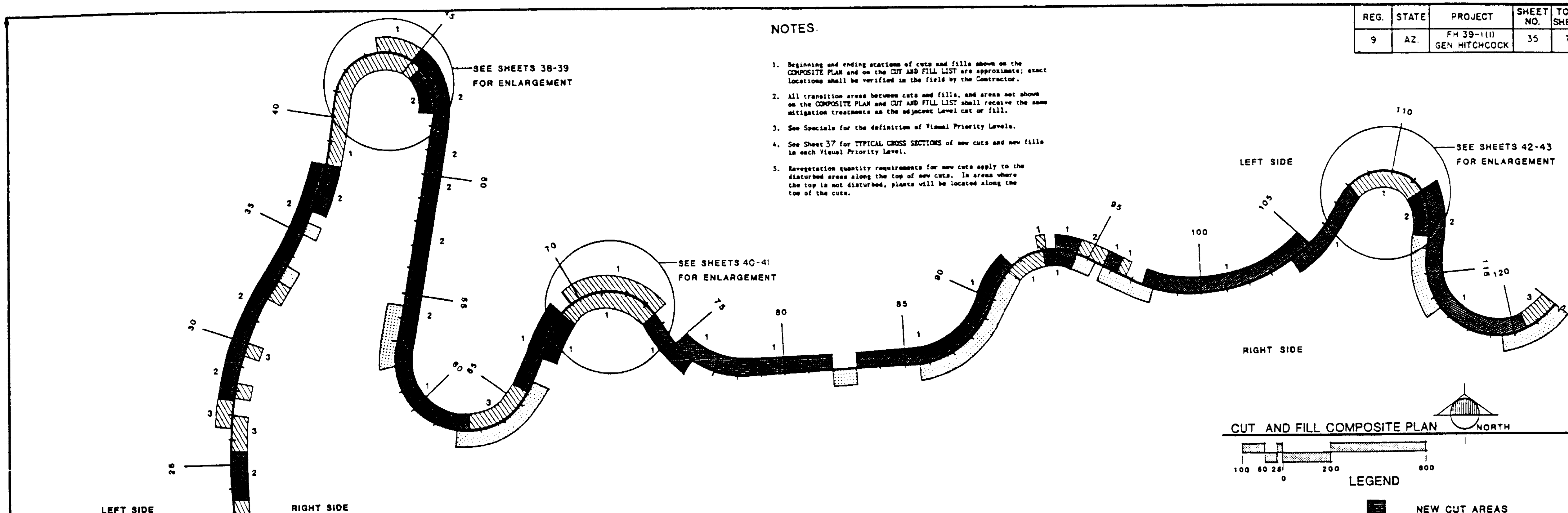
The shift in the alignment, with increased cut on the left to leave the rock formation in place, is an

Figure B-14. Fill 3, Project 1, VPL 3—Middleground view from the highway.

Figure B-15. Fill 3, Project 1, VPL 3—Middlegroundview from the highway.

Figure B-16. Unique rock structure saved during design by alignment shift.

REG.	STATE	PROJECT	SHEET NO.	TOTAL SHEETS
9	AZ.	FH 39-1(1) GEN HITCHCOCK	35	71



NOTES:

1. Beginning and ending stations of cuts and fills shown on the COMPOSITE PLAN and on the CUT AND FILL LIST are approximate; exact locations shall be verified in the field by the Contractor.
2. All transition areas between cuts and fills, and areas not shown on the COMPOSITE PLAN and CUT AND FILL LIST shall receive the same mitigation treatments as the adjacent Level cut or fill.
3. See Specials for the definition of Visual Priority Levels.
4. See Sheet 37 for TYPICAL CROSS SECTIONS of new cuts and new fills in each Visual Priority Level.
5. Revegetation quantity requirements for new cuts apply to the disturbed areas along the top of new cuts. In areas where the top is not disturbed, plants will be located along the toe of the cuts.

LEGEND

- NEW CUT AREAS
- NEW FILL AREAS
- EXISTING FILL AREAS
- 1,2,3 VISUAL PRIORITY LEVEL OF CUT AND FILL SLOPES
- 50 STATION 50+00

CUT AND FILL LIST

	Station of Cut LEFT	RIGHT	Visual Priority Level	Special Mitigation Measure
1		17+00 - 18+00	3	
2	Station	23+50 - 25+50	2	
3	Station 27+50 to 30+00		2	
4	Station 30+00 to 33+50		2	
5	Station 34+00 to 38+00	36+00 - 38+00	2	
6	Station 45+00 to 48+00	45+50 - 47+50	2	LBD-W
7	Station 48+00 to 50+00		2	
8	Station 50+00 to 51+50		2	LBD-S
9	Station 51+00 to 54+50		2	
10	Station 54+50 to 57+00		2	
11	Station 57+00 to 62+50		1	WARP
12	Station 65+50 to 69+50	67+00 - 69+00	1	WARP
13	Station 75+00 to 77+00	73+50 - 76+00	1	
14	Station 77+00 to 82+00		1	LBD-E WARP
15	Station 83+00 to 88+50		1	LBD-W WARP
16	Station 88+50 to 91+50		1	WARP
17	Station 93+50 to 94+50	93+00 - 94+50	1	WARP
18	Station 95+50 to 96+50		1	WARP
19	Station 97+50 to 105+00	104+00 -105+00	1	WARP
20	Station	105+00 -108+00	3	
21	Station 111+50 to 114+00	111+50 -113+50	2	
22	Station 114+00 to 120+50		1	WARP

	Station of Fill			
1	Station	12+00 to 17+00	3	
2	Station	18+00 to 23+50	3	
3	Station 26+50 to 27+50	25+50 to 27+00	3	
4	Station	27+75 to 28+25	3	
5	Station 33+50	29+50 to 30+50	3	
6	Station 43+50 to 45+00	38+00 to 45+50	SMA	
7	Station 62+50 to 65+50		3	
8	Station 69+50 to 73+50	69+00 to 73+50	SMA	
9	Station 93+00	91+25 to 93+00	1	SMAL
10	Station 94+50 to 95+50		2	
11	Station 96+50		1	
12	Station	108+00 to 111+50	SMA	
13	Station 119+00 to 122+00		3	

NOTE: inventory ranking was not applied to areas designated as Special Mitigation Areas
SMA - Special Mitigation Area
LBD-E LAY BACK DRAW (EAST END OF CUT) (SEE DETAIL L, sheet 50)
WARP - WARP TOP AND/OR TOE OF SLOPE (SEE DETAIL F, sheet 49)

MITIGATION MATRIX

DETAIL*		VISUAL PRIORITY LEVEL 1	2	3
	MITIGATION MEASURES FOR NEW CUTS* (see Cut and Fill List, this sheet, for specific mitigation locations)			
See Specs	Rock/slope sculpture:			
F	Warping top & toe	X	X	
L	Slope rounding	X	X	
	Detailed rock/slope work:			
C	Highlighting rock outcrops	X		
I	Soil pockets	15/100sy	13/100sy	11/100sy
	Revegetation:			
J	Transplant cacti	4/100sy	3/100sy	1/100sy
G	Transplant ocotillo	2/100sy	1/100sy	1/100sy
See Specs	Plating soil and seeding	X	X	X
	MITIGATION MEASURES FOR NEW FILLS*			
See Specs	Rock/slope sculpture:			
H	Slope warping	2:1	1 3/4:1	1 1/2:1
D	Slope rounding	X	X	X
	Detailed rock/slope work:			
A	Boulder placement	3/100sy	2/100sy	1/100sy
B	Soil pocket	7/100sy	5/100sy	3/100sy
	Revegetation:			
J	Transplant cacti	4/100sy	3/100sy	1/100sy
C	Transplant ocotillo	2/100sy	1/100sy	1/100sy
See Specs	Plating soil and seeding	X	X	X
	MITIGATION MEASURES FOR EXISTING FILLS			
	Revegetation:			
See Specs	Seeding			

* Details are located on sheets 49 - 50

LEDGE LOCATIONS ON CUTS

NOTE: See design cross sections, sheets 63-71

Height above ground at beginning station:	Begin at station:	End at station:	Height above ground at ending station:	Depth:	Notes:
6'	34 + 30	34 + 50	Daylight	3'	Round to draw at 93 + 40
7'	35 + 15	35 + 40	Daylight	4'	
0'	36 + 15	36 + 60	Daylight	3'	LBD on top
Daylight	45 + 60	46 + 00	8'	3'	Follow top of black
Daylight	46 + 10	46 + 60	0'	3'	Follow top of black
13'	46 + 60	46 + 70	18'		Follow fracture
18'	46 + 70	47 + 50	0'	3'	Follow top of black
Daylight	47 + 40	48 + 00	5'	3'	Round to draw at 48 + 00
Daylight	48 + 70	49 + 50	2'	3'	
14'	52 + 30	52 + 50	10'	Varies	See (1)
Daylight	52 + 70	53 + 00	20'	Varies	See (1)
Daylight	53 + 50	53 + 70	20'	Varies	See (1)
Daylight	55 + 20	55 + 90	Daylight	5'	
Daylight	57 + 25	57 + 70	13'	4'	
Daylight	57 + 60	58 + 00	25'	5'	
5'	66 + 50	66 + 75	Daylight	Varies	See (2)
11'	67 + 35	67 + 65	Daylight	Varies	See (2)
7'	67 + 80	67 + 95	13'	Varies	See (2)
0'	68 + 70	69 + 00	Daylight	Varies	See (2)
10'	80 + 85	81 + 20	16'	5'	See (3)
0'	81 + 50	82 + 20			Round at 81+20
3'	91 + 00	91 + 90	10'	5'	
Daylight	93 + 40	94 + 00	7'	5'	Round at 93+40
5'	93 + 20	94 + 00(R)	5'	2'	
10'	103 + 50	104 + 70	Daylight	4'	Begin at seam
5'	104 + 00	106 + 50(R)	5'	2'	
5'	106 + 30	107 + 00(R)	6'	2'	
17'	112 + 00	112 + 50	10'	3'	Repeat existing ledge
Daylight	113 + 20	113 + 60	0'	3'	Follow top of black

(1) vary width of ledge 2' to 7' with widest dimension at beginning stations
(2) vary width of ledge 2' to 7' with widest dimension at ending stations
(3) step ledge up between 81 + 00 and 81 + 10
(R) - indicates cut on right side

U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
CENTRAL DIRECT FEDERAL DIVISION
DENVER, COLORADO

COMPOSITE PLAN
STATION 0 - 122+00
SHEET L1 OF 18

SPECIAL - 8

DESIGNED
DRAWN

Figure B-17. Project 1 Composite plan, sheet L1, Mt. Lemmon Highway.

REG.	STATE	PROJECT	SHEET NO.	TOTAL SHEETS
9	AZ	FH 39-1(3) GENERAL HITCHCOCK	66	100

Material List

LABEL	SCIENTIFIC NAME / COMMON NAME	QUANTITY	SIZE/ COND.	# 1 GPH EMITTERS
	Salvaged plant material			
S1	Opuntia engelmannii Prickly pear	167	1 - 10 pads/BR	0
S2	Ferocactus wislizeni Barrel cactus	21	1 - 2' BR	0
S3	Agave sp. Century plant	75	1 - 3' BR	1
S4	Yucca sp. Yucca	2	BR	1
S5	Yucca sp. Yucca	2	15 gal	4
S6	Dasylirion wheeleri Desert Spoon	15	5 gal	1
S7	Cercidium microphyllum Foothill paloverde	2	30" box	10
S8	Prosopis velutina Velvet mesquite	1	48" box	14
	Container grown plant material			
C1	Celtis pallida Desert hackberry	32	1 gal	1
C2	Rhamnus crocea Hollyleaf buckthorn	27	1 gal	1
C3	Quercus emoryi Emoryi oak	84	3 gal	4
C4	Cercidium microphyllum Foothill paloverde	20	5 gal	4
C5	Prosopis velutina Velvet mesquite	71	5 gal	4
C6	Vauquelinia californica Arizona rosewood	65	5 gal	4
C7	Ziziphus obtusifolia Greythorn	32	5 gal	4
C8	Fraxinus velutina Velvet ash	11	5 gal	6
C9	Populus fremontii Fremont Cottonwood	5	5 gal	6
C10	Platanus wrightii Sycamore	4	5 gal	6
	Inert material			
S	Plating soil			
B	Boulder	76	1/3 to 1 cu.yd.	
T	Irrigation tank	24	varies (see sheet 57)	

Irrigation Material Schedule

SYMBOL	MANUFACTURER/MODEL	DESCRIPTION
●	Spears	2" x 1 1/2" reducer bushing, Sch 80 pvc thread by thread
■	Spears	1" pvc tank adapter
⊠	FLO Control	1" plastic foot screen
□	Spears	1" x 1" male adapter insert
	Mundo SA1GVI	1" gate valve
⊠	Hardie 420-1"-155	1" Y-filter w/ 155 mesh screen
C	Hardie VVAO 201	1/2" drain/flush valve at ends of all poly lines
	Irridelco MF Micro Flapper	pressure compensating 1 gph drip emitter
	Irridelco MFS Micro Flapper	pressure compensating 1 gph drip emitter w/ 5 outlets
———	Hardie Dura-pol EHS81648	polyethylene tubing 1" (1.049" ID)
— —	"	3/4" (.824" ID)
- - - -	"	1/2" (.613" ID)
○	FLO Control series 1205-1"	pvc adjustable check valve, set at 5 lbs.
	Agricultural Products 187 x 125 - 100	3/16" micro tubing

Mitigation Matrix

DETAIL	MITIGATION MEASURE	VISUAL PRIORITY LEVEL 1	2	3
	MITIGATION MEASURE FOR NEW CUT:			
	Rock/slope sculpture:			
F	Warping top/toe	x	x	
L	Slope rounding	x	x	
M	Closely spaced drill holes with staggered alignment on upper lift; more widely spaced drill holes on lower lift	x	x	
(See Note 1)	Closely spaced drill holes with staggered alignment	x	x	x
	Detailed rock/slope work:			
I	Soil pockets	15/100sy	13/100sy	11/100sy
L	Ledge (see Note 2)	1/200lf	1/300lf	1/500lf
	MITIGATION MEASURE FOR NEW FILL:			
	Rock/slope sculpture:			
M	Slope warping	2:1	1 3/4:1	1 1/2:1
D	Slope rounding	x	x	x

NOTES:
1. Applies to cuts listed on Sheet 2. See photo example, Sheet 68, at Station 119+00L.
2. Minimum ledge length is 25'; minimum depth is 2'.

Visual Inventory

VISUAL PRIORITY LEVELS: CUTS

#	VPL	LEFT	RIGHT
1	1	158+00 - 161+00	159+00 - 163+00
2	1	166+50 - 170+00	
3	1	171+50 - 176+00	
4	1	176+00 - 183+00	
5	1	185+00 - 191+50	
6	2		193+50 - 195+00
7	1		197+70 - 201+20
8	1	207+00 - 213+50	
9	2		217+00 - 218+50
10	1	228+00 - 230+00	227+40 - 228+50
11	1	231+50 - 240+00	
12	2		245+00 - 248+50
13	1	252+50 - 260+25	
14	3	261+75 - 264+00	
15	2	265+50 - 272+50	
16	3	276+50 - 277+60	275+00 - 277+00
17	2	278+80 - 285+50	
18	2	288+50 - 293+50	
19	2		296+00 - 300+50
20	3	310+50 - 314+00	
21	3	320+50 - 321+50	
22	1		328+00 - 335+00
23	1		339+00 - 342+50

VISUAL PRIORITY LEVELS: FILLS

#	VPL	LEFT	RIGHT
1	1	165+00 - 165+75	
2	3	183+50 - 184+50	
3	3		
4	2		
5	3		
6	2		205+00 - 207+00
7	2		214+00 - 216+00
8	2		
9	2		
10	2	230+00 - 231+00	
11	3	240+50 - 244+50	240+50 - 244+50
12	1		249+00 - 252+50
13	1	260+50 - 261+00	
14	3		264+00 - 267+00
15	3		272+50 - 275+00
16	3	278+00 - 278+60	
17	1	286+00 - 287+00	286+00 - 288+00
18	1	294+00 - 295+50	293+50 - 295+50
19	1	298+00 - 300+50	
20	2	307+50 - 309+50	
21	3	314+00 - 317+00	
22	1	322+50 - 328+50	
23	1	336+00 - 338+00	337+50 - 339+00

PLANTING AREA	SHEET NO.	S1	S2	S3	S4	S5	S6	S7	S8	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	BOULDER	TOTAL GPH	TOTAL GAL	TANK SIZE	TANK STATION	1" POLY LN.FT.
1	51	4	1							9			2	8							49	98	280	178·00 RT	1700
2	·	2	2							4			1	2							16	32	100	179·50 LT	1400
3	·		1							3			2	1							15	30	100	185·00 RT	1500
4	52									4			3	5							36	72	282	207·00 RT	1500
5	·	10	3							2			5	10	5	7				5	110	220	500	218·22 RT	1720
6	53	4	4		1					2			5	10	1	3				6	79	158	500	227·30 RT	1200
7	·									7			2	6	4	2					63	126	500	235·30 RT	1500
8	·	5	2				1			1				2	2	1				3	22	44	100	249·50 LT	1850
9(242R)	58	18		3			1					1		5	3	1				6	44	88	500	253·00 RT	1000
10(242L)	·	8		6								4		7	4					7	66	132	280	256·20 LT	1200
11(251)	59	9		5								6		4	4	1				6	65	130	280	266·00 RT	1500
12(254)	63	9	3			2	2	2	1			2		4		2				8	76	152	280	271·00 RT	1600
13	54	3	1									1		1	1					1	12	24	100	273·50 LT	1200
14	·	1	1	4			1					2		2	2	1				1	33	66	280	276·50 RT	1200
15(274)	60	6		3								4		3	2	1				4	43	86	100	284·75 RT	1100
16	55	10	3	5	1		2					7		1	3						52	104	280	300·00 RT	2200
17	·			6			1				5	3				2	4	2		3	68	136	500	310·00 LT	2300
18	·										6	11			1	3	3	1	1		96	192	280	309·00 RT	1500
19	·	6		5			1				3				4	3				2	37	74	500	313·50 LT	1900
20	56	6		9			2				10	10			4	2	4			3	109	218	500	320·20 LT	1700
21	·	10		2											4				3	1	36	72	280	317·60 RT	1000
22	·	9		6			1				3	9			3	1				3	62	124	280	326·50 LT	1000
23	·	4		3											2	1					15	30	500	338·50 LT	1300
(325)	61	30		6								19			6					12	106	212	·	·	·
24	57	5		4			1								2	1				1	17	34	280	350·00 LT	1000
(337)	62	8		5								5			6					4	49	98	·	·	·
TOTAL		167	21	72	2	2	13	2	1	32	27	84	20	71	63	32	11	3	4	76	1376	2752		24 REQ'D	35070

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CENTRAL FEDERAL LANDS HIGHWAY DIVISION
DENVER, COLORADO

LANDSCAPING SCHEDULES

SHEET 16 OF 18

SPECIAL-12

Figure B-18. Project 2 Landscaping schedules, sheet 16, Mt. Lemmon Highway.

example of highway design responding to the preliminary VPP findings during the early highway design process.

Final VPP Inventory

The preliminary VPP was finalized, with the final cut and fill stationing and field checking, and adjusting the subsequent inventory results accordingly. Each cut and fill was checked in the field according to the scores, total inventory points received, and the VPL rating scale for appropriateness and comparative treatments.

The final VPP inventory was incorporated into the construction documents on projects 1 and 2 of the Mt. Lemmon Highway reconstruction. Project 1 contract plans include a Cut and Fill Composite Plan, where the VPL of each cut and fill is indicated (see figure B-17). The project 1 cuts and fills previously shown as examples of the different VPL's are highlighted on the Composite Plans, and are also included in the Cut and Fill List. The project 2 contract plans indicate the VPL of each new cut and fill in the Visual Inventory (see figure B-18). The contract documents also include the mitigation measures and quantities required for each VPL.

Evaluate Overall Mitigation Plan

The mitigation measures on these two projects of the Mt. Lemmon Highway project were distributed to each new cut and fill according to their VPL rating (see Mitigation Matrix, figures 17 and 18). Consequently, the cuts and fills with the highest visual sensitivity received the most mitigation effort, which maximized the effectiveness of mitigation expenditures.

The unit costs of mitigation for the VPL 1, 2, and 3 cut and VPL 1, 2, and 3 fill on the Mt. Lemmon Highway project are shown below:

CUT	VPL 1	VPL 2	VPL 3
Excavation details (including specialized blasting):			
• Ledges, warping, rounding, and highlighting rock outcrops	0.60	0.45	0.32
• Soil pockets	0.11	0.08	0.06
• Revegetation	0.20	0.15	0.10
Total cost/sq ft:	$0.91	0.68	0.48
($/sq m)	($9.80)	(7.32)	(5.71)

FILL			
Embankment details:			
• Warping	0.08	0.06	0.04
• Rounding	0.01	0.01	0.01
• Staggered ledges	0.13	0.10	0.07
• Boulders	0.04	0.03	0.02
• Revegetation	0.26	0.20	0.14
Total cost/sq ft:	$0.52	0.40	0.28
($/sq m)	($5.60)	(4.31)	(3.01)

The total mitigation costs for this project were approximately 15 percent of the total project cost.

Final Design

The final mitigation costs, together with the roadway costs, were evaluated during final design. The mitigation measures were not reduced during final design, as is often the case when budget constraints occur, due to the degree of detail in distributing the mitigation dollars where they would be most effective. Alternate project lengths were bid to keep the final project within the budget.

Construction

The VPP process was used during the construction of the second project, where two new fill areas were added. One fill area, which replaced a planned retaining structure, was rated as a VPL 1. This area was an existing rocky fill without revegetation, so the added fill with mitigation was an improvement over the existing condition. Associated levels of mitigation were added by a change order. The other fill area was located to waste excess material in a VPL 3 location, to avoid additional impacts to visually sensitive areas.

The VPP inventory results continue to be used during roadway maintenance activities. Ditch debris and material storage is hauled to low visibility VPL 3 fill areas designated for excess material (see Figure B-19).

Evaluation of Partial VPP

The range of mitigation quantities for VPL 1, 2, and 3 reflect the natural range of variety found in the Sonoran Desert ecosystem, regarding plant density, variety of terrain, and rock outcroppings.

A typical design approach is to determine mitigation for a project and apply the mitigation uniformly throughout the areas of impact. Even on a roadway of high visual sensitivity, such as the Mt. Lemmon

Highway with Retention as a Visual Quality Objective, visual sensitivity varies. The VPP was used to identify this variation and distribute mitigation accordingly.

It is difficult to predict the outcome of this project if this approach was not developed. Most likely, a level of mitigation would have been proposed for the entire project. When budget constraints were applied, the mitigation likely would have been cut, either in size or quantity of plants, amount of soil, or effort in specialized grading and blasting techniques.

The result could have been a uniform VPL 2 application of mitigation measures throughout the entire project. Although the costs may have been the same or similar, the effectiveness would have been lessened considerably, with VPL 1 areas receiving inadequate mitigation and VPL 3 areas receiving more than needed.

Visual resource goals were achieved on the Mt. Lemmon Highway project. The following photographs show the inventoried cuts and fills after completion of construction, with the varying levels of mitigation measures applied according to the VPL (see figures B-20, B-21, B-22, B-23, B-24 and B-25).

SUMMARY

The Mt. Lemmon Highway case study presents the application of a partial VPP analysis that addressed only the prominent visual impacts of cut and fill on a roadway project. The process was successfully utilized from the preliminary design through final design stages, and was incorporated into the construction documents. The VPP process was also applied during the changing field conditions during construction to achieve consistent visual goals.

The application of the partial VPP may be useful on projects where visual impacts are concentrated to a minimal number of elements, as in the case of cuts and fills on Mt. Lemmon Highway, or where time and available resources prevents a complete VPP inventory. The significant visual elements must be defined for each project. In this case, inventory of the *loss of significant visual resources* for the entire project would have been useful during the preliminary design phase, if it had been incorporated into the VPP. The partial application of VPP was successful in achieving visual goals and distributing mitigation dollars with economic efficiency. Results continue to be utilized for maintenance activities.

The next case study shows a complete VPP analysis on a roadway in the preliminary design phase.

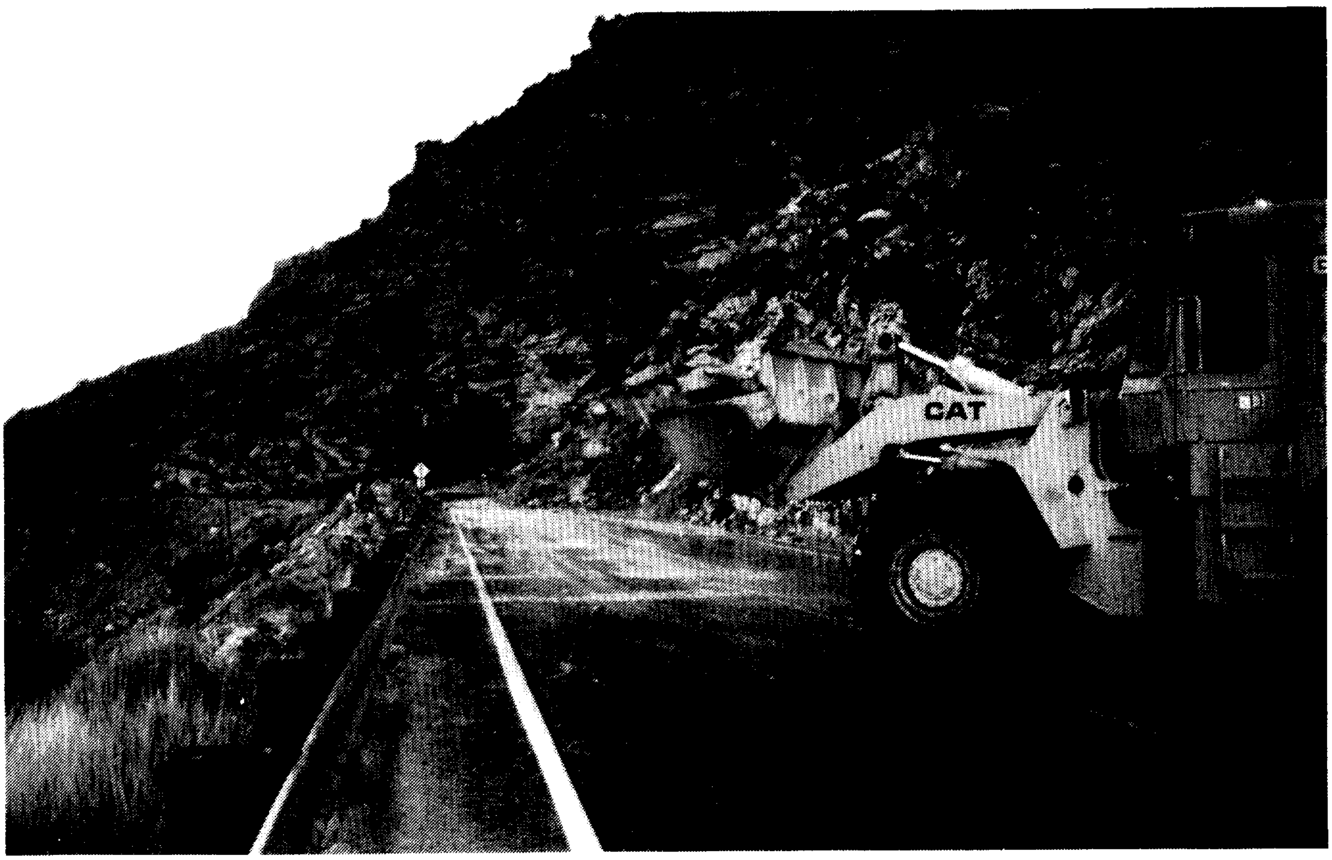


Figure B-19. After heavy rains, slide material from unimproved portions of the roadway is cleared and hauled to a designated VPL 3 waste site.

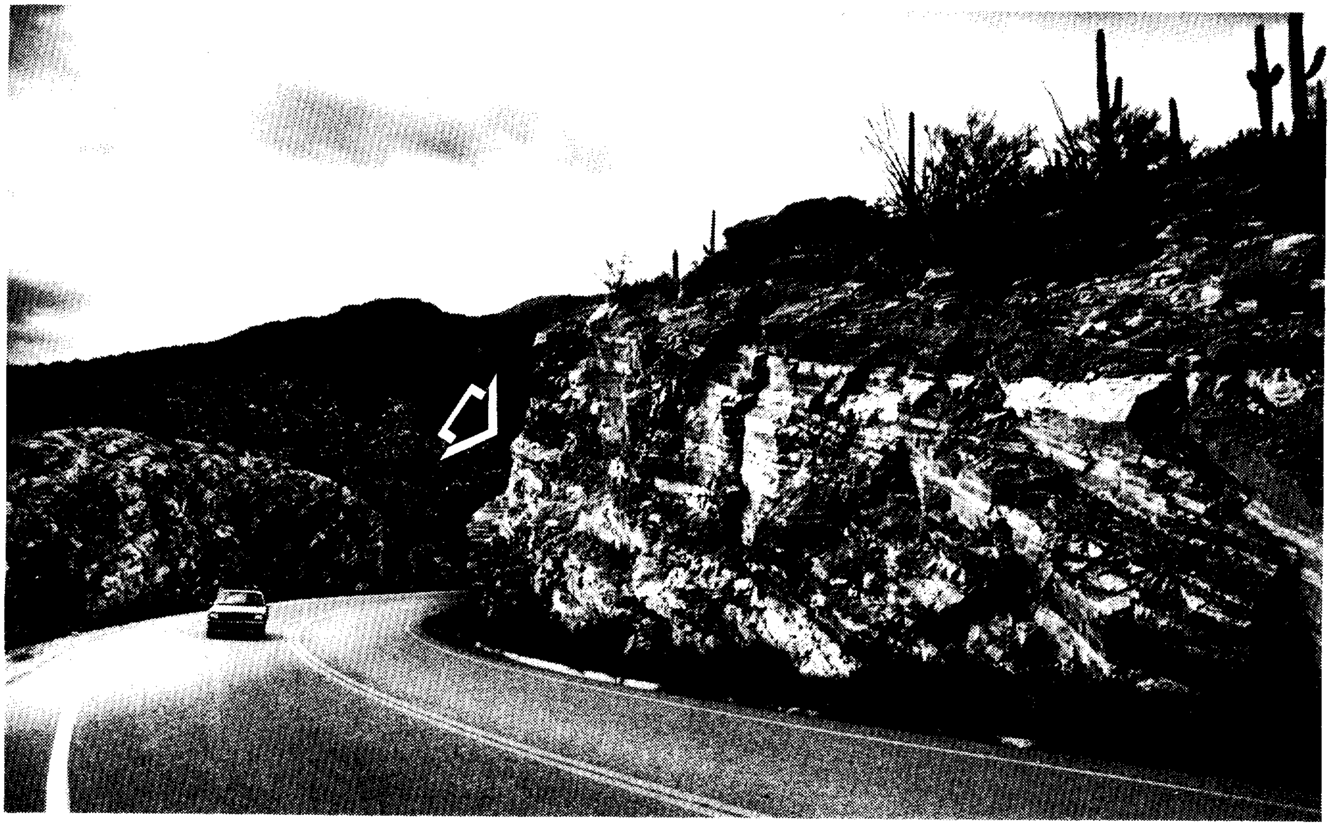


Figure B-20. Cut 11, VPL 1, 3 years after construction (see figure B-5 for comparison).

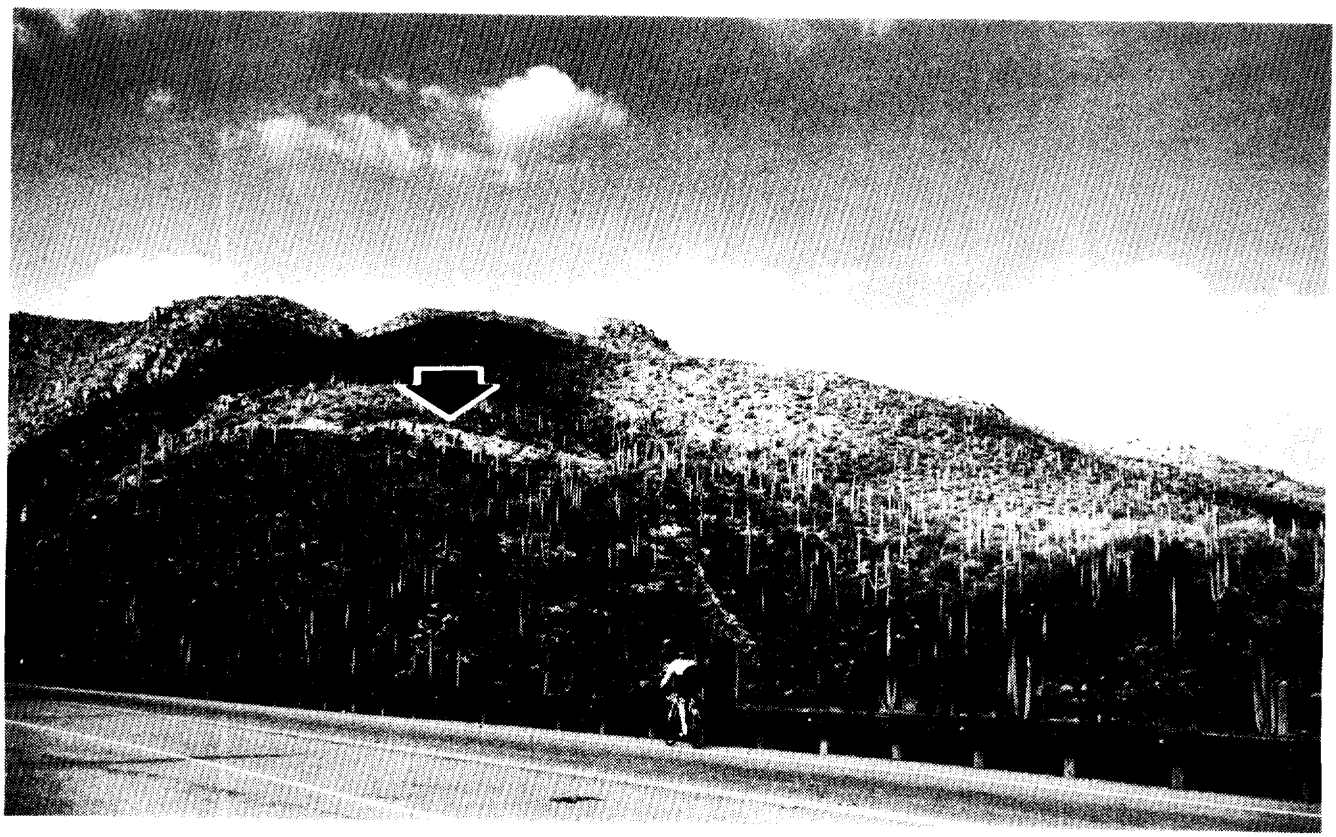


Figure B-21. Cut 11, viewed from middleground (see figure b-6 for comparison).

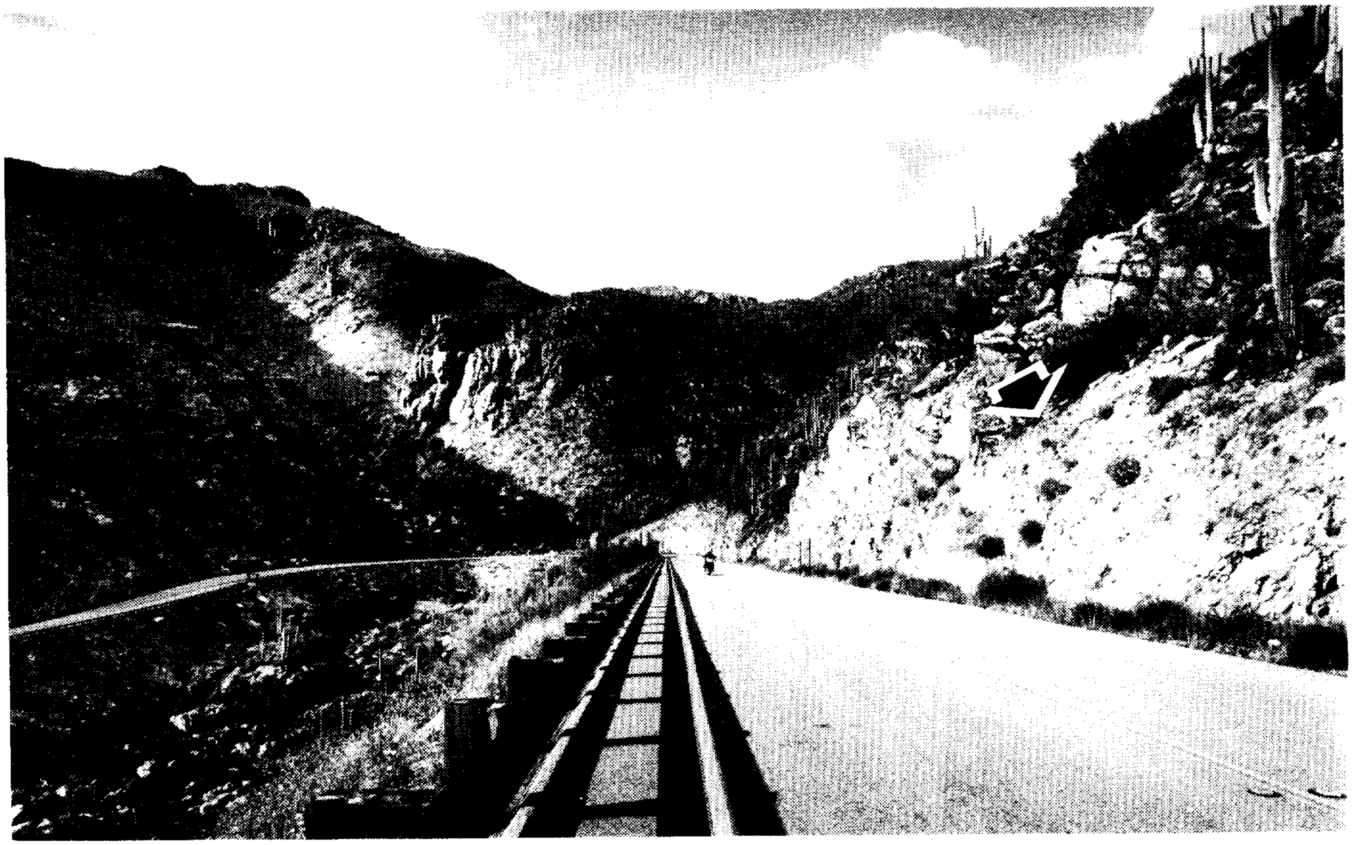


Figure B-22. Cut 10, VPL 2,3 yr after construction (see figure B-10 for comparison).

Figure B-23. Cut 24, VPL 3, 3 years after construction (see figure B-11 for comparison).

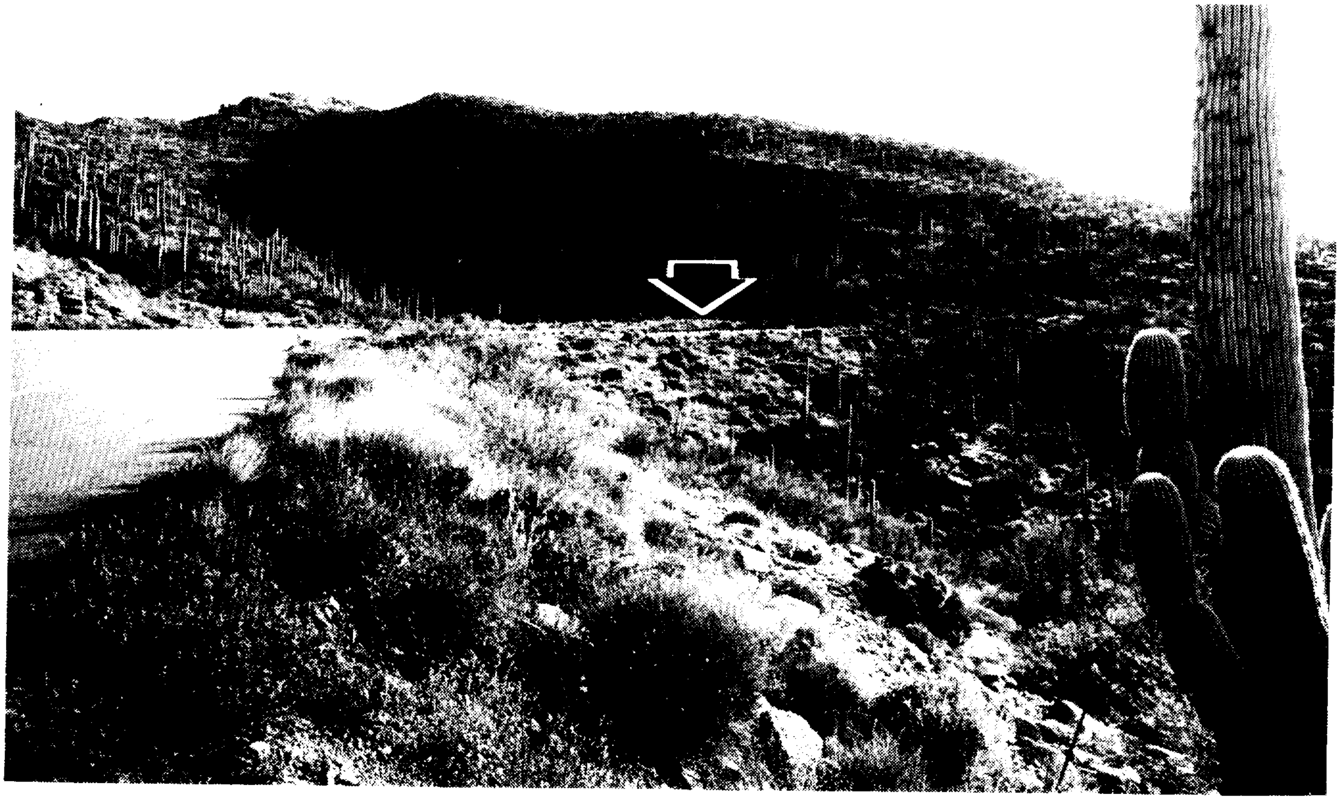


Figure B-24. Fill 8, VPL 1, 3 years after construction (see figure B-12 for comparison).

Figure B-25. Fill 3, VPL 3, 3 years after construction (see figure B-15 for comparison).

Navajo Bridge

INTRODUCTION

The Navajo Bridge project includes the design and construction of a new bridge over the Colorado River, and the adaptive reuse of the historic bridge as a pedestrian facility, near Lee's Ferry, in Northern Arizona (see figure B-26). The project also includes the realignment and construction of State Highway 89A as it approaches the new bridge from both directions, at a design speed of 45 mph (72.5 km/h). The project was 0.8 miles (1.29 km) long. The highway reconstruction and maintenance are funded by the Arizona Department of Transportation.

The highway goes through the Navajo Nation on the east side of the bridge, and the Glen Canyon National Recreation Area, managed by the National Park Service, on the west side of the bridge. The bridge crosses the Grand Canyon National Park, also managed by the National Park Service.

This case study demonstrates the complete VPP—including the inventory of proposed, new visual elements and the loss of existing, significant visual elements, as applied through the preliminary design phase.

PHASE I—EXISTING VISUAL RESOURCES

Character Zones

The existing visual character at the project site is defined largely by strong contrast in geologic and vegetative features located in Marble Canyon and the surrounding Kaibab Plateau. Marble Canyon's associated riparian vegetation and dramatic rock formations are prominent visual features in the region, surrounded by the expansive terrain, and low, sparse vegetation of the plateau (see figure B-27). The Navajo Bridge is a strong visual element associated with defining the character of the site. The bridge, built in 1928, is listed on the National Register of Historic Places.

Visual Quality/Variety

Variety of the existing landscape was defined according to the conditions found within the characteristic landscape, as follows:

Outstanding—High degree of variety within the defining visual elements of the natural and built environment (vegetation, water, geology and structures), visual cohesiveness,

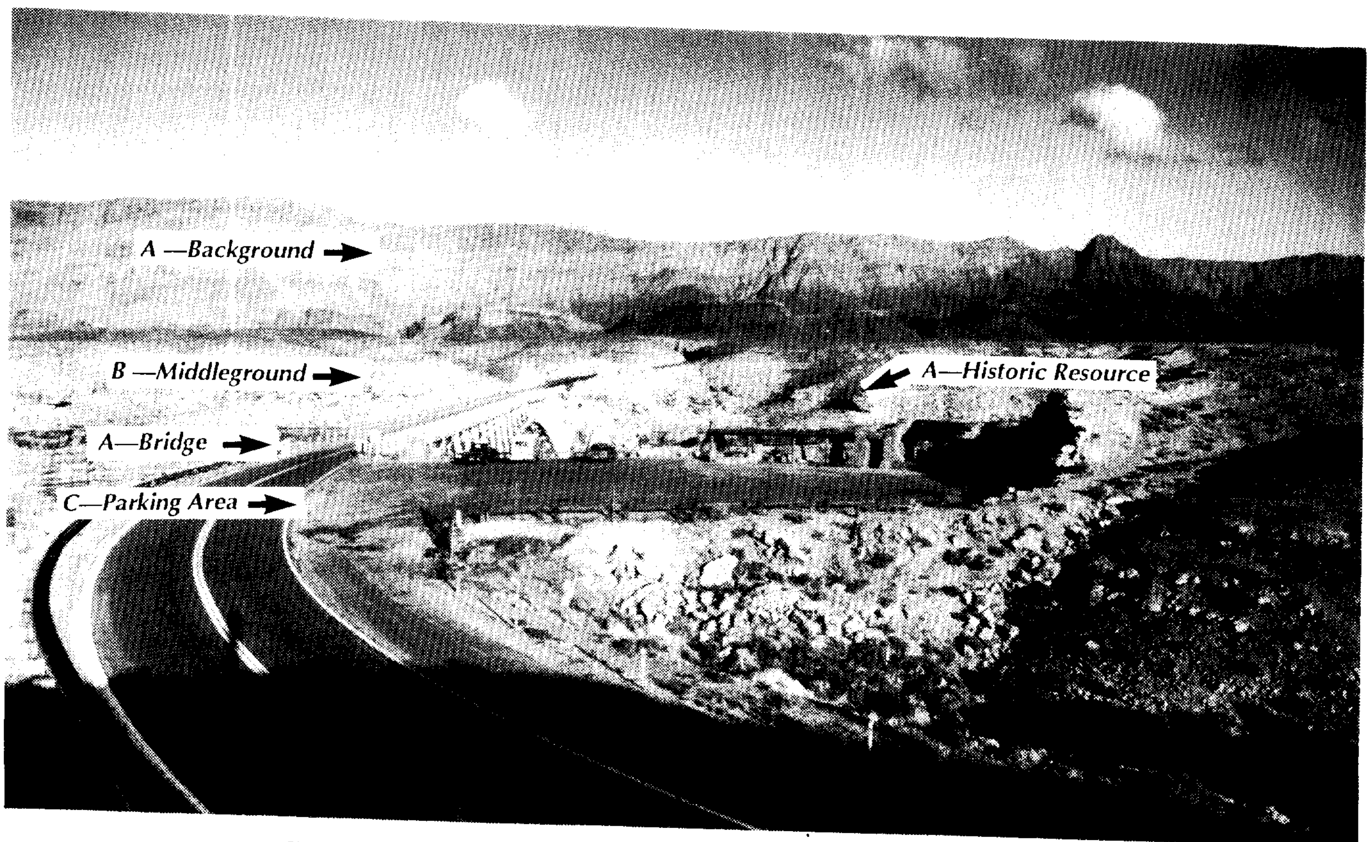


Figure B-26. The historic Navajo Bridge crossing the Colorado River.

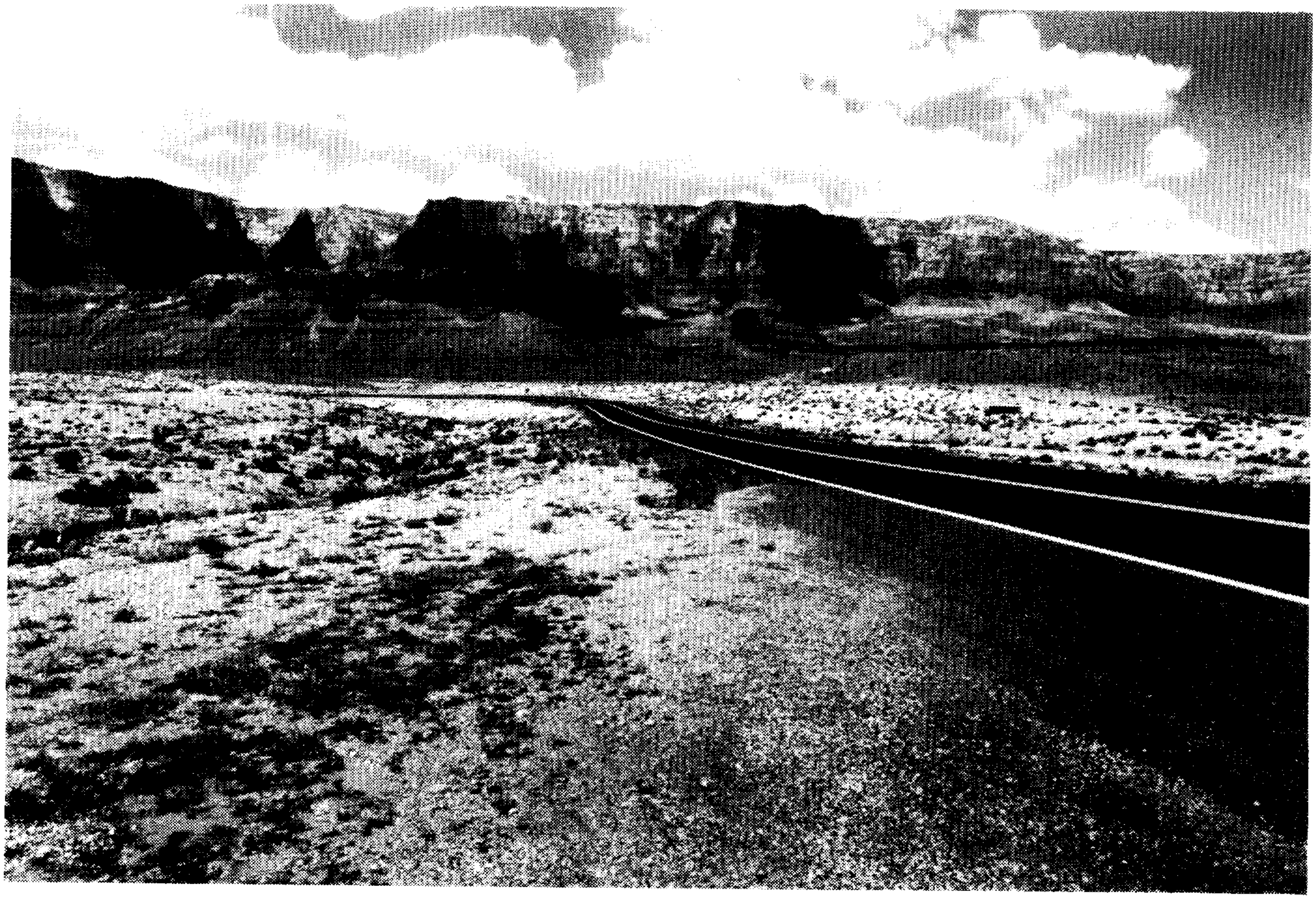


Figure B-27. Expansive views and dramatic rock formations in the Navajo Bridge area.

significant native vegetation in good condition, and structures introduced elements respond to the natural and cultural resources of the site. Included, also, are elements that respond and are well maintained, unique features and focal points of interest, panoramic views, and visible natural drainages.

Typical—Average amount of variety within the defining visual elements of the natural and built environment, native and introduced species are in average condition; structures and introduced elements are generally in character with the surrounding area, and are in average condition, with average views.

Below Average/Incongruous—Monotonous visual elements or excessive amounts of elements with no cohesiveness, natural features have been disturbed, vegetation is in poor or declining condition, structures and introduced elements do not relate to the character of the area and are not well maintained, little or no variety in form, line, color, or texture of geology and vegetation.

The existing visual quality of the area is described in Phase II, the Detailed Visual Inventory.

Visual Concern

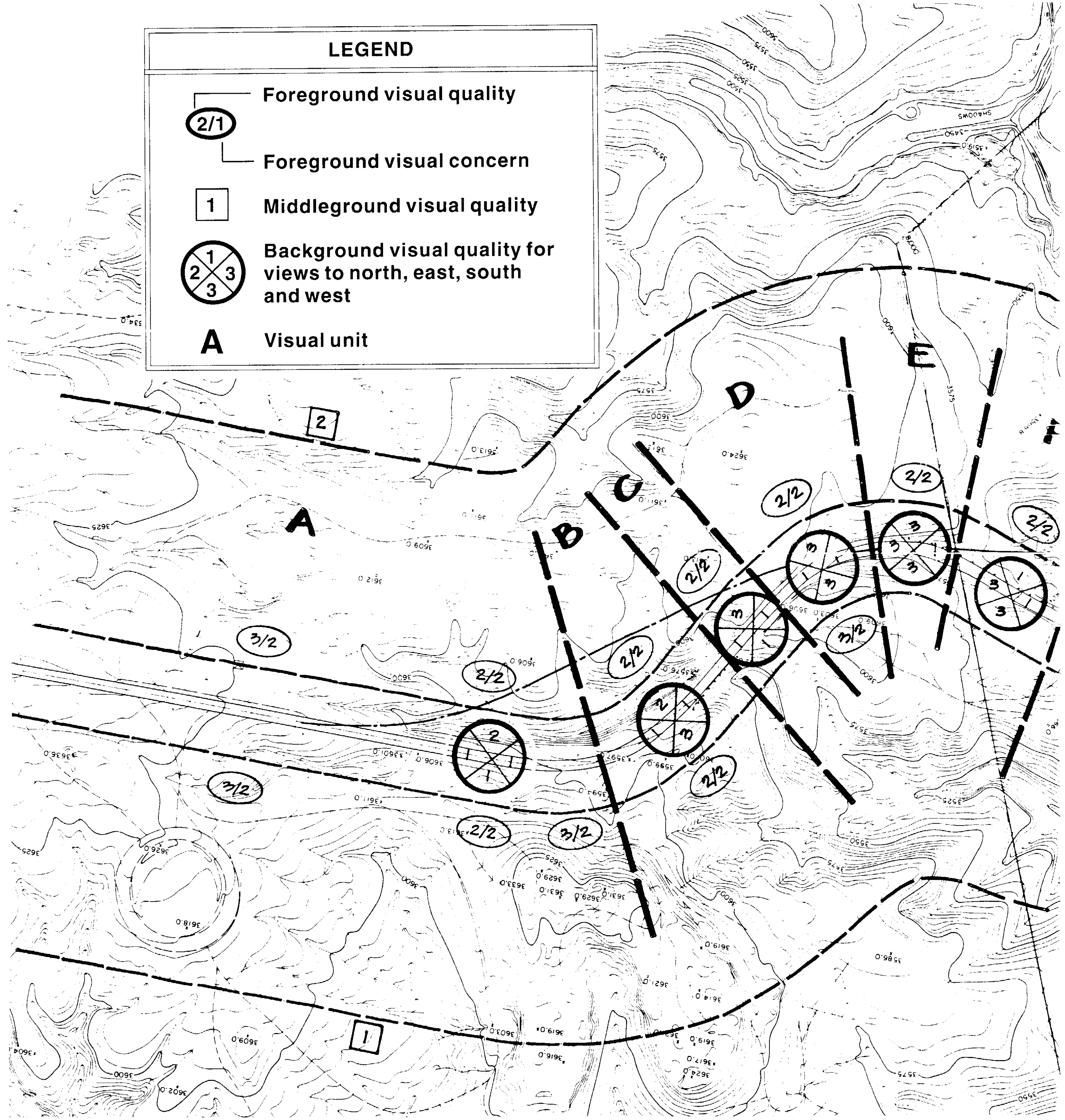
Visual concern is twofold: Concern for the visual quality for visitors traveling along the route and those adjacent to and within viewing distance of the route. Highway 89A is a primary route in the area and receives a high percentage of recreationists en route to Lee's Ferry, the North Rim of the Grand Canyon, and other regional recreational attractions. The Visual Concern, or concern of roadway travelers for visual quality, was determined to be high, because of a relatively high percentage of highway users having a strong interest in visual quality and scenery.

Visual concern of adjacent landowners/managers was defined according to a combination of:

- Existing attention to visual quality demonstrated by landowner/manager
- Existing and proposed land uses
- Public participation.

Ratings were assigned as follows:

High—Landowners/managers have an above average concern for visual resources.



LEGEND
Foreground visual quality
2/1
Foreground visual concern
Middleground visual quality
Background visual quality for views to north, east, south and west
Visual unit
A
B
C
D
E

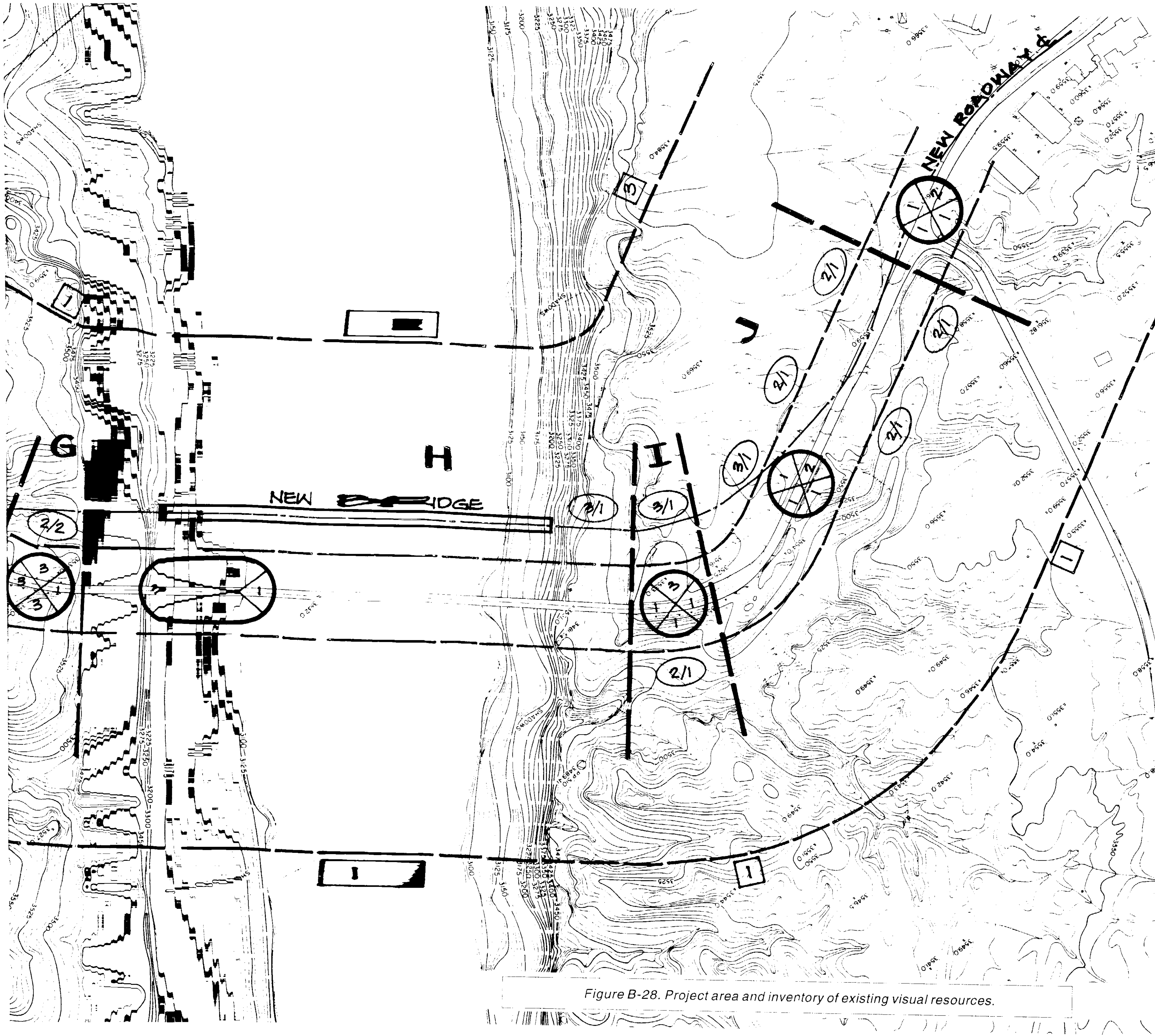


Figure B-28. Project area and inventory of existing visual resources.

Average—Landowners/managers have an average concern for visual quality.

Low—landowners/managers have a below average concern for visual quality.

Visual Goals

The goals for the Navajo Bridge project is to protect significant design elements, integrate new design elements, and mitigate construction activities so that, following construction, the new design elements will compliment the characteristic landscape, and disturbed areas will blend into the natural landscape and will not be evident.

PHASE II—VISUAL IMPACTS

Conceptual/Preliminary Design

The preliminary design of the new bridge approach roads increases the design speed to 55 mph (88.6 km/h) on the Navajo side and 45 mph (72.5 km/h) on the NPS side (see figure B-28). The historic bridge and the new bridge will come into view slightly earlier than the existing view sequence, but will still be a surprise for the first-time visitor.

Preliminary VPP Inventory

Conduct Detailed Visual Inventory

The existing approach to the Navajo Bridge is marked by continuous, expansive views of the characteristic landscape until beginning the descent toward the bridge. Views of the bridge are blocked by terrain until rounding the last curve, on both sides, when the bridge, Marble Canyon, and the Colorado River all come into view. This dramatic view is the highlight of the trip through the area, and usually a nice surprise for the first-time visitor.

1. Distance Zones

The project area was inventoried according to distance zones and viewing areas calculated for the design speed of 45 mph (72.5 km/h) and field checked for this landscape character type. The angle of vision at the 45 mph (72.5 km/h) design speed is 57-1/2 deg; and the focusing distance is 1,250 ft (381 m). With the existing roadway centerline centered in the immediate foreground, distance zone widths determined for this project are (see figure B-29):

Immediate foreground	200 ft (60.96 m)
Foreground	1,200 ft (365.8 m)
Middleground	5 mi (8.05 km)
Background	5+ mi (8.05+ km)

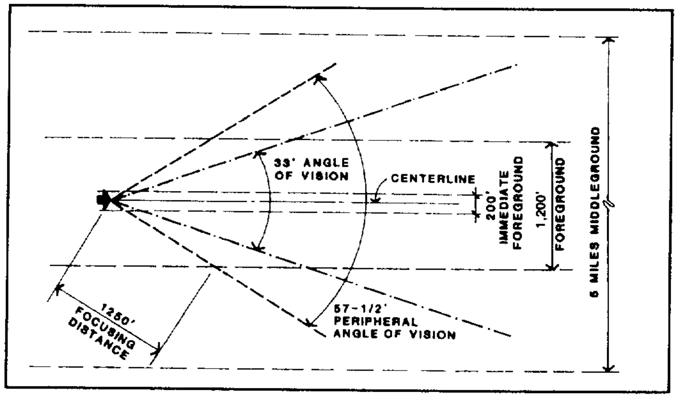


Figure B-29. Distance zones and angle of vision for Navajo Bridge.

Based on changes in views and the sequential viewing experience traveling in both directions, the corridor was broken into eight visual units. The foreground, middleground, and background portions of the project area were inventoried for existing visual quality (variety). The immediate foreground is addressed in the VPP inventory.

Following is a summary of the visual quality inventory (see figure B-28):

- The existing, foreground visual quality at the Navajo Bridge site is rated "outstanding" due to the large amount of variety in the defining visual elements of the natural and built environment. The graceful element of the existing bridge, views of the Colorado River in the midst of an arid region, richness of form, line, color, and texture of the canyon geology, and thicker, taller, and more diverse vegetation along the river bank all combine to create a high degree of visual variety. Introduced, "built" elements, in addition to the bridge, include the roadway, cuts and fills along the road, commercial stands on the Navajo side, and a ramada and parking area on the Park Service side of the bridge.

- The roadway alignment fits into the existing terrain, with the existing cuts retaining irregularities and blending with the landscape. Existing fills are not highly visible from the roadway, parking area, or river. The ramada, near the parking area, is constructed of native stone and wood, and is in character with the area.

- Due to off-road vehicle disturbances on the Navajo side of the bridge, visual quality is lowered to an "average" rating in a relatively small area.

- The paved parking area is rated "below average" in visual quality, as it is not well defined and is in declining condition. Middleground ratings are primarily "average" on the Navajo side of the bridge and "outstanding" on the bridge and on the Park Service side of the bridge. Background views are rated "outstanding" in all directions from the existing bridge site.

2. Visual Elements/Views

The preliminary roadway alignment used for the VPP inventory responds to earlier visual inventory findings regarding the sequential views of the travel experience approaching the existing Navajo Bridge. The following new visual elements were identified according to the preliminary design:

- Cuts
- Fills
- View of Colorado River
- View of Marble Canyon
- Headwalls and endwalls
- Guardrail
- Historic bridge
- Navajo commercial area
- New bridge
- Interpretive area/overlook
- Retaining walls
- Railing
- Restroom structure
- Parking
- Open view
- Enclosed view

The preliminary design results in the following loss of significant visual elements:

- Native vegetation
- Open view
- View of existing Navajo commercial area
- View of natural drainage
- Enclosed view
- View of historic structure at interpretive area
- Rock wall

These visual elements were located on the plan sheets within each unit (see figure B-30). The preliminary VPP quantifies the new visual elements and the loss of significant visual resources in the immediate foreground, foreground, middleground, and background zones, according to the preliminary roadway design.

Determine Values of Inventory Variables

For each of the new visual elements, for each numerical score, values were determined to inventory in the field and from the proposed plans. Values for each variable were determined in the field based on the characteristic landscape, the degree of variety, and the relative importance/proportion of new visual elements (see figure B-31).

Assumptions used for the VPP values on this project were made at this time. For example, the assumption was made to add different angles of view, visible from different distance zones, together. This assumption places an emphasis on the angle of view variable, which was appropriate for this characteristic landscape.

Setup Unit VPP Inventory Forms

The VPP inventory forms were developed for this project, with the visual elements identified for this project and the VPP variables included (see figures B-32 and B-33).

Perform Inventory

The proposed new visual elements and each significant visual element that would be lost were inventoried within each of the visual units, in terms of the variables listed, based on the preliminary cross sections, plans, and field reconnaissance. The application of VPP is demonstrated on this project in Unit H, where the natural rock wall at the historic structure is visible from the immediate foreground and foreground distance zones (see figure B-34).

New visual elements in Unit H include the view of the historic bridge and new bridge, view of the overlook, rock wall and ramada area (visible from Unit H), two fills (H1 and H2), and views of Marble Canyon and the Colorado River. Significant visual elements which will be lost include native vegetation within the construction limits. The inventory of new visual elements for Unit H is shown in figure B-32.

Two fills, H1 and H2, are located within this unit, and have a proposed size of 7,475 sq ft (694.4 sq m) and 31,000 sq ft (2,879.9 sq m). These fills, visible from the immediate foreground, foreground, and middleground views, are within the value range with a numerical score of 3 in the variable.

The H1 fill is visible peripherally from the new bridge from the foreground and immediate foreground distance zone, and is also visible from the river

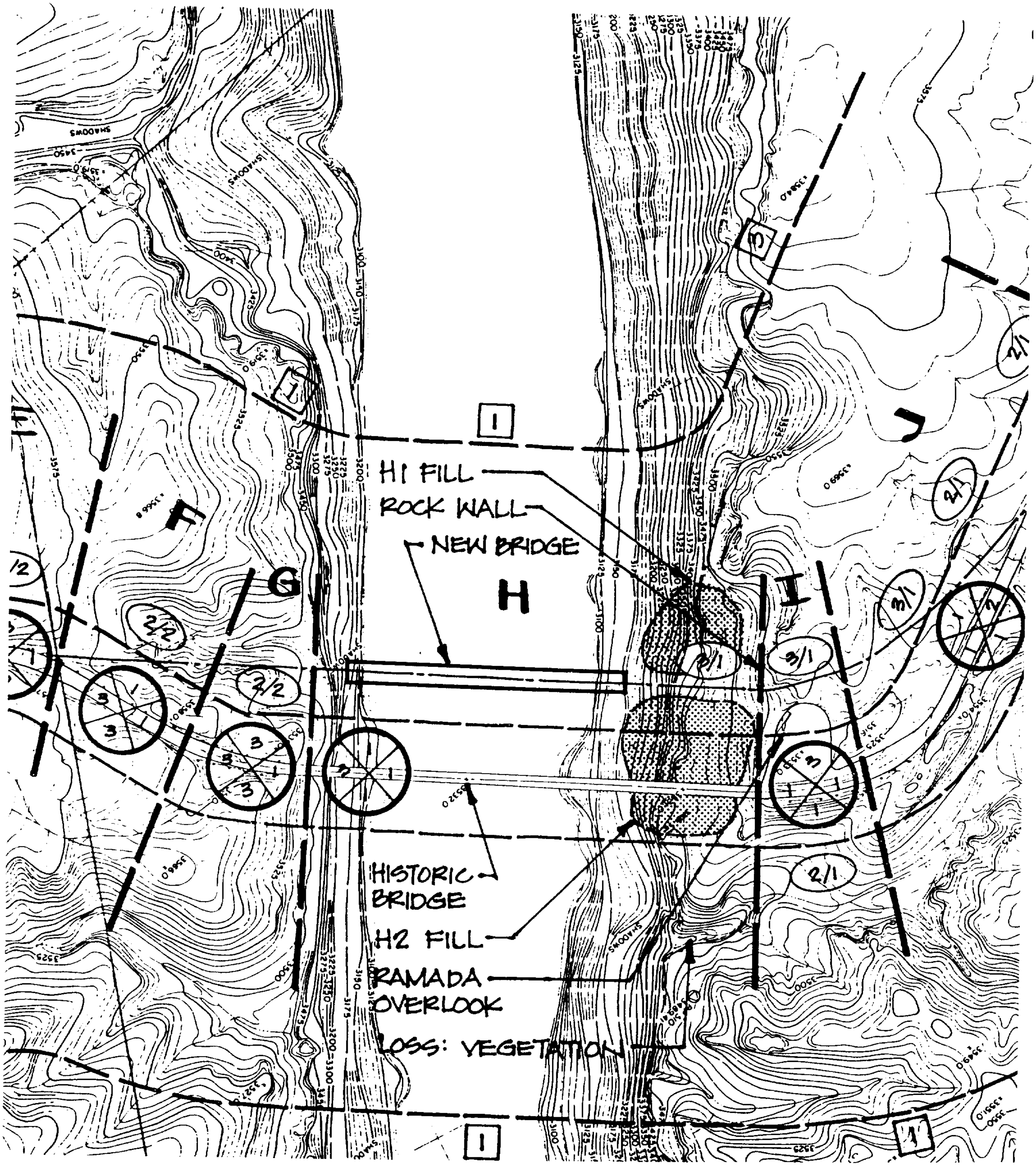


Figure B-30. Preliminary plan, new visual elements and loss of visual elements.

INVENTORY VARIABLES	NUMERICAL SCORE
1) Distance from the viewer:	N/A
Immediate foreground: 100' and less	
Foreground: 100' to 600'	
Middleground: 600' to 2.5 miles	
Background: 2.5 miles+	
2) Magnitude:	
Cuts and fills -	
0 - 600 sf	1
600 - 4,000 sf	2
4,000 sf+	3
Headwalls, endwalls and retaining walls -	
0 - 999 sf	1
1,000 - 1,999 sf	2
2,000+ sf	3
Guard rail and railing -	
0 - 199 lf	1
200 - 499 lf	2
500+ lf	3
Bridges-	
0 -99 lf	1
100 - 299 lf	2
300+ lf	3
Structures and parking area-	
small, sited to remain subordinate to characteristic landscape	1
moderate size, visual element in characteristic landscape	2
large, highly visible	3
Views -	
relatively insignificant	1
moderately significant	2
significant	3
3) Angle of the view:	
Horizontal-	
57.5 degrees - 180 degrees	1
33 degrees - 57.5 degrees	2
0 degrees - 33 degrees	3
Vertical-	
0 degrees - 30 degrees	1
30 degrees - 60 degrees	2
60 degrees - 90 degrees	3

Note: the assumption was made that, if more than one angle of view occurred, the variables would be added together.

4) Duration of the view/visibility*: VIEWED FROM ROADWAY:		FROM DISTANCE ZONE:
Immediate foreground		
0 - 3 seconds (less than or equal to 198')	1	BV*
3 - 6 seconds (198' - 396')	2	PV*
6+ seconds (396'+)	3	AV*
Foreground		
0 - 6 seconds (less than or equal to 396'	1	BV
6 - 10 seconds (396' - 660')	2	PV
10+ seconds (660'+)	3	AV
Middleground and background		
8 - 10 seconds (less than or equal to 660')	1	BV
10 - 20 seconds (660' - 1,320')	2	PV
20+ seconds (1,320'+)	3	AV

***Visibility ranking measures the equivalent of the duration of the view, when the element is viewed from a stationary location, and is defined as follows:**

BV - barely visible, indicating that the visual element is obscured or not an important visual element when viewed from this location
PV - partially visible, indicating that the visual element is partially obscured but is visible, and of average importance when viewed from this location
AV - always visible, and an important visual element when viewed from this location

Note: the assumption was made that, if more than one duration of view/visibility factor was involved, the most sensitive ranking was used.

5) Silhouette condition:	
no silhouette	0
background is vegetation/land	1
background is vegetation/land/sky combination	2
background is sky	3
6) Aspect:	
angles 0 to 30 degrees or 30 degrees away from viewer	1
angles 30 degrees to 60 degrees from viewer	2
perpendicular nearly vertical (90 - 60 degrees)	3

Figure B-31. VPP inventory variables for Navajo Bridge.

NAVAJO BRIDGE

UNIT VPP INVENTORY-NEW VISUAL ELEMENTS

UNIT NO. H:3744+30-3752+58	MAGNITUDE				ANGLE: HORIZONTAL				ANGLE: VERTICAL				DURATION/ VISIBILITY				SILHOUETTE				ASPECT				SUB TOTAL	TOTAL/ ELEMENT
STATION 820 LF	I	F	M	B	I	F	M	B	I	F	M	B	I	F	M	B	I	F	M	B	I	F	M	B		
CUTS																										
NONE																										
FILLS																										
H1 L 3751+80-3752+58	3	3	3		1	1	1						1	3	2		-	-	2		2	2	2		26	
H2 R 3751+80-3752+58	3	3	3		4	4	1						3	3	2		-	-	2		2	2	2		34	
																										60
WALLS, RAILING, GUARDRAIL																										
3752+58-3754+00	2	2	-		3	5	-						1	3	-		2	2	-		3	3	-		26	
																										26
BRIDGES																										
NEW 3744+30-3752+58	3	3	3		3	3	3						3	3	3		3	3	3		3	3	3		45	
OLD 3744+30-3752+58	3	3	3		3	3	3						3	3	3		3	3	3		3	3	3		45	
																										90
STRUCTURES																										
RAMADA/OVERLOOK/ROCK WALL	**4**	2			**5**	2							**3**	3			**1**	1			**3**	3			**27**	
																										27
																									UNIT TOTAL	**203**

Figure B-32. VPP inventory form, Navajo Bridge.

NAVAJO BRIDGE

UNIT VPP INVENTORY-LOSS OF SIGNIFICANT VISUAL RESOURCES

UNIT NO. H:3744+30-3752+58

STATION	MAGNITUDE				ANGLE: HORIZONTAL				ANGLE: VERTICAL				DURATION/ VISIBILITY				SILHOUETTE				ASPECT				SUB TOTAL	TOTAL/ ELEMENT
	I	F	M	B	I	F	M	B	I	F	M	B	I	F	M	B	I	F	M	B	I	F	M	B		
VEGETATION																										
L 3744+30-3752+58	3	3			1	2							3	3			0	0			2	2			19	
R 3744+30-3752+58	2	2			2	3							3	3			0	0			2	2			19	
																										38
WALLS																										
STRUCTURES																										
ENCLOSED VIEW																										
OPEN VIEW																										
																									UNIT TOTAL	38

Figure B-33. VPP inventory form, loss of significant visual resources.

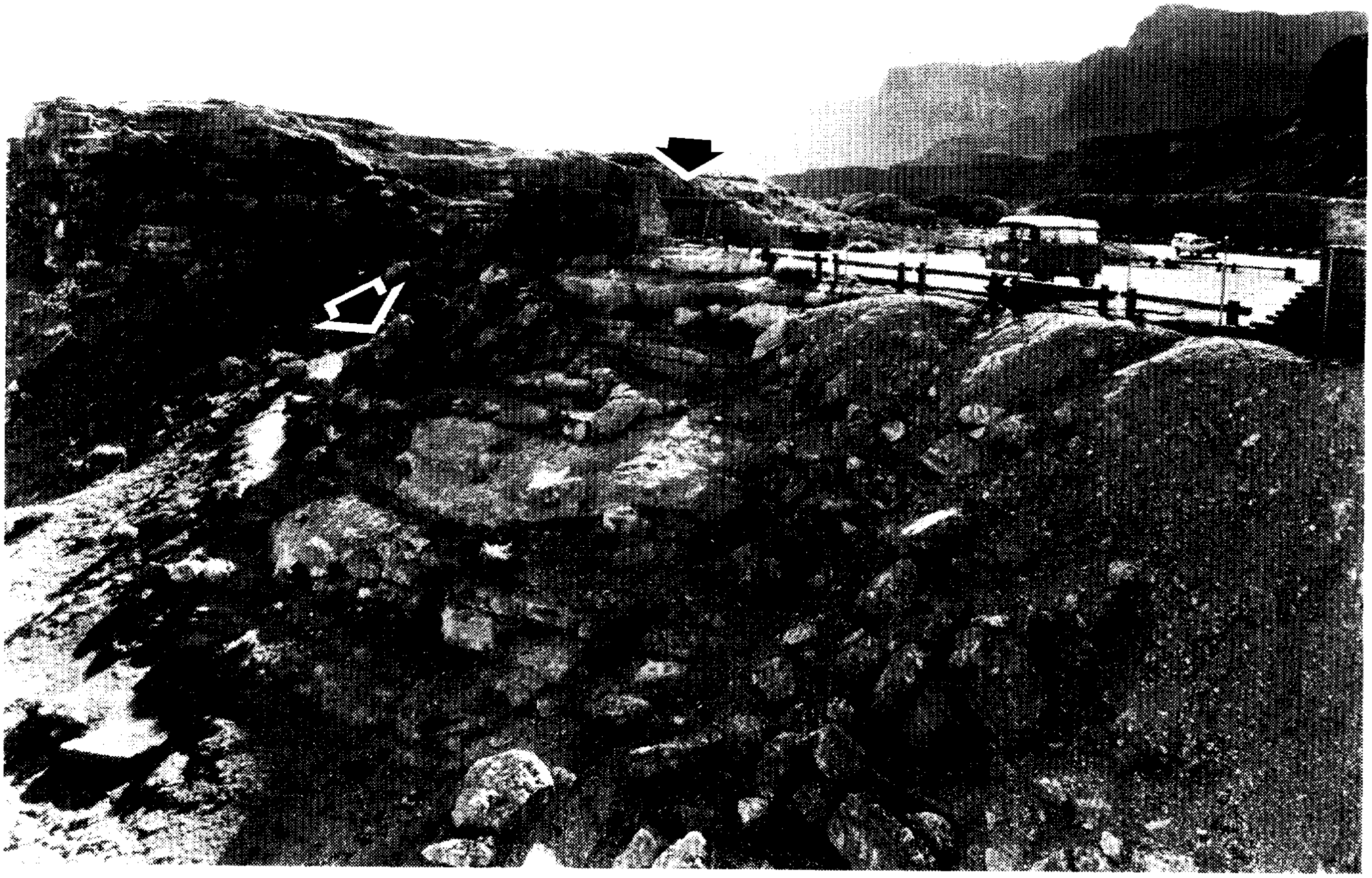


Figure B-34. Proposed H2 fill area and wall in interpretive area, viewed from historic bridge.

(rafter's perspective) at a high vertical angle of view. The H2 fill is visible from these same angles, but is also in direct view from the interpretive area and historic, pedestrian bridge. These two scores 1 and 3 are added together for H2, according to an assumption made earlier in the inventory process. The result is a total of 4 for angle of view for the immediate foreground and foreground distance zones.

H2, a proposed fill, also provides a greater duration of view score due to its visibility from the interpretive area and historic, pedestrian bridge (see figure B-34). For this reason, H2 receives a higher overall score than H1, with 34 total points compared to 26. The total inventory for fills in Unit H is 60, combining H1 and H2 (see figure B-32).

The proposed wall in the interpretive area, at Station 3752+58 to 3754+00, is located in Unit I. The wall is visible from Unit H at the immediate foreground and foreground distance zones.

The magnitude of the wall is approximately 1,500 sq ft (139.4 sq m), and is scored 2 in *magnitude*. The angle of view is direct from the roadway traveling across the bridge, and is scored 3 in the immediate foreground. From the foreground view, the wall is visible directly, again while traveling across the bridge, and also at an angle from the historic, pedestrian bridge (see figure B-32). The two scores of 3 and 2 are added together for a total angle of view at the foreground distance zone of 5.

The *duration of view* is 2 seconds in the immediate foreground, scored 1 and always visible, and an important visual element, when viewed from the foreground, scored 3. The wall has a silhouette against vegetation/land/sky combined, and is scored 2 from both distance zones. Because it is proposed to be nearly vertical, the aspect is scored 3. The new wall scores for Unit H total 26.

Tally Total Value

The total inventory scores for each unit are compiled on a chart (see figure B-35). The visual elements are listed in order of their scores to determine the rating of the VPL's and logical cut-off points (see figure B-36). On the Navajo Bridge project, the cuts, fills, and bridge views were assigned VPL's of 1, 2, and 3. Fill

NAVAJO BRIDGE

UNIT TOTALS

UNIT	SPECIF AREA	CUT	VPL	FILL	VPL	WALLS	VPL	BRIDGE	VPL	NAV. COMM. AREA	VPL	STRUC-TURES	VPL	CUMMULATIVE UNIT TOTAL NEW	CUMMULATIVE UNIT TOTAL LOSS
A	1	21	3	19	3										
	2	25	3	24	2										
UNIT TOTAL		46		43										89	39
B	1	24	3	23	2										
	2	23	3	25	2										
UNIT TOTAL		47		48										95	67
C	1	29	2	19	3										
	2	22	3												
UNIT TOTAL		51		19										70	73
D	1	33	2	17	3										
	2	24	3	25	2										
	3	25	3	21	2										
UNIT TOTAL		82		63										145	105
E	1	38	1					24	3						
	2	38	1												
UNIT TOTAL		76						24						100	135
F	1	28	2	34	1			26	2	32	1				
	2	31	2												
UNIT TOTAL		59		34				26		32				151	117
G	1	32	2	30	1			23	3	32	1				
UNIT TOTAL		32		30				23		32				117	121
H	1			26		26		45				11			
	2			34				45							
UNIT TOTAL				60		26		90				11		**203**	38
I	1	28				43						[1] 23			
	2	34										[2] 25			
UNIT TOTAL		62				43						48		153	68
J	1	26		23											
	2	35		15											
UNIT TOTAL		61		38										99	46

[1] BATHROOMS

[2] OVERLOOK

Figure B-35. Tally total values.

NAVAJO BRIDGE

VISUAL PRIORITY LEVELS - NEW ELEMENT RANKINGS

CUT RANKINGS			FILL RANKINGS			BRIDGE RANKINGS			WALL RANKINGS			STRUCTURE RANKINGS			VIEW RANKINGS		
SCORE	SPECIF AREA	VPL	SCORE	SPECIF AREA	VPL	SCORE	SPECIF AREA	VPL	SCORE	SPECIF AREA	VPL	SCORE	SPECIF AREA	VPL	SCORE	SPECIF AREA	VPL
38	E1		34	F1		45	H1	1									
38	E2		34	H2		45	H2										
35	J2	1	30	G1		26	F1	2									
34	I2		26	H1	1	24	E1	3									
33	D1		25	D2		23	G1										
32	G1		25	B2													
31	F2		24	A2													
29	C1	2	23	J1													
28	I1		23	B1	2												
28	F1		21	D3													
26	J1		19	A1													
25	D3		19	C1	3												
25	A2		17	D1													
24	D2	3	15	J2													
24	B1																
23	B2																
22	C2																
21	A1																

Figure B-36. Visual Priority Levels.

H1 and H2, and the views of the new and historic bridges are designated as VPL 1 in Unit H.

Calculate Total and Net Visual Change

The total visual impacts, both new visual elements and losses, can then be compared by unit and by element within the units. The new elements and loss of visual elements within a unit can also be compared to see where the largest total impacts are. Unit H has the highest new visual element cumulative total on the project, at 203, and a total loss value of 38.

The next step involves identifying the visual sensitivity of the new and lost elements.

Field Check Preliminary Visual Priority Levels

At this point in the VPP process, it is important to field check the inventory data from a project-wide perspective. The extremes of each visual element (those rated highest and lowest) should be checked for accuracy. In addition, it is good to check the borderline visual elements which fall into the VPL's.

On this project, at the 60 percent complete review level, a member of the review team requested that the rating of the H1 fill, which was designated as a preliminary VPL 2, be checked for accuracy. Because the fill is continuous between H1 and H2, it was determined that the original designation of the H2 fill was extending into areas which were in fact visible from the interpretive area. The VPL 2 rating was adjusted in this case to a VPL 1, and the boundary of H2 was refined to accurately separate the area which was not visible from the interpretive site.

Design Mitigation Measures

The preliminary mitigation measures can be identified based on the visual goals of fitting new development into the existing characteristic landscape, compatibility of the historic/cultural elements, and replacement of the visual elements which have been identified as being lost in the development. For each new visual element and each lost visual element, mitigation measures are identified which reflect the form, line, color, and texture of the characteristic landscape, and are compatible with other resource goals on the project.

Develop Mitigation Plan

The VPP is applied in the design and recommended distribution of the mitigation measures throughout the project. Replacement of the lost resources will be according to natural systems and/or according to VPL, preferably within the same unit where the loss occurred.

Mitigation determined for the new visual elements on the Navajo Bridge project include the following:

- *Cuts and fills*—Detailed specialized grading and blasting techniques, rock placement in fill slopes, and revegetation to repeat the surrounding form, line, color, and texture found in the natural landscape. Quantities of detailed, bid items are distributed according to VPL.

- *View of Colorado River, view of Marble Canyon*—An open railing is proposed for the new bridge to protect views of the river and canyon, and also to provide views of the historic bridge. The open railing is patterned after the existing railing on the historic bridge. The interpretive area is being extended toward the river to provide safe, accessible visibility of the river and canyon.

- *Headwalls, endwalls, guardrail, retaining walls, railing*—Colored, patterned concrete is proposed for the headwalls and endwalls which have higher visual ratings. The guardrail is proposed to be a treated, non-reflective finish to lessen the visual impact. A stone masonry guardrail is being considered at the highest visual rating areas. High-ranked retaining walls are proposed to be faced or constructed with field stone. Handrails will be a combination of stone and steel railing.

- *Historic bridge*—The bridge will be maintained in its existing condition.

- *Navajo commercial area (Nav. comm. area)*—A location for commercial stands is being provided to be accessible by pedestrians, crossing the historic bridge, and by vehicles.

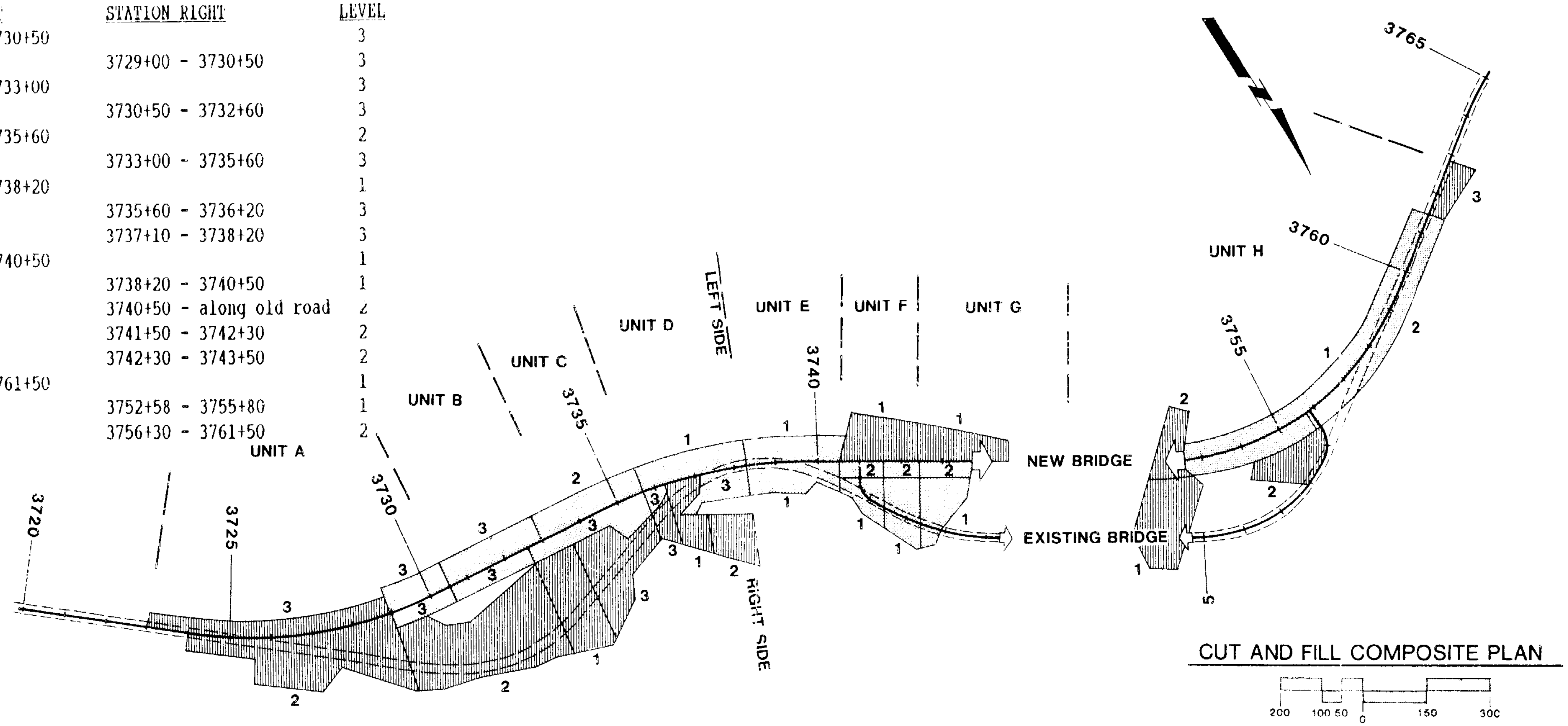
- *New bridge*—The new bridge, the largest new visual element in the area, is being designed to reflect the character of the historic bridge.

- *Interpretive area/overlook, restroom structure, parking*—Special detailing in these areas specifies structures built from native rock and wood, in scale with the existing, historic structures, which will be preserved in place.

- *Open view, enclosed view*—The approach roads were designed to meet new design speed criteria but continue to provide a gradual sequential viewing experience between the high plateau and the river/canyon crossing.

STATION OF CUT

UNIT		STATION LEFT	STATION RIGHT	VISUAL PRIORITY LEVEL
A	1	3729+00 - 3730+50		3
	2		3729+00 - 3730+50	3
B	3	3730+50 - 3733+00		3
	4		3730+50 - 3732+60	3
C	5	3733+00 - 3735+60		2
	6		3733+00 - 3735+60	3
D	7	3735+60 - 3738+20		1
	8		3735+60 - 3736+20	3
	9		3737+10 - 3738+20	3
E	10	3738+20 - 3740+50		1
	11		3738+20 - 3740+50	1
F	12		3740+50 - along old road	2
	13		3741+50 - 3742+30	2
G	14		3742+30 - 3743+50	2
H	15	3752+58 - 3761+50		1
	16		3752+58 - 3755+80	1
	17		3756+30 - 3761+50	2



STATION OF FILL

UNIT		STATION LEFT	STATION RIGHT	VISUAL PRIORITY LEVEL
A	1	3723+00 - 3729+00		3
	2		3724+00 - 3729+00	2
B	3		3730+50 - 3732+60	2
	4		3732+60 - 3733+60	1
C	5		3733+00 - 3735+60	3
D	6		3735+60 - 3736+20	3
	7		3736+20 - 3737+10	1
	8		3737+10 - 3738+20	2
F	9	3740+50 - 3742+30		1
G	10	3742+30 - 3744+30		1
H	11	3751+80 - 3752+58		2
	12		3751+80 - 3752+58	1
	13		3754+00 - 3755+00	2
	14		3761+00 - 3762+50	3

LEGEND

- CUT AREAS
- FILL AREAS
- 1,2,3 VISUAL PRIORITY LEVEL OF CUT AND FILL SLOPES
- 3720 STATION 3720+00

F.H.W.A. REGION 9 | STATE ARIZ | PROJECT NO | SHEET NO | TOTAL SHEETS | AS BUILT

ARIZONA DEPARTMENT OF TRANSPORTATION HIGHWAYS DIVISION

DESIGN / DRAWN / CHECKED | NAME | DATE

TRACS NO

SHEET ___ OF ___

Figure B-37. Cut and fill composite plan.

The loss of visual elements scores indicate where the greatest visual losses occur on the project. The list of mitigation measures is developed to mitigate loss and to detail the new elements so that they respond to the surrounding characteristic landscape.

The loss of native vegetation is one of the most significant visual elements that can be mitigated. Revegetation is proposed to be a combined effort involving seed collection, contract growing native plants, salvaging plants from the construction area for replanting, and seeding.

Other lost visual elements include existing, open views from the historic bridge and from under the historic bridge on the Park Service side, which will be blocked for safety reasons. These views will be replaced by new views offered from the new bridge, new pedestrian access on the historic bridge, and from the new overlook area. Other lost views, such as the view of the existing Navajo commercial area, view of the natural drainage, and the enclosed view while approaching the historic bridge, will be replaced by new views of the same or similar features.

The existing rock wall at the interpretive site is an important visual element to retain. Detailed blasting specifications are proposed to save this rock wall in place. If it is damaged during construction, the wall will be rebuilt using native rock.

Estimate Preliminary Mitigation Cost

The cost estimate for the 60 percent complete natural resource mitigation plans, distributed according to VPL's and inventory scores, was approximately $358,000, or 2.8 percent of the total construction cost. The project is over budget at this level, and methods are being considered to reduce the project costs.

Evaluate Overall Mitigation Plan

The final mitigation plans are being developed and adjusted according to concentrating the effective, and higher cost mitigation details to the VPL 1 areas, and other elements in units with high overall impact. The VPP is being used as a guide to direct mitigation measures while keeping the project on budget.

PHASE III—IMPLEMENTATION

Intermediate Design

During intermediate design, the alignment was shifted to attempt to save the rock structure in place, based on the preliminary VPP findings. At the 60 percent level, the new, large fill area, with a VPL 1 rating, is being detailed to have a natural-appearing character.

Final VPP Inventory/Final Design

The inventoried cuts and fills are highlighted on the Cut and Fill Composite Plan (see figure B-37). The plans include the inventoried VPL ratings of each new cut and fill along the highway, the mitigation measures, and mitigation quantities required for each VPL. By inclusion in the plans, the construction project manager and contractor will beaware of the visual quality objectives and priority levels during actual construction.

SUMMARY—
EVALUATION OF COMPLETE VPP

By having unit totals for both the New Visual Elements and the Loss of Significant Visual Resources, it was possible to better gauge the total project impact, or Total Visual Change, in a given area. The "loss" total was extremely useful during the preliminary design phase, as the highway alignment could respond to avoid areas where resource loss was the greatest. Mitigation measures were identified to try to save or replace as much of a significant resource as possible.

Total Visual Change and Net Visual Change were not calculated for this project for all units due to time and budget constraints.

River Road

INTRODUCTION

The widening of five sections of River Road was authorized by a 1986 Pima County (Tucson, AZ) bond election. The segment of River Road between Fifteenth Avenue and First Avenue, 1.25 miles (2.01 km) is the first section of the roadway to be widened from its existing, two-lane configuration to a four-lane, divided roadway, with a design speed of 50 mph (80.5 km/h). Where possible, right-of-way is being purchased by Pima County at this time for the future widening of the roadway to six lanes. Major expenditures, such as bridges and culverts, will be designed to the six-lane width as part of this project.

This widening project also includes a linear park connection between River Road and the Rillito River Park, and improvements to the Oracle Road/River Road intersection. The study area is defined as the Rillito Creek/River Road area of influence around the project area. This area is bounded roughly by the Rillito Creek on the south, the foothill bluffs of the Catalina Mountains on the north, Fifteenth Avenue on the west, and First Avenue on the east. Portions of the study area are within the limits of the City of Tucson, and portions are under the jurisdiction of Pima County.

This application of the complete VPP extends to the final design stage.

PHASE I—EXISTING VISUAL RESOURCES

Character Zones

Many significant natural, cultural, and visual resources are located in the Rillito Creek/River Road area, which together define the area's character. Four "character zones" are defined along the entire Rillito Creek/River Road corridor: Historic Floodplain Influence Zone, Urban Influence Zone, Semi-rural/Agricultural Zone, and the Foothills Residential Zone (see figure B-38).

The River Road experience in the project area is marked by traveling at the edges of the Rillito River basin and the abrupt bluffs marking the foothills of the Santa Catalina Mountains. This study area is located within the Urban Influence Zone, Pima Wash to Camino Real Wash.

This section is characterized by mixed qualities and types of development, primarily commercial and multifamily residential. The topography is still relatively flat, due to the proximity of the Rillito Creek, however, the bluffs to the north become a prominent visual element. The bluffs extend to River Road in several locations, with exposed, eroded faces where River Road has encroached upon them (see figure B-39).

In addition to the bluffs, landmarks in this area include the Bates House, a two-story adobe, Rillito Downs racetrack, the University of Arizona Farms, Joesler buildings (unique architecture), Catalina Foothills School, St. Phillips Church, historic irrigation ditches, the "Pink Adobe," and other miscellaneous adobe residences. A historic route to the old Camp Grant, located north of the Catalina Mountains, crosses River Road just west of Oracle Road.

In this 1.25-mile (2.01 km) section, River Road begins to reflect the natural landform, and has a few curves in the existing alignment. This section contains the most congested traffic and has right-of-way constraints.

Visual Quality/Variety

The following definitions of visual quality were determined for River Road, according to the characteristic landscape:

- *Outstanding* visual quality/interest, unique features, and focal points of interest resulting in a high degree of visual variety with continuity, significant vegetation, good character of development, well maintained structures, good view (middleground), panoramic mountain view (background).

- *Typical* visual quality or interest, typical or average vegetation in fair or good condition, lack of definition of development, structures in average condition, average view (middleground), mountains visible but not outstanding (background).

- *Below Average/Incongruous* visual quality, disturbed land, incongruous development, poor condition and appearance of built and natural elements (middleground), mountains are not visible or are not a factor (background).

Visual Concern

Visual concern of adjacent landowners/managers was defined according to a combination of:

- Existing attention to visual quality demonstrated by landowner/manager
- Existing and proposed land uses
- Public participation.

Ratings were assigned as follows:

High—Landowners/managers have an above average concern for visual resources.

Average—Landowners/managers have an average concern for visual quality.

Low—Landowners/managers have a below average concern for visual quality.

Visual Goal

River Road is a designated scenic route in the City of Tucson and Pima County. The development of the roadway should respond to the setting which includes physiographic landmarks, topography, natural and cultural resources, and surrounding land use. A corridor-wide study, "Rillito Creek/River Road Design Process and Guidelines" (reference 9) was completed to identify resources and goals, and to direct future projects within the corridor.

Visual priorities adopted for this project are:

1. Protect and enhance variety in foreground visual resources which contribute to the character of the Santa Catalina foothills

   - protect and enhance significant native vegetation
   - rehabilitate disturbed areas
   - provide visual definition and views of washes
   - protect washes in the natural state
   - provide for wildlife movement along washes at roadway crossings
   - provide visual definition of major intersections.

2. Protect and enhance corridor and panoramic views of the Tucson Basin and surrounding mountains.

3. Provide a visual transition to developed areas along and at each end of the corridor.

The goals for view preservation and enhancement are summarized as follows:

- Preservation of natural mountain or open space vistas
- Elimination of obtrusive cut and fill slopes
- Preservation of desirable urban views
- Elimination of incongruous views.

PHASE II—VISUAL IMPACTS

Conceptual/Preliminary Design

The preliminary design is based on widening the roadway while minimizing impacts to resources and adjacent property owners, in a cost effective manner.

Because of the increased design speed of 50 mph (80.5 km/h), the existing curves and dips into washes are being lessened or eliminated in the roadway improvements.

Preliminary VPP Inventory

Conduct Detailed Visual Inventory

This study includes a visual inventory which defines existing visual quality and concern, opportunities for improving visual conditions along the route, potential visual impact, and mitigation treatments. The project area was inventoried according to a 55-degree peripheral angle of vision and a 1,400-ft (426.7 m) focusing distance, at the design speed of 50 mph (80.5 km/h).

1. Distance Zones

With the existing roadway centerline centered in the immediate foreground, distance zone widths determined for this project are (see figure B-40):

- *Immediate foreground*—Roadway right-of-way, approximately 150 ft (45.7 m) in width.

- *Foreground*—Area beyond immediate foreground, within the driver's "cone of vision" at the 50 mph (80.5 km/h) design speed, approximately 1,300 ft (396.2 m) in width.

- *Middleground*—Area beyond foreground, 5 mi (8.05 km) in width.

- *Background*—Visible area beyond the middleground.

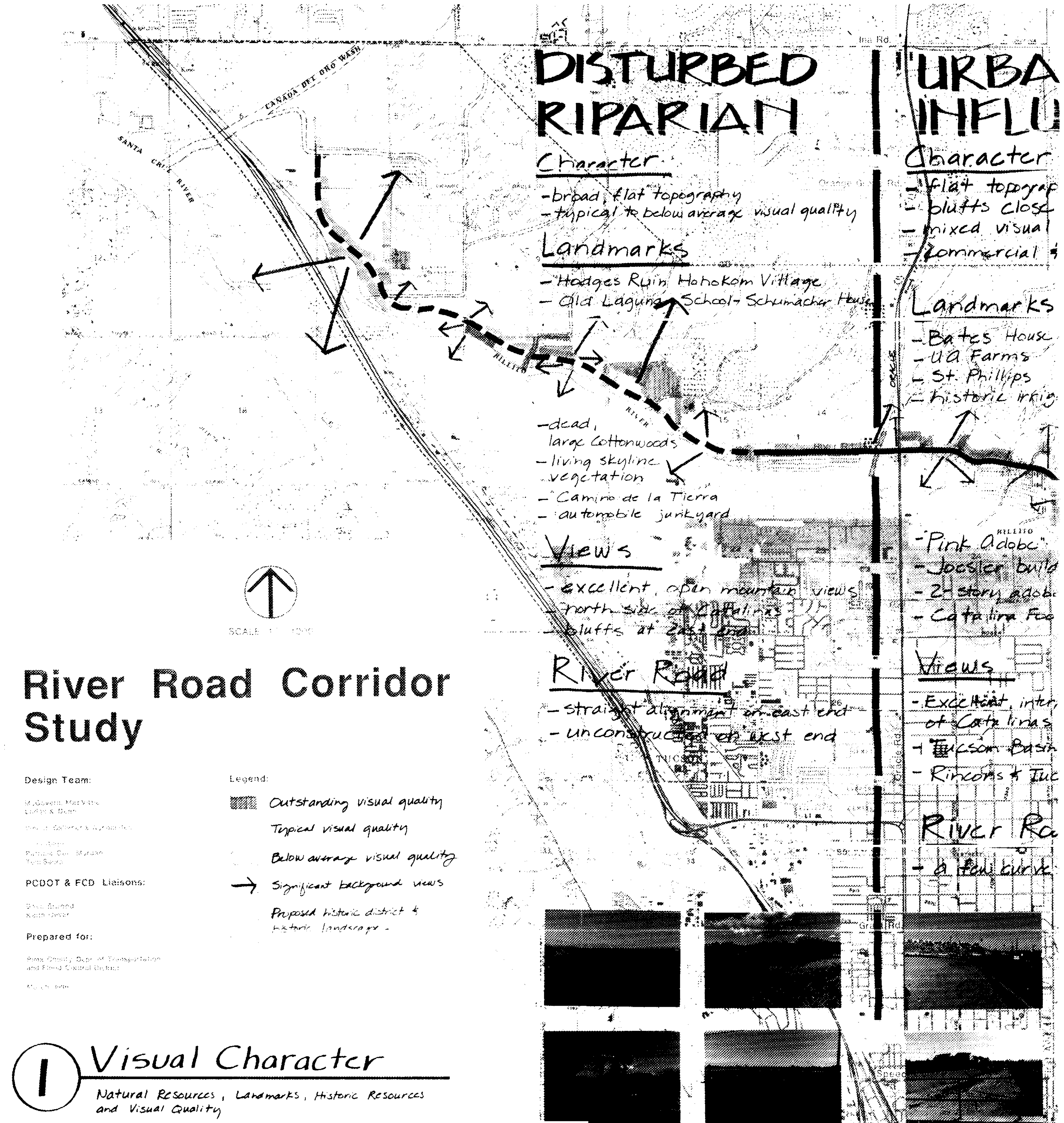
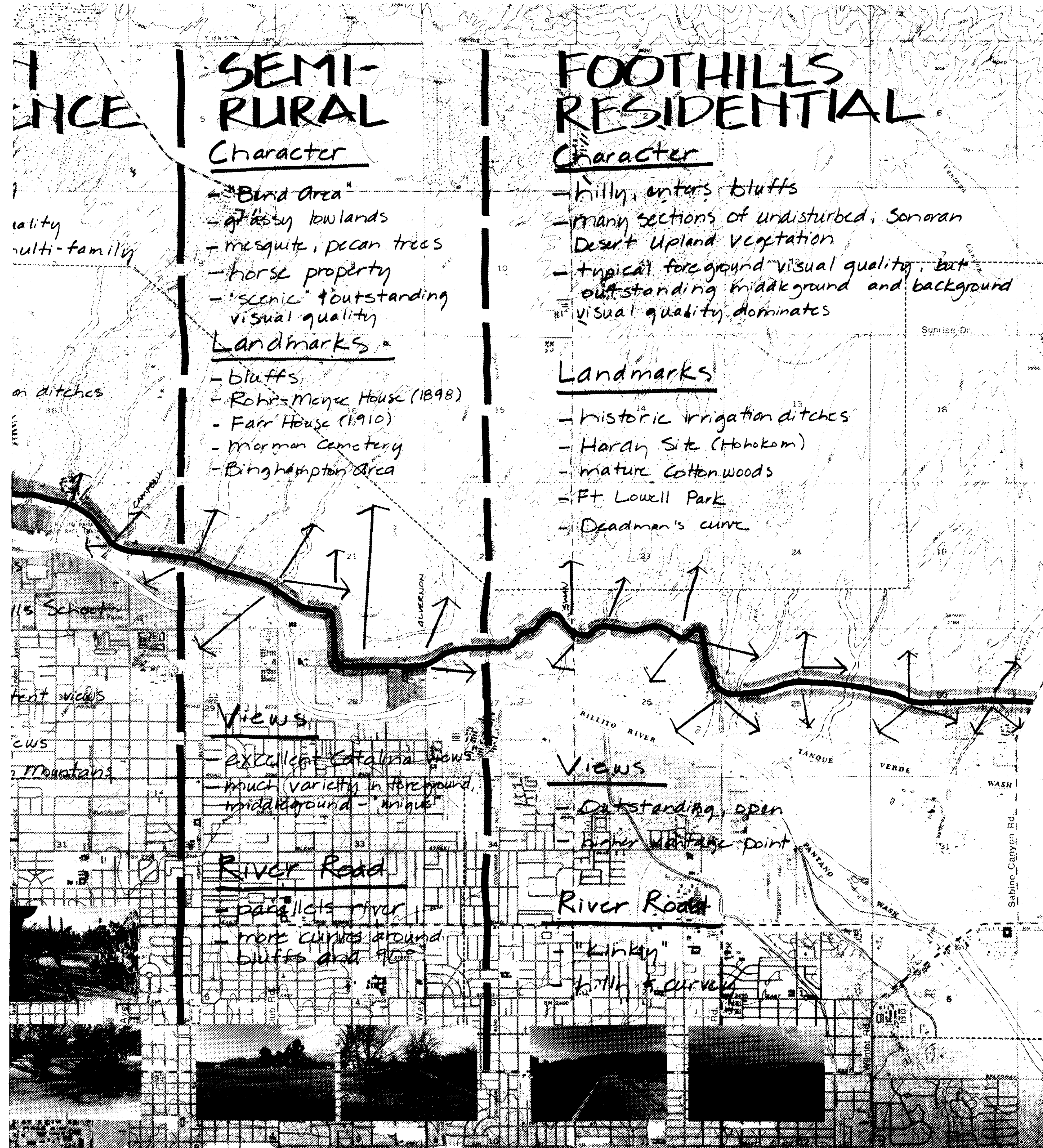


Figure B-38. Character zones along River Road.



SEMI-RURAL
Character
- "Bend Area"
- grassy lowlands
- mesquite, pecan trees
- horse property
- "scenic" & outstanding visual quality
Landmarks
- bluffs
- Rohr-Menze House (1898)
- Farr House (1910)
- Mormon Cemetery
- Binghampton Area
Views
- excellent Catalina views
- much variety in foreground, middleground - unique
River Road
- parallels river
- more curves around bluffs and
FOOTHILLS RESIDENTIAL
Character
- hilly, enters bluffs
- many sections of undisturbed, Sonoran Desert Upland Vegetation
- typical foreground visual quality, but outstanding middleground and background visual quality dominates
Landmarks
- historic irrigation ditches
- Hardy Site (Hohokam)
- mature Cottonwoods
- Ft. Lowell Park
- Deadman's curve
Views
- Outstanding, open
- higher vantage point
River Road
- "Kinky"
- hilly & curvey
RILLITO RIVER
TANQUE VERDE WASH
PANTANO WASH
ALVERNON
Sabino Canyon Rd
Sunrise Dr.

Figure B-39. Existing curve adjacent to bluff along River Road.

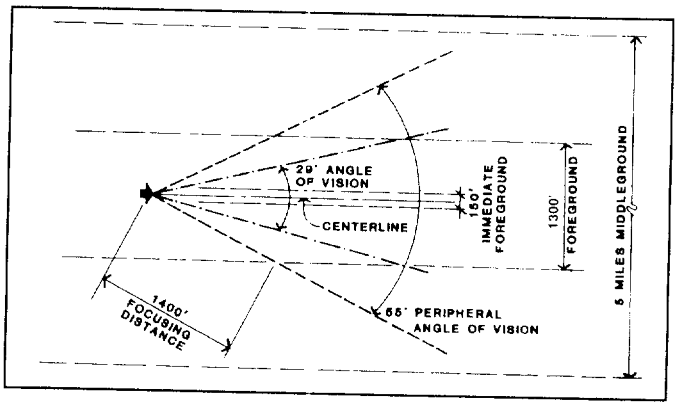


Figure B-40. Distance zones and angle of vision for River Road.

2. Visual Elements/Views

The following new visual elements were identified according to the preliminary design:

- Cuts
- Fills
- Headwalls and endwalls
- Guardrail
- Parking area
- View of new bridge
- View of drainages
- Bank stabilization
- Retention basin
- Open views
- Median
- New intersection
- Noise walls and sign walls
- Handrail
- Dike
- Equestrian trail

The preliminary design results in the following loss of significant visual elements:

- Native vegetation
- Introduced vegetation
- Sharp curves around bluffs
- View of natural drainage
- Enclosed view
- Walls

The preliminary VPP quantifies the new visual elements and loss of significant visual resources in the immediate foreground, foreground, middleground, and background zones, according to the preliminary roadway design.

3. Visual Units/Viewpoints

The corridor is divided into 14 visual units where changes in visual character and background views occur (see figure B-41). The two-part rating, for visual quality and visual concern, are assigned to the foreground and middleground areas (immediate foreground is addressed in the

VPP). Background views are also rated for visual quality, concentrating primarily on existing mountain vistas and significant urban view opportunities.

Following is a summary of the visual quality inventory for this character zone, comprised of 14 visual units (see figure B-41):

- Visual quality is outstanding, where native vegetation remains in place and quality development occurs; typical, and below average, where most of the development hasoccurred.

- Views of the Catalinas are also excellent in this section. Catalina views are intermittent and framed by structures,bluffs and sky line vegetation, which adds to the visual quality. Views are also available of the Tucson Basin (especially in the area of the new Stone Avenue intersection), the Rincon Mountains, and the Tucson Mountains.

- Visual concern in this section varies along the route, but is primarily average.

Unit L, located between Oracle Road, on the west, and Old River Road, on the east, is described in greater detail for this case study. Land use in the unit includes residential (trailer park and single family homes) and commercial (service station, restaurant, and shopping center). The existing visual quality in Unit L rates "outstanding" (from the eastern boundary of the unit to the eastern edge of the commercial area at the corner of River Road and Oracle Road) due to native vegetation in good condition and development, which is in character with the area. The shopping center is rated low. The south side of River Road is rated typical at the trailer park and low at the service station at the corner of River Road and Oracle Road. Visual concern is average throughout the unit on adjacent land and high for the roadway traveler. Background views are typical to the west, east and north, and low to the south.

Determine Values of Inventory Variables

The inventory rating levels of each criteria used on this project (see figure B-42) has been presented. Ratings for each variable were determined in the field based on the characteristic landscape, the degree of variety, and the relative importance/proportion of new or lost visual elements.

Each proposed new visual element and each significant visual element that would be lost were inventoried for the above conditions, based on the preliminary cross sections, plans, and field reconnaissance.

Setup Unit VPP Inventory Forms

The VPP inventory forms were developed for this project with the visual elements identified and the VPP variables included (see figures 43 and 44).

Perform Inventory

The proposed new visual elements and each significant visual element that would be lost were inventoried within each of the visual units, in terms of the variables listed, based on the preliminary cross sections, plans, and field reconnaissance. The application of VPP is demonstrated on this project by examining both selected scores of the new and lost visual elements, and also mitigation measures for selected elements in Unit L (see figure B-43).

Proposed new visual elements in the unit include two fills, four noise walls, handrail and concrete drainage inlet, new median, and a new view to the southeast due to a new curve in the realignment of the roadway (see figure B-44).

The inventory of significant visual resources which will be lost include native vegetation, introduced vegetation, and an enclosed view (due to the removal of introduced vegetation) (see figure B-45). These visual elements were inventoried for their magnitude only.

These elements were inventoried according to the criteria defined for this project. The total of new visual element scores for Unit L is 198. The total of loss of significant visual elements for the unit is 65 (see figures 44 and 45). Total Visual Change and Net Visual Change were not calculated for this project due to time and budget constraints.

Tally Total Value

The total inventory scores for each unit were compiled for the project.

Calculate Total and Net Visual Change

The total visual impacts, both new visual elements and losses, were then compared by unit and by element within the units.

Field Check Preliminary Visual Priority Levels

The proposed noise walls in Unit L, with a total score of 78, rated high and was determined to be a VPL 1 wall. The VPL's were checked in the field, during the preliminary design phase, to ensure appropri-

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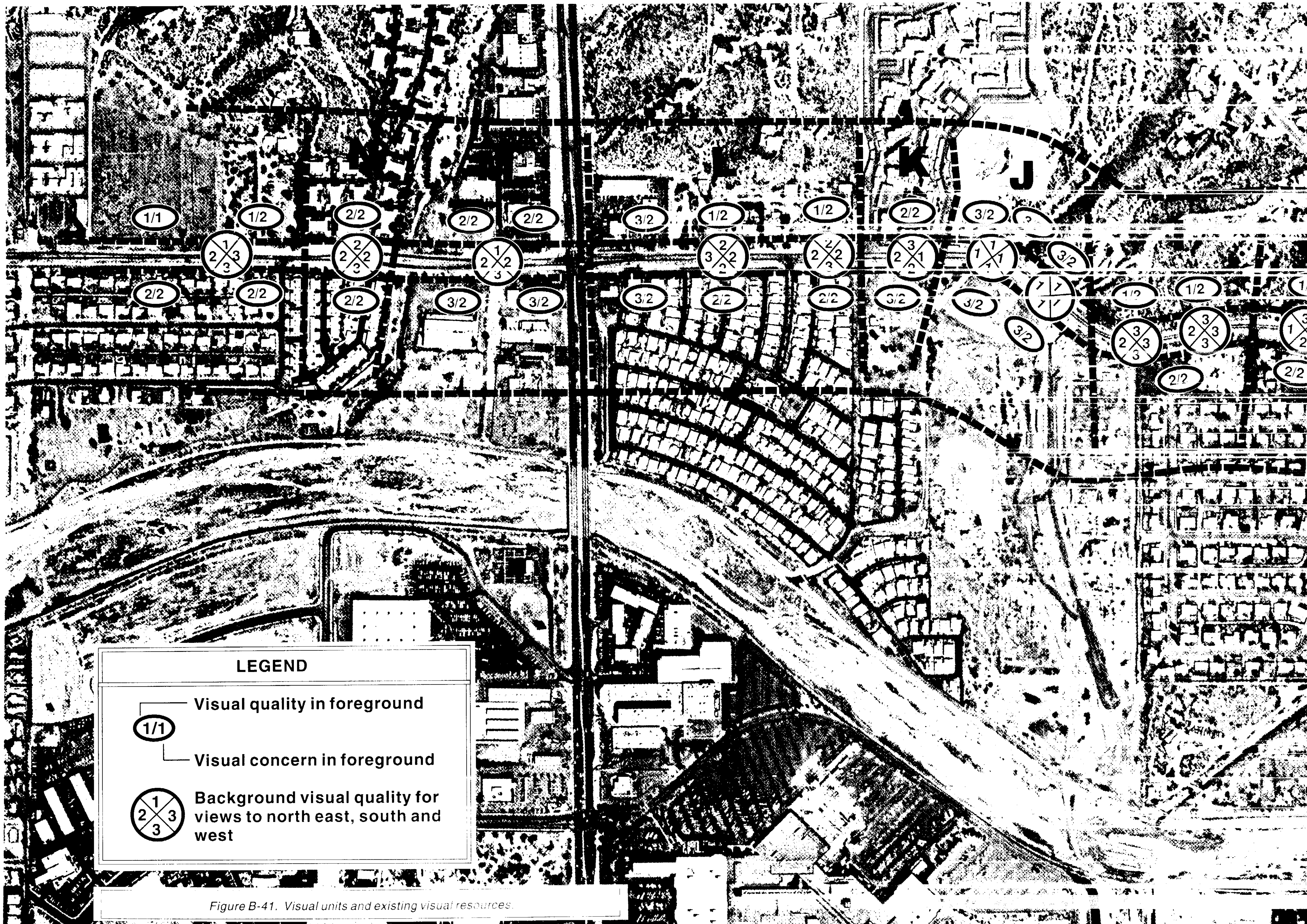


Figure B-41. Visual units and existing visual resources.

INVENTORY VARIABLES	NUMERICAL SCORE	
1) Distance from the viewer:	N/A	
Immediate foreground: 75' and less		
Foreground: 75' to 660'		
Middleground: 660' to 2.5 miles		
Background: 2.5 miles+		

Note: the distance zones are set up as measured from centerline.

2) Magnitude:		
Cuts, fills, bank grading, bank protection, dikes and swales:		
0 - 499 sf	1	
500 - 1,499 sf	2	
1,500 sf+	3	
Walls:		
0 - 999 sf	1	
1,000 - 1,999 sf	2	
2,000 sf+	3	
Equestrian trail:		
0 - 499 lf	1	
500 - 999 lf	2	
1,000 lf+	3	
Intersections:		
secondary access 'T'	1	
primary access 'T'	2	
4-way intersection	3	
Median:		
wide (20')	1	
narrow, less than 300 lf	2	
narrow, greater than 300 lf	3	
Guardrail, handrail:		
0 - 199 lf	1	
200 - 499 lf	2	
500 lf+	3	
Bridges:		
0 - 2,499 sf	1	
2,500 - 9,999 sf	2	
10,000 sf+	3	
Views:		
minimally significant views of typical resources	1	
average view of typical resources	2	
significant view of characteristic landscape	3	
3) Angle of the view:		
Horizontal:		
55 degrees - 180 degrees	1	
29 degrees - 55 degrees	2	
0 degrees - 29 degrees	3	
Vertical:		
0 to 30 degrees	1	
30 to 60 degrees	2	
60 to 90 degrees	3	
4) Duration of the view/visibility*:		
VIEWED FROM ROADWAY:		**FROM DISTANCE ZONE:**
Immediate foreground		
0 - 3 seconds (less than or equal to 220')	1	BV*
3 - 6 seconds (220' - 440')	2	PV*
6+ seconds (440'+)	3	AV*
Foreground		
0 - 6 seconds (less than or equal to 440')	1	BV
6 - 10 seconds (440' - 733')	2	PV
10+ seconds (733'+)	3	AV
Middleground and background		
8 - 10 seconds (586' to 733')	1	BV
10 - 20 seconds (733' - 1,466')	2	PV
20+ seconds (1,466'+)	3	AV

***Visibility ranking measures the equivalent of the duration of the view, when the element is viewed from a stationary location, and is defined as follows:**

BV - barely visible, indicating that the visual element is obscured or not an important visual element when viewed from this location
PV - partially visible, indicating that the visual element is partially obscured but is visible, and of average importance or is codominant with other elements when viewed from this location
AV - always visible, and an important or dominant visual element when viewed from this location

5) Silhouette condition:		
no silhouette	0	
background is vegetation/land	1	
background is vegetation/land/sky combination	2	
background is sky	3	
6) Aspect:		
faces directly away from viewer	1	
angles indirectly away from or toward viewer	2	
faces viewer directly	3	

Figure B-42. VPP inventory variables for River Road.

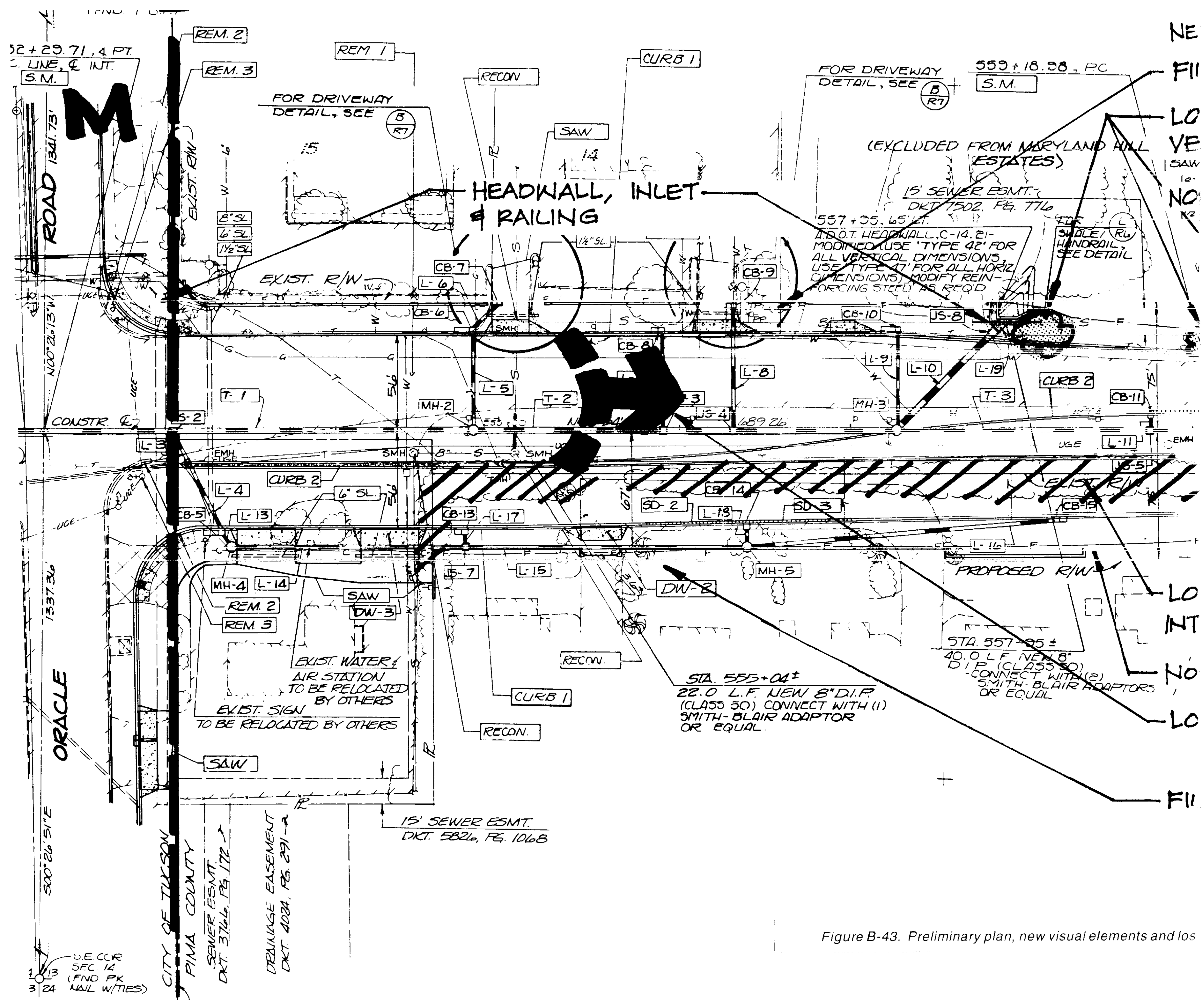
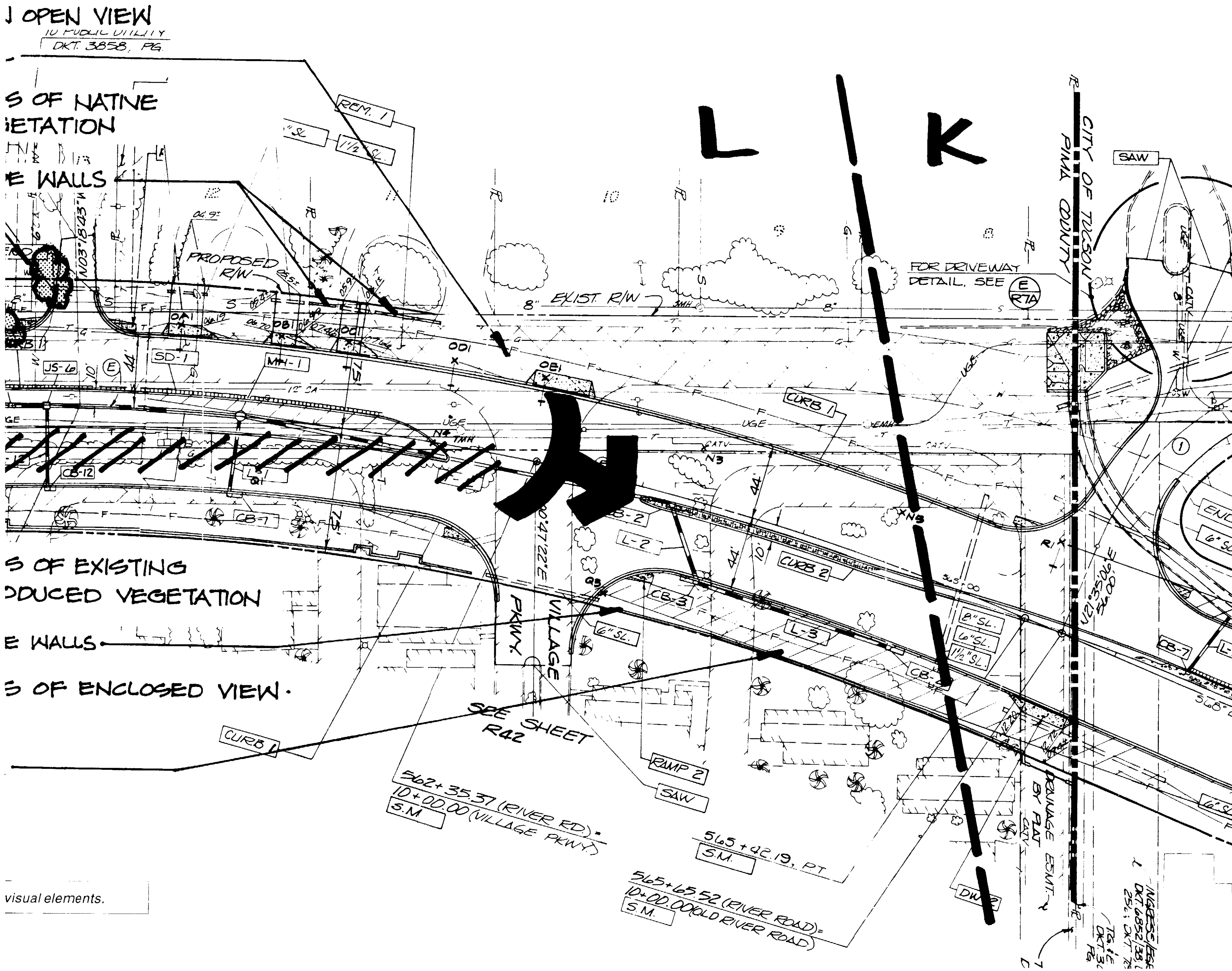


Figure B-43. Preliminary plan, new visual elements and los



OPEN VIEW
S OF NATIVE
ETATION
E WALLS
S OF EXISTING
ODUCED VEGETATION
E WALLS
S OF ENCLOSED VIEW.
L
K
CITY OF TUCSON
PIMA COUNTY
FOR DRIVEWAY DETAIL, SEE
EXIST. R/W
PROPOSED R/W
VILLAGE PKWY.
SEE SHEET R42
562+35.37 (RIVER RD.)= 10+00.00 (VILLAGE PKWY.)
S.M.
565+42.19, PT
565+65.52 (RIVER ROAD)= 10+00.00 (OLD RIVER ROAD)
DRAINAGE ESMT. BY PLAT
CURB 1
CURB 2
RAMP 2
SAW
REM. 1
visual elements.

RIVER ROAD

UNIT VPP INVENTORY-NEW VISUAL ELEMENTS

UNIT NO. L : 553+00 - 565+00

STATION	MAGNITUDE				ANGLE: HORIZONTAL				ANGLE: VERTICAL				DURATION/ VISIBILITY				SILHOUETTE				ASPECT				SUB TOTAL	TOTAL/ ELEMENT
	I	F	M	B	I	F	M	B	I	F	M	B	I	F	M	B	I	F	M	B	I	F	M	B		
MEDIAN																										
553+00 - 565+00	3	3			1	2							1	2							1	1			14	14
FILLS																										
L 553+00 - 565+00	3	3			3	3							3	3							3	3			24	
R 553+00 - 565+00	3	3			3	3							3	3							3	3			24	48
WALLS																										
R 554+55 - 562+10	3	3			2	2							3	3			1	1			2	2			22	
R 563+02 - 565+00	2	2			2	2							3	3			1	1			2	2			20	
L 560+90 - 561+05	1	1			2	2							3	3			1	1			2	2			18	
L 561+28 - 561+67	1	1			2	2							3	3			1	1			2	2			18	78
VIEWS																										
OPEN 560+00 - 565+50	2	2			3	2							3	2							3	3			20	20
CONCRETE DRAINAGE INLET, HEADWALL																										
L 557+50 - 557+90	2	2			3	2							3	3							2	2			19	
																										19
HANDRAIL																										
L 557+50 - 557+90	1	1			3	2							3	3			1	1			2	2			19	
																										19
																									UNIT TOTAL	198

Figure B-44. River Road VPP form—New Visual Elements.

RIVER ROAD

UNIT VPP INVENTORY-LOSS OF SIGNIFICANT VISUAL RESOURCES

UNIT NO. L: 553+00-565+50

STATION	MAGNITUDE				ANGLE: HORIZONTAL				ANGLE: VERTICAL				DURATION/ VISIBILITY				SILHOUETTE				ASPECT				SUB TOTAL	TOTAL/ ELEMENT
	I	F	M	B	I	F	M	B	I	F	M	B	I	F	M	B	I	F	M	B	I	F	M	B		
VEGETATION																										
L INTRODUCED	1	1			3	2							1	1			1	1			2	2			15	
R INTRODUCED	2	2			3	2							2	2			1	1			2	2			19	
L NATIVE	1	1			3	2							1	1			1	1			2	2			15	49
WALLS																										
STRUCTURES																										
ENCLOSED VIEW																										
554+50-565+00	2	2			2	2							2	2							2	2			16	
																										16
OPEN VIEW																										
																									UNIT TOTAL	65

Figure B-45. River Road VPP form—Lost Visual Elements.

ateness. During the field review, a notation was made to indicate visual elements which were continuous between units to evaluate their magnitude scores.

Design Mitigation Measures

Mitigation measures for all new visual elements and lost elements were developed to respond to and reinforce the character of River Road, the visual goals for the project, and the existing visual quality and concern ratings.

The preliminary mitigation measures for the noise walls included identifying significant walls and materials along River Road which contribute to the character of the area, and the walls within the project area which will be lost due to the roadway construction (see Units H and N). Preliminary design ideas were developed to construct the new noise walls with adobe block, similar to the wall which will be partially removed in Unit H (see figure B-46), and simulated adobe block, similar to the wall which will be removed and replaced in Unit N. These mitigation measures, in addition to revegetation plans, were developed according to the most significant resources lost during construction. In addition, several details were developed to add interest and variety to areas where long stretches of noise wall are required, such as in Unit L (see figures 47 and 48).

Develop Mitigation Plans

The details which were developed to add variety to the proposed noise walls were distributed according to the VPL's of the new walls throughout the project. In addition to the details shown, the wall was stepped in and out in areas to increase variety.

In Unit L, a VPL 1 wall, a gate, two adobe buttresses, a pot wall detail, and three niches were detailed (see figure B-49). In addition, both wall materials (the stucco and exposed adobe) were used, and the wall stepped in and out in two locations. This treatment illustrated the highest level of noise wall mitigation in the project.

SUMMARY—
EVALUATION OF COMPLETE VPP

The VPP inventory was utilized on the River Road project to distribute mitigation design throughout the roadway project according to where the largest combined visual impacts were occurring. With the use of the VPP, both the proposed new visual impacts and the loss of significant visual resources were addressed.

The VPP process was used to design mitigation measures by identifying the significant visual resources which would be lost, in an effort to replace these resources. This mitigation included the wall example shown as well as native vegetation along the route (see figure B-46).

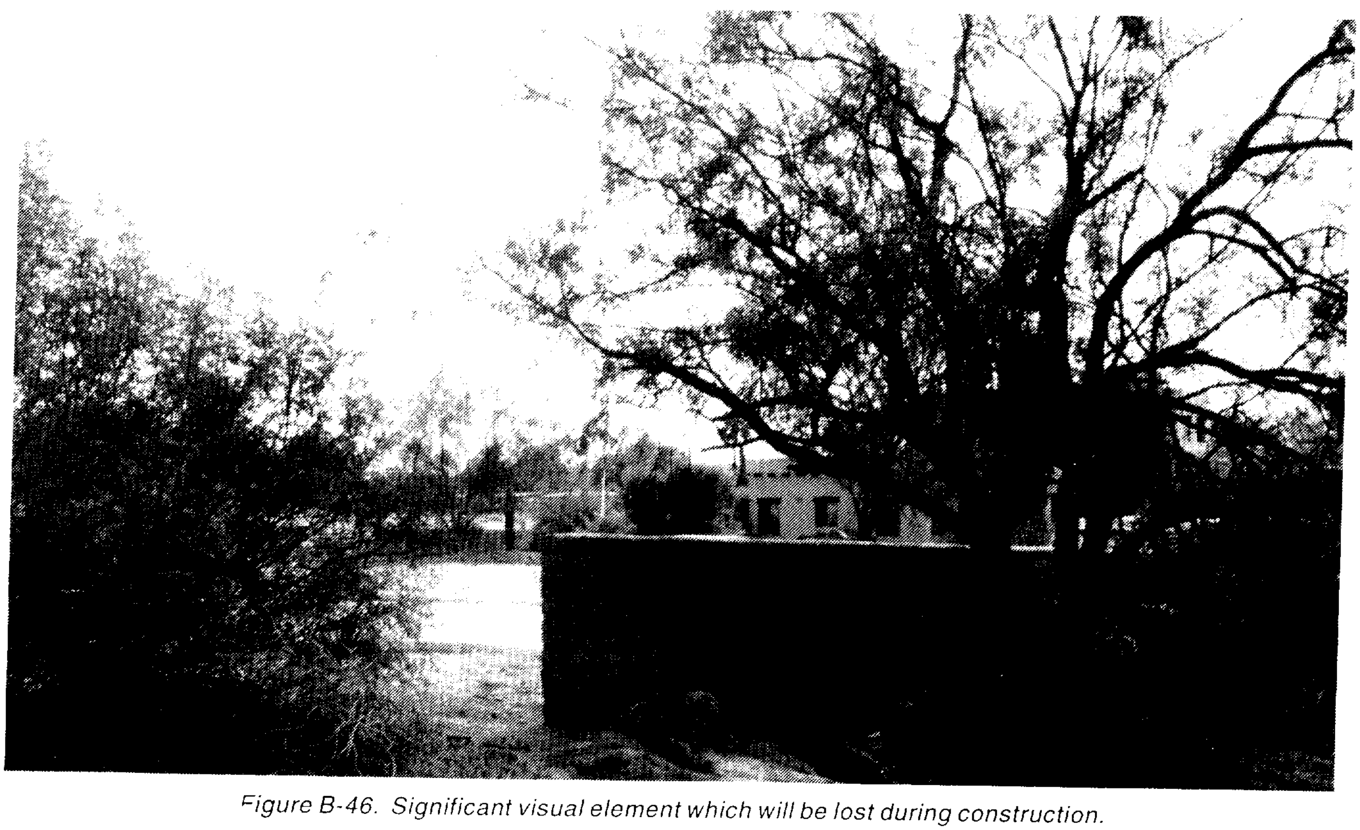


Figure B-46. Significant visual element which will be lost during construction.

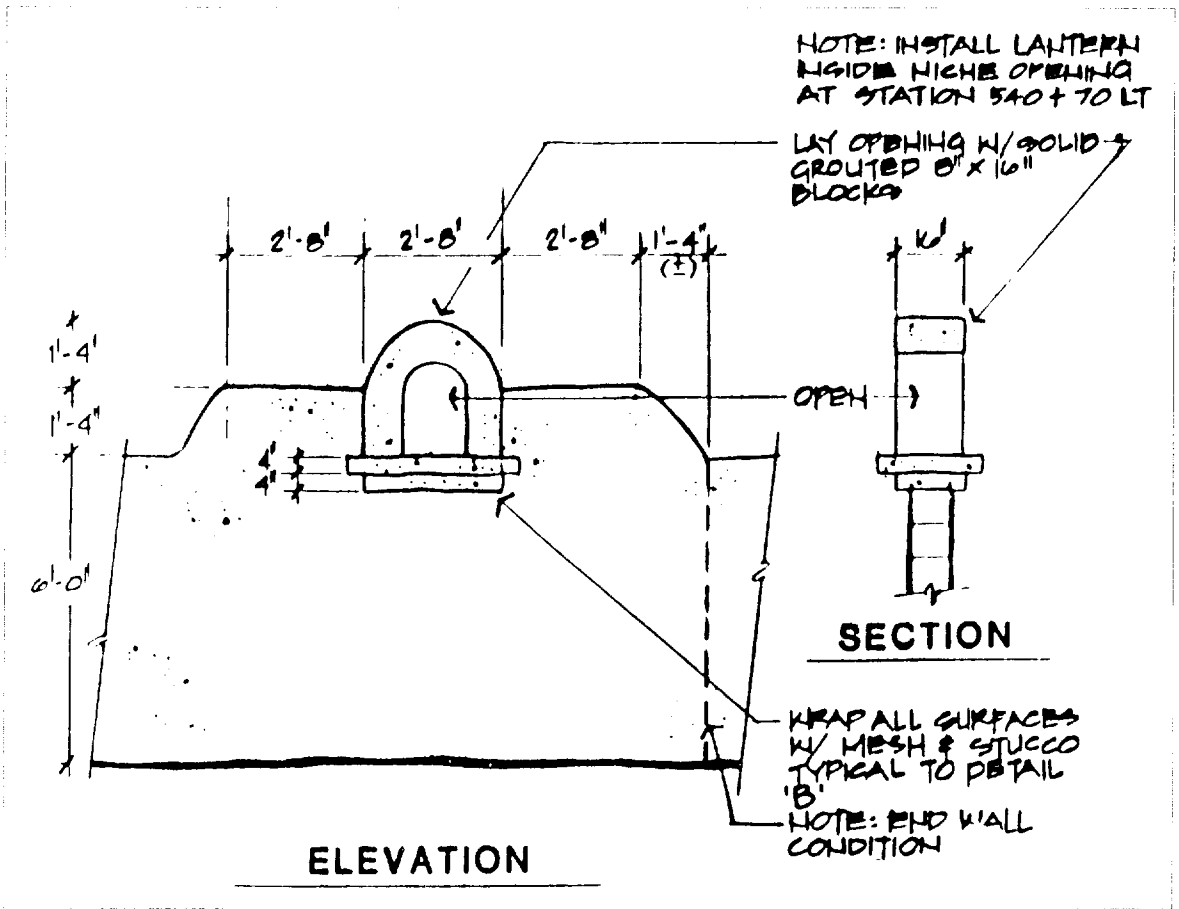


Figure B-47. New adobe wall detail—niche.

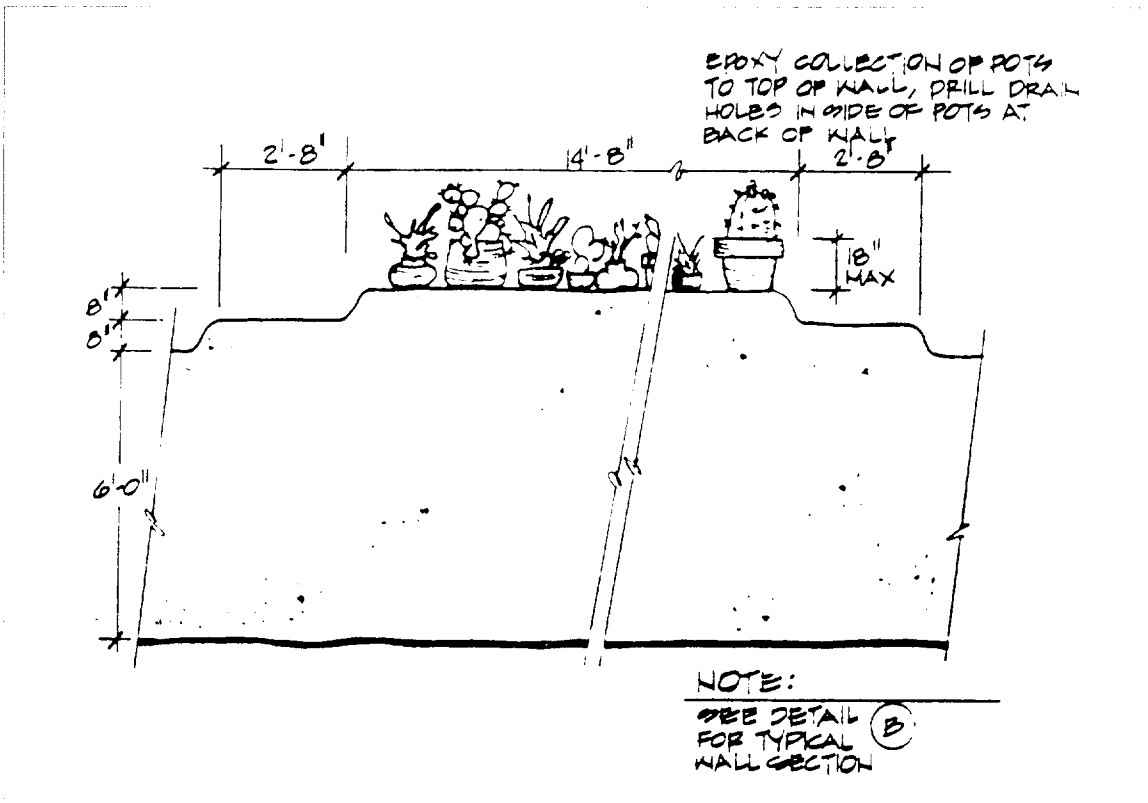


Figure B-48. New stucco wall detail—pot wall.

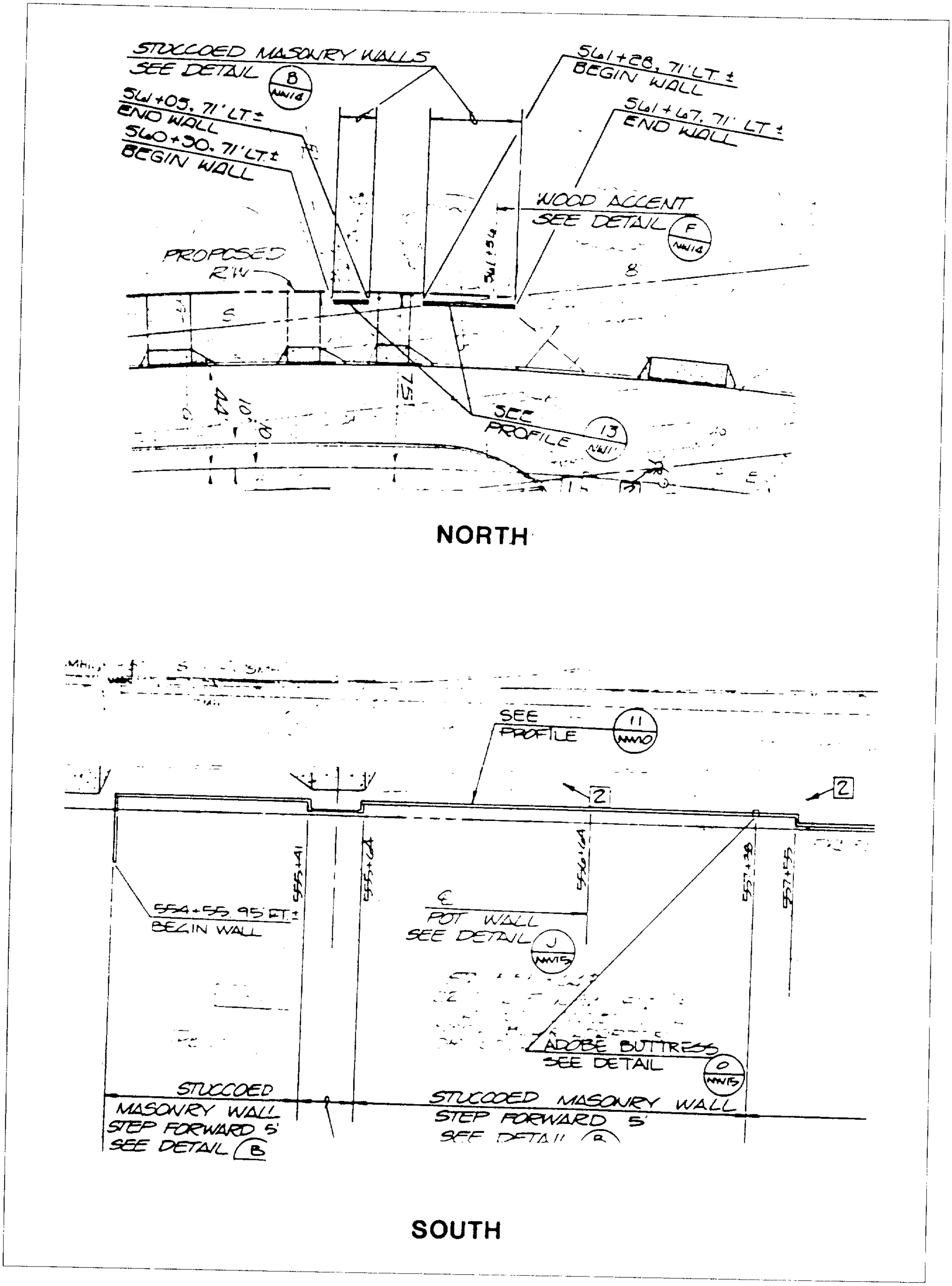


Figure B-49. Unit L noise wall plan.

The VPP process also indicated which of the new visual elements were the most highly visible. This enabled the mitigation measures to concentrate on the most visibly sensitive elements. For example, concrete headwalls and endwalls of new culverts were treated with colored and textured concrete, with increased screen plantings, in areas of high visibility. Where these elements were a low VPL, untreated concrete was specified.

Additional mitigation, which was not included in the inventory process, included placing an existing overhead power line underground. This measure improved the visual quality along the corridor by removing an existing negative visual element.

INTRODUCTION

The Natchez Trace Parkway is a roadway within the National Park System which, upon completion, will stretch from Nashville, Tennessee, to Natchez, Mississippi. The Parkway follows the prehistoric and historic routes of the Natchez, Chickasaw, and Choctaw Indians, French and Spanish settlers, and Americans. Nearly 445 mi (716.5 km) long, the Natchez Trace began as Indian trails and grew into a national road and communications link between the lower Mississippi Valley to the Union in the early 1800's. Conserved sections of the historic route, known as the "Old Trace," are located adjacent to the Parkway in several locations and available for hiking and interpretation.

Construction began in the late 1930's, and is expected to be complete in 1997. Over 80 percent of the 445-mi (716.5 km) Parkway has been completed, with three sections remaining: The northernmost link near Nashville, the section near Jackson, Mississippi, and the southernmost portion, which will terminate at Natchez, Mississippi.

Natchez Trace Parkway is a scenic route. The National Park Service obtained a wide right-of-way for the development and management of the Parkway. Visual, natural, and cultural resources along the route are managed by the National Park Service, both in-house and by contract, sometimes with adjacent land owners. The posted speed limit varies along the route, but never exceeds 50 mph (80.5 km/h).

This study demonstrates the use of VPP during the location phase of preliminary design on a 3.4-mi (5.47 km) section of the Parkway near Jackson, Mississippi. The VPP process was applied on a 6,000-ft (1,829 m) section of the new alignment where two alternatives are being considered.

PHASE I—EXISTING VISUAL RESOURCES

Character Zone

The section of Natchez Trace Parkway in the Jackson, Mississippi area is characterized by gently rolling topography, mixtures of deciduous and coniferous tree cover, open meadows and clearings for agriculture, periodic views of drainages, ponds and lakes, and primarily rural land uses with fringe urbanization as the roadway nears Jackson (see figure B-50).

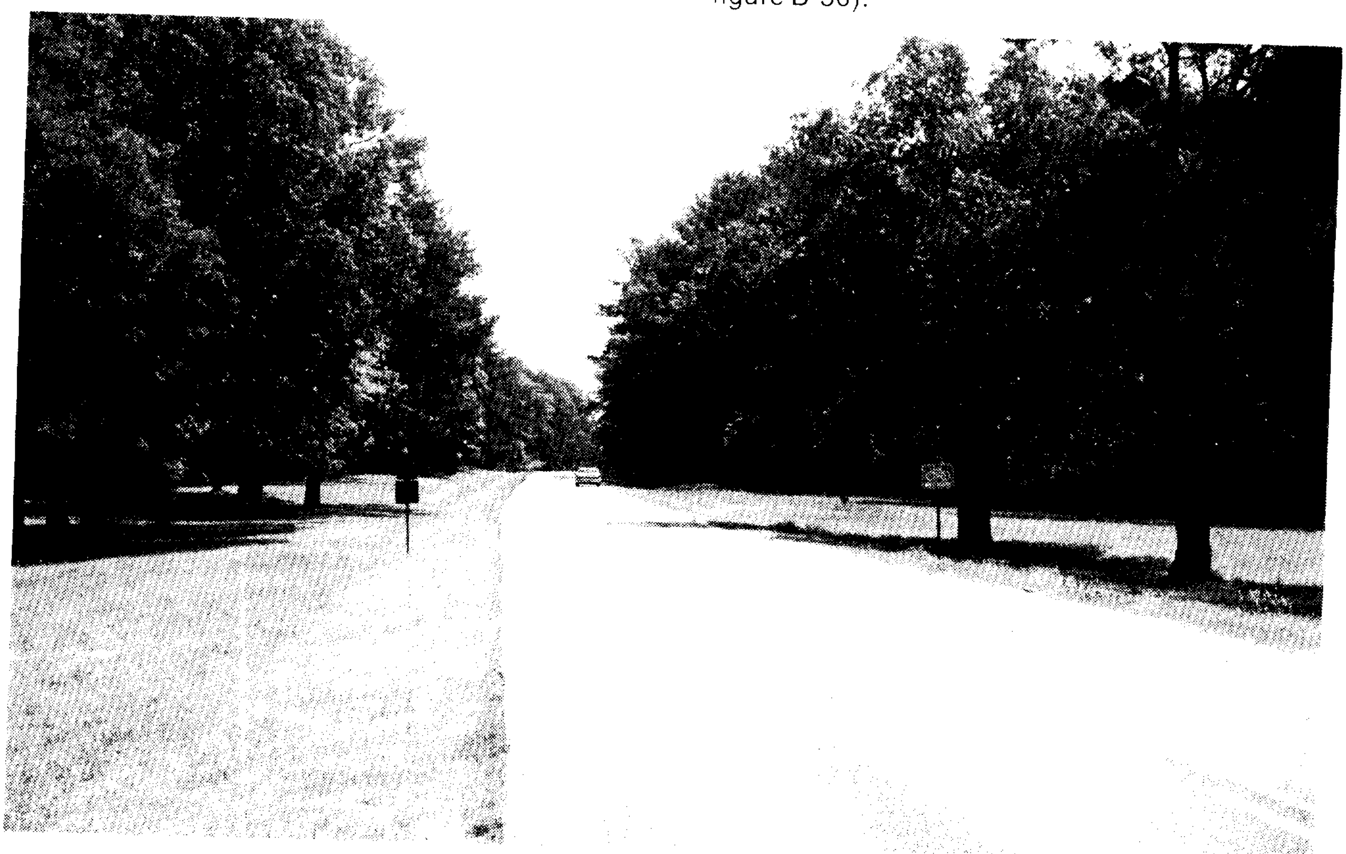


Figure B-50. Characteristic landscape of Natchez Trace near Jackson.

Forested areas include broad-leaf deciduous and needle-leaf evergreen trees, such as loblolly pine, short-leaf pine, oak, hickory, sweetgum, blackgum, red maple, and elm. The main grasses are bluestem, panicums, and long-leaf uniola. Dogwood, viburnum, blueberry, American beauty-berry, youpon, and numerous woody vines are common. Views along the route vary between forested enclosures and open meadows, ponds, lakes, rural structures, and residences.

Visual Quality/Variety

Variety of the existing landscape was defined according to the conditions found within the characteristic landscape, as follows:

• *Outstanding*—High degree of variety within the defining natural resource visual elements (primarily vegetation and water), structures reflect the rural character or historic periods in the area, vegetation is in good condition, visual cohesiveness, interesting mixture of enclosed and open views due to variety in the vegetation, introduced elements respond to the natural and cultural resources of the area, and are well maintained, interrupted and intriguing views into the distance are partially obscured by vegetation, views of unique features and focal points of interest.

•*Typical*—Average amount of variety within the defining natural resource visual elements, vegetation is in average condition, structures and introduced elements are generally in character with the surrounding area and are in average condition views have some variety in degree of openness and enclosures.

• *Below Average/Incongruous*—Monotonous visual elements or excessive amounts of elements with no cohesiveness, natural features have been disturbed, vegetation is in poor or declining condition, structures and introduced elements do not relate to the character of the area and/or are not well maintained, little or no variety in form, line, color, or texture of the topography and vegetation.

Visual Concern

Visual concern is twofold: Concern for the visual quality of visitors traveling along the route and those adjacent to and within viewing distance of the route.

Visual concern of adjacent landowners/managers was defined according to a combination of:

- Existing attention to visual quality demonstrated by landowner/manager.
- Existing and proposed land uses.
- Public participation.

Ratings were assigned as follows:

High—Landowners/managers have an above average concern for visual resources.

Average—Landowners/managers have an average concern for visual quality.

Low—Landowners/managers have a below average concern for visual quality.

The Visual Concern, or concern of roadway travelers for visual quality, was determined to be high. A relatively high percentage of Parkway users have a strong interest in visual quality and scenery.

Visual Goals

The visual resource goal for the Natchez Trace project is to preserve the rural character of the area, while providing the traveler an opportunity to pass through the area at an "unhurried" pace and view scenic resources (see figure B-51). The road and structural-related elements of the Parkway are visually minimized along the route. For example, the shoulder is constructed of a gravel subbase and topped with soil/gravel mix and seeded, resulting in a grass-covered, visually unobtrusive shoulder. Other special details, such as bridge abutments, have been designed to reflect the character of the area.

The Natchez Trace Parkway ranges from 500 ft (152.4 m) to 1,250 ft (381.0 m) in width. This enables the National Park Service to manage and protect the land use and visual quality in the immediate foreground. Specific visual objectives include protecting and offering views of outstanding visual elements visible from the roadway, integrating new design elements and mitigating construction activities so that, immediately following construction, the new design elements will compliment the characteristic landscape. Disturbed areas will then blend into the natural landscape and will not be evident. This visual goal is equivalent to the Retention Visual Quality Objective of the Forest Service. When alternative views are available, preference is given to offering rural, as opposed to urban, views from the roadway.

PHASE II - VISUAL IMPACTS

Conceptual/Preliminary Design

The FHWA has prepared a preliminary location alignment of a 3.4-mi (5.47 km) section of roadway for review. This section includes alternatives for

Figure B-51. View of future Natchez Trace Parkway at project location.

crossing the existing Old Agency Road at-grade or on an elevated bridge. The Natchez Trace Parkway is a limited access facility, which requires alternative local access routes.

Both alternatives can be designed to meet the visual goals for the project. The bridge alternative is more costly than the at-grade alternative, however, cost alone is not the deciding issue in the final alternative selection. Because the right-of-way is bordered by a multitude of private landowners and the area has a history of use and access, visual resource concerns are a significant issue in the evaluation of alternatives. Both alternatives have local access solutions proposed. The description of the alternatives follows.

Alternative 1: Natchez Trace crossing Old Agency Road at-grade

This alternative requires a 762.0 m (2500-ft) section of Old Agency Road to be abandoned as a roadway, and renovated for pedestrians, as an Old Trace interpretive area (see figure B-52). The closure of a section of Old Agency Road requires a new local access road, "Old Agency Junior," running parallel to the Natchez Trace Parkway to the south. This roadway would provide access to residences at the southwest part of the study area, the Dinsmor subdivision, and the Greenwood Plantation.

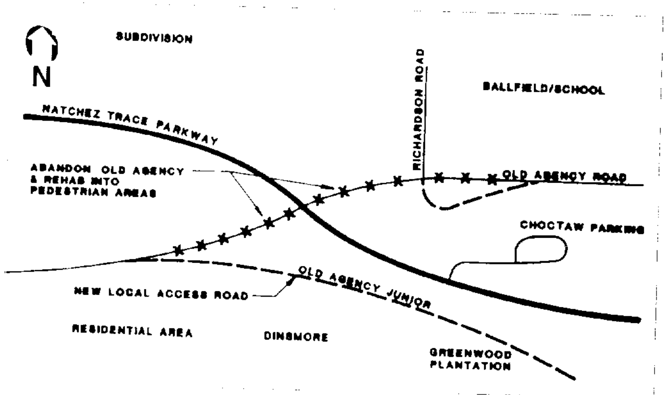


Figure B-52. At-grade alternative.

In addition, Old Agency Road would be slightly realigned on the north side of Natchez Trace to connect with the existing Richardson Road. A newly constructed section of County Road B is proposed to provide additional local access on the north side of the Parkway (not shown).

Alternative 2: Natchez Trace crossing Old Agency Road on a bridge

This alternative does not alter the current alignment of Old Agency Road, with Natchez Trace Parkway crossing on an elevated bridge (see figure B-53). Local access is altered in one location on the south side of the Parkway, on the east end, where a new section of Old Agency Junior is proposed to connect with Brame Road. In addition, a new driveway is extended to the Greenwood Plantation.

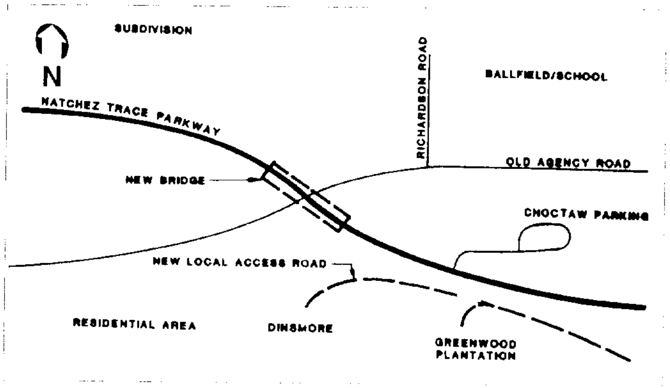


Figure B-53. Bridge alternative.

Preliminary VPP Inventory

Conduct Detailed Visual Inventory

This study includes a visual inventory for the 6,000-ft (1,828.7 m) section of the new Parkway where alternative alignments are being evaluated. The visual inventory defines existing visual quality and concern along the route. The project area was inventoried according to a 45-deg peripheral angle of vision and a 1,800-ft (548.6 m) focusing distance, at the design speed of 60 mph (96.6 km/h).

1. Distance Zones

With the existing roadway centerline centered in the immediate foreground, distance zone widths determined for this project are (see figure B-54):

- *Immediate foreground*—Area immediately adjacent to the roadway, approximately 150 ft (45.72 m) in width.

- *Foreground*—Area beyond immediate foreground, within the driver's "cone of vision" at the 60 mph (96.6 km/h) design speed, approximately 1,600 ft (490 m) in width.

- *Middleground*—Area beyond foreground, 5 mi (8.05 km) in width.

- *Background*—Visible area beyond the middleground.

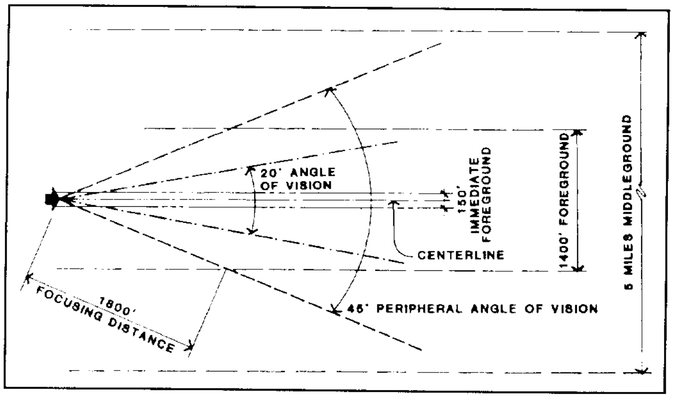


Figure B-54. Distance zones and angle of vision for Natchez Trace.

Following is a summary of the visual quality inventory for this section of the Natchez Trace Parkway:

- Visual resources along this section of the Natchez Trace Parkway are outstanding in forested areas on the west end, north of the Dinsmor subdivision, and in the central portion, south of the ball field and west of Brame Road. Another area of outstanding visual quality is the tree-canopied, narrow, Old Agency Road, especially along the section near the ball field. This section of existing roadway is a strong character-defining resource in the area. Other areas of outstanding visual quality include the Greenwood Plantation house south of the right-of-way (somewhat of a landmark in the area), and two grassy openings, one near the intersection of Old Agency Road and the proposed Natchez Trace Parkway, and one east of Brame Road, which includes a pond and small stands of trees (see figure B-55).

- Areas of average visual quality include the remaining residential areas adjacent to the right-of-way, the ball field and school located north of Old Agency Road on the east end of the study area, and a grassy clearing located west of the Dinsmor entry road.

- Areas of below average visual quality are located in weedy, unkept fields north of Dinsmor and north of the intersection of Old Agency Road and the proposed Natchez Trace Parkway.

2. Visual Elements/Views

The following new, significant visual elements were identified according to the preliminary design:

- Cuts
- Fills
- Enclosed views
- Structures

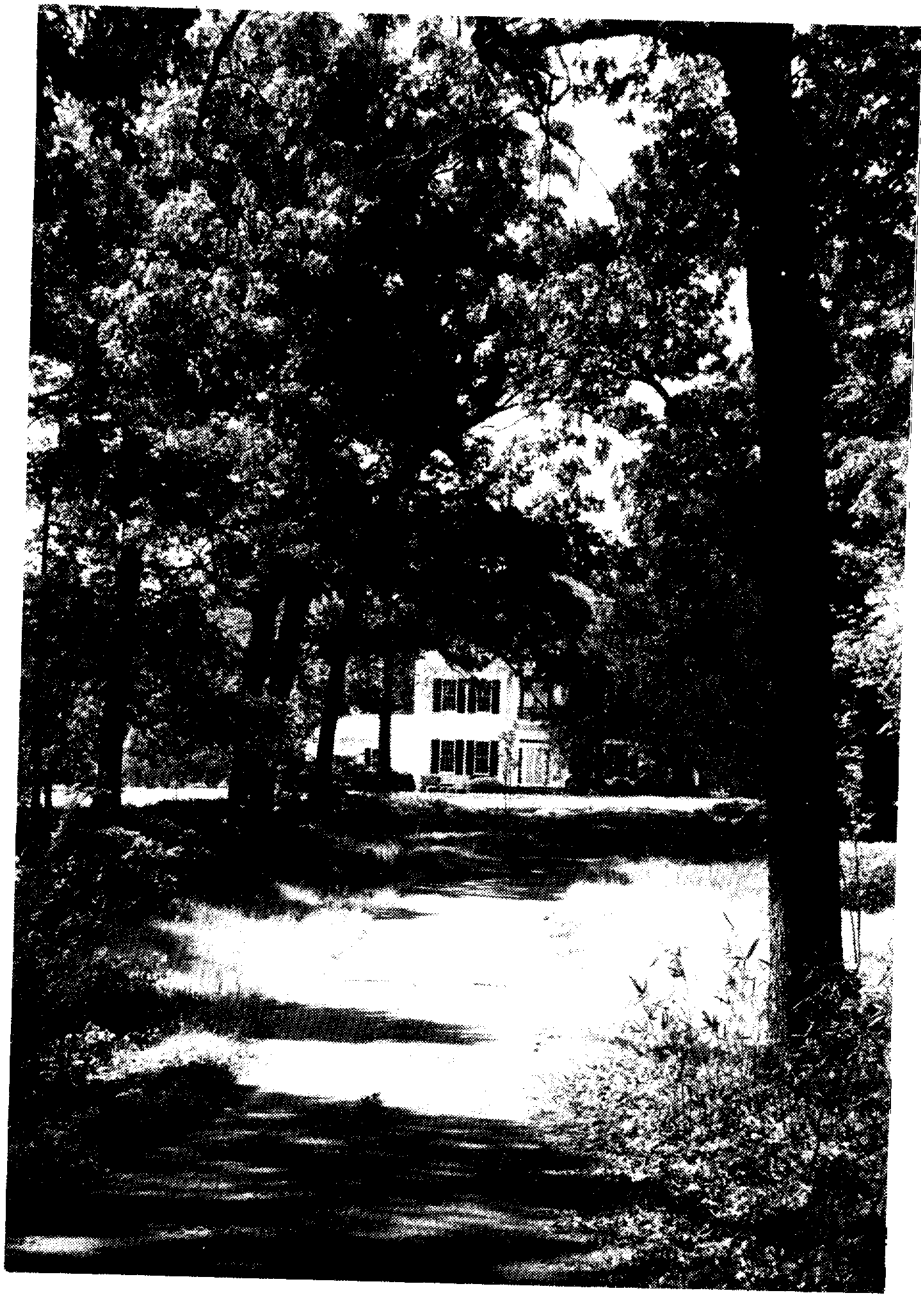


Figure 55. Potential view of Greenwood Plantation adds to character of area.

- Bridge
- Pedestrian area
- Open views
- Adjacent development
- Parking area
- Local access roads

The preliminary design results in the following loss of significant visual elements:

- Forested areas
- Tree canopy along Old Agency Road
- Clearings, fields, and meadows
- Enclosed views down narrow drives
- Enclosed view on Old Agency Road.

The preliminary VPP quantifies the new visual elements and loss of significant visual resources in the immediate foreground, foreground, middleground, and background zones, according to the preliminary roadway design.

Determine Values of Inventory Variables

The inventory value ranges of each variable used on this project is shown in figure B-56. Values for each variable were determined in the field based on the characteristic landscape, the degree of variety, and the relative importance/proportion of new or lost visual elements. Each proposed new visual element and each significant visual element that would be lost were inventoried for the above conditions, based on the preliminary cross sections, plans, and field reconnaissance.

Setup Unit VPP Inventory Forms

The VPP inventory forms were developed with the visual elements identified and the VPP variables included (see figures B-57 through B-60).

The proposed, new visual elements and each significant visual element that would be lost were inventoried in the 6,000-ft (1,828.7 m) section, from Station 820+00 to 880+00 of the proposed Parkway, where the alternative alignments are developed. The inventory focused on the variables listed, and was based on the preliminary cross sections, plans, and field reconnaissance.

The VPP inventory includes the assessment of the visual impacts of the new Parkway and associated access roads from nine areas adjacent to and within the right-of-way in this area. It also includes impacts viewed from the proposed

INVENTORY VARIABLES	NUMERICAL SCORE	
1) Distance from the viewer:	N/A	
Immediate foreground: 75′ and less		
Foreground: 75′ to 800′		
Middleground: 800′ to 2.5 miles		
Background: 2.5 miles+		
Note: the distance zones are set up as measured from centerline.		
2) Magnitude:		
Cuts and fills:		
0 - 2,499 sf	1	
2,500 - 7,499 sf	2	
7,500 sf+	3	
Pedestrian area:		
0 - 499 lf	1	
500 - 999 lf	2	
1,000 lf+	3	
Bridges (plan view or elevation):		
0 - 2,499 sf	1	
2,500 - 9,999 sf	2	
10,000 sf+	3	
New Views:		
minimally significant views	1	
view with some significance, average degree of change	2	
significant view, noticeable change from existing	3	
Structures, adjacent development and parking areas:		
minimally significant	1	
some significance	2	
visually significant	3	
3) Angle of the view:		
Horizontal:		
45 degrees - 180 degrees	1	
20 degrees - 45 degrees	2	
0 degrees - 20 degrees	3	
Vertical:		
0 to 30 degrees	1	
30 to 60 degrees	2	
60 to 90 degrees	3	
4) Duration of the view/visibility*:		
VIEWED FROM ROADWAY:		**FROM DISTANCE ZONE:**
Immediate foreground		
0 - 3 seconds (less than or equal to 264′)	1	BV*
3 - 6 seconds (264′ - 528′)	2	PV*
6+ seconds (528′+)	3	AV*
Foreground		
0 - 6 seconds (less than or equal to 528′)	1	BV
6 - 10 seconds (528′ - 880′)	2	PV
10+ seconds (880′+)	3	AV
Middleground and background		
8 - 10 seconds (704′ to 880′)	1	BV
10 - 20 seconds (880′ - 1,760′)	2	PV
20+ seconds (1,760′+)	3	AV

***Visibility ranking measures the equivalent of the duration of the view, when the element is viewed from a stationary location, and is defined as follows:**

BV - barely visible, indicating that the visual element is obscured or not an important visual element when viewed from this location
PV - partially visible, indicating that the visual element is partially obscured but is visible, and of average importance or is codominant with other elements when viewed from this location
AV - always visible, and an important or dominant visual element when viewed from this location

5) Silhouette condition:		
no silhouette	0	
background is vegetation/land	1	
background is vegetation/land/sky combination	2	
background is sky	3	
6) Aspect:		
faces directly away from viewer	1	
angles indirectly away from or toward viewer	2	
faces viewer directly	3	

Figure B-56. VPP inventory variables for Natchez Trace Parkway.

NATCHEZ TRACE

UNIT VPP INVENTORY-NEW VISUAL ELEMENTS

ALTERNATIVE NO. 1 - AT-GRADE

STATION	MAGNITUDE				ANGLE: HORIZONTAL				ANGLE: VERTICAL				DURATION/ VISIBILITY				SILHOUETTE				ASPECT				SUB TOTAL	TOTAL/ ELEMENT
	I	F	M	B	I	F	M	B	I	F	M	B	I	F	M	B	I	F	M	B	I	F	M	B		
CUTS																										
b: from I	3	3			3	2							2	1			1	1			2	1			19	
b: from NT	3	3			2	2							3	2			1	1			3	2			22	
b: from C	3	2			3	2							3	3			1	1			1	1			20	
e: from NT	2	2			2	2							3	1			1	1			3	2			19	80
FILLS																										
a: from NT	2	2			1	2							3	1							1	1			13	
c: from NT	1	1			1	2							3	1							1	1			11	
c: from H		1				3								1								3			8	
c: from I	1	1			3	2							2	1								3			13	
d: from NT	2	2			2	1							3	1							1	1			13	
d: from H		2				3								2								3			10	
d: from I		2				2								2								3			9	77
VIEWS																										
a: from NT	2	1			2	2							3	1							2	2			15	
b: from NT	1	1			2	2							2	1							3	3			15	
c: from NT	1	1			2	2							2	1							2	1			12	
d: from NT	2	2			2	2							2	1							2	1			14	
e: from NT	1	1			2	2							2	1							3	3			15	71
STRUCTURES/ADJACENT DEVELOPMENT																										
F: from NT		1				2								1								1			5	
F: from E		1				2								2								1			6	
E: from NT		1				2								1								1			5	
E: of NT		2				2								2								1			7	
B: from NT		2				1								1								3			7	
B: of NT		2				1								1								2			6	
A: from NT		2				2								2								2			8	
A: of NT		2				3								2								1			8	
A: of I		1				2								1								2			6	
A: from I		1				2								1								3			7	
H: from NT		2				2								2								3			9	
H: of NT		2				3								2								1			8	
H: of I		1				1								1								1			4	
H: from I		1				2								1								3			7	
G: of NT		2				2								2								1			7	
G: from NT		2				2								2								3			9	
C: from NT		2				2								2								3			9	
C: of NT		2				3								2								1			8	
G: of I		1				2								2								1			6	
G: from I		2				2								2								3			9	141
ADJACENT ACCESS																										
I: from NT	1	1			2	2							1	1								1			9	
I: of NT	2	2			3	2							2	2								1			14	
OAR: from NT	1	2			2	2							1	2							1	1			12	
F: from OAR		1				2								1								1			5	
OARJr.: from D		2				3								3							1	1			10	
OARJr.: from I		2				2								3								1			8	
OARJr.: from NT		2				2								3								1			8	
OARJr.: from B		2				3								2								1			8	
OARJr.: from A		2				3								3								1			9	
OARJr.: from H		2				3								3								1			9	
RICH: from G		2				2								1								1			6	
RICH: from I	2	2			3	3							2	1							1	1			15	113

UNIT TOTAL 482

Figure B-57. Natchez Trace VPP form—New Visual Elements (Alternative 1—At-Grade).

NATCHEZ TRACE

UNIT VPP INVENTORY-NEW VISUAL ELEMENTS

ALTERNATIVE NO. 2 - BRIDGE	MAGNITUDE				ANGLE: HORIZONTAL				ANGLE: VERTICAL				DURATION/ VISIBILITY				SILHOUETTE				ASPECT				SUB TOTAL	TOTAL/ ELEMENT
STATION	I	F	M	B	I	F	M	B	I	F	M	B	I	F	M	B	I	F	M	B	I	F	M	B		
CUTS																										
b: from NT	2	2			2	2							2	1			1	1			3	2			18	
e: from NT	3	3			2	2							3	2			1	1			3	2			22	
b: from C	2	1			3	2							3	2			1	1			1	1			17	57
FILLS																										
a: from NT	2	2			2	1							3	1							1	1			13	
c: from NT	1	1			2	2							3	1							1	1			12	
c: from C		1				3								2			1	1				3			11	
d: from NT	3	3			2	1							3	1							1	1			15	
d: from H		3				3								3								2			11	
d: from OAR	3				2									2			1				1				9	71
VIEWS																										
a: from NT	2	2			2	2							2	1							2	2			15	
b: from NT	2	2			2	1							2	1							2	1			13	
c: from NT	3	3			2	2							2	1							2	1			16	
d: from NT	2	2			3	3							2	1							2	1			16	
e: from NT	1	1			2	2							2	1							1	1			11	71
BRIDGES																										
from: NT	1	1			2	2							2	1			1	1			1	1			13	
from: A		2				3								1				1				2			9	
from: G		2				3								1				1				2			9	
from: C		3				3								3				1				2			12	43
STRUCTURES/ADJACENT DEVELOPMENT																										
F: from NT		1				2								1								1			5	
F: from E		1				2								1								1			5	
F: from OAR		1				2								1								1			5	
E: from NT		1				2								1								1			5	
E: of NT		2				2								1								1			6	
B: from NT		3				1								1								3			8	
B: of NT		2				3								1								1			7	
A: from NT		2				2								2								2			8	
A: of NT		2				3								3								1			9	
H: from NT		2				2								2								3			9	
H: of NT		2				3								3								1			9	
G: of NT		2				2								2								1			7	
G: from NT		2				2								2								3			9	
C: from NT		2				2								2								3			9	
C: of NT		2				3								3								1			9	110
ADJACENT ACCESS																										
OAR: from NT	2	2			2	2							1	2							1	1			13	
OAR: of bridge	3	3			3	2							2	2			2	2			3	3			25	
OAR: of d	3	3			2	2							3	3							3	3			22	
ADJACENT ACCESS (continued)																										
OAR: of C	1	1			2	2							2	2							3	3			16	
OAJr.: from NT		1				2								1								1			5	
OAJr.: from B		1				3								1								1			6	87

UNIT TOTAL 439

Figure B-58. Natchez Trace VPP form—New Visual Elements (Alternative 2—Bridge).

NATCHEZ TRACE

UNIT VPP INVENTORY-LOSS OF SIGNIFICANT VISUAL RESOURCES

ALTERNATIVE NO. 1 - AT-GRADE

STATION	MAGNITUDE				ANGLE: HORIZONTAL				ANGLE: VERTICAL				DURATION/ VISIBILITY				SILHOUETTE				ASPECT				SUB TOTAL	TOTAL/ ELEMENT
	I	F	M	B	I	F	M	B	I	F	M	B	I	F	M	B	I	F	M	B	I	F	M	B		
VEGETATION																										
FORESTED AREAS	2	3			2	1							1	1			2	2			3	3			20	
TREE CANOPY	3	3			2	2							3	3			2	2			3	3			26	
																										46
ENCLOSED VIEW																										
OLD AGENCY ROAD	3	3			2	2							3	3							3	3			22	
NARROW DRIVES	2				1								1				2				3				9	
																										31
CLEARINGS																										
OPEN MEADOWS	2				2								3								1				8	
WEEDY FIELDS	2				2								3								1				8	
																										16
																									UNIT TOTAL	93

ALTERNATIVE 1
TOTAL: NEW POSITIVE VISUAL ELEMENTS - 177
TOTAL: NEW NEGATIVE VISUAL ELEMENTS - 305
TOTAL: NEW POSITIVE ELEMENTS LOST - 85
TOTAL: NEW NEGATIVE ELEMENTS LOST - 8

TOTAL VISUAL CHANGE = 575

NET VISUAL CHANGE = -205

Figure B-59. Natchez Trace VPP form—Lost Visual Elements (Alternative No. 1—At-grade)

NATCHEZ TRACE

UNIT VPP INVENTORY-LOSS OF SIGNIFICANT VISUAL RESOURCES

ALTERNATIVE NO. 2 - BRIDGE

STATION	MAGNITUDE				ANGLE: HORIZONTAL				ANGLE: VERTICAL				DURATION/ VISIBILITY				SILHOUETTE				ASPECT				SUB TOTAL	TOTAL/ ELEMENT
	I	F	M	B	I	F	M	B	I	F	M	B	I	F	M	B	I	F	M	B	I	F	M	B		
VEGETATION																										
FORESTED AREAS	1	2			2	1							1	1			2	2			3	3			18	
TREE CANOPY	1	1			2	1							1	1			2	2			3	3			17	
																										35
ENCLOSED VIEW																										
NARROW DRIVES	2				1								1								3				7	
																										7
CLEARINGS																										
OPEN MEADOWS	2				2								3								1				8	
WEEDY FIELDS	2				2								3								1				8	
																										16
																									UNIT TOTAL	58

ALTERNATIVE 2
TOTAL: NEW POSITIVE ELEMENTS - 147
TOTAL: NEW NEGATIVE ELEMENTS - 292
TOTAL: EXISTING POSITIVE ELEMENTS LOST - 50
TOTAL: EXISTING NEGATIVE ELEMENTS LOST - 8

TOTAL VISUAL CHANGE = 497

NET VISUAL CHANGE = -187

Figure B-60. Natchez Trace VPP form—Lost Visual Elements (Alternative No. 2—Bridge)

Figure B-61. Typical view of Natchez Trace Parkway from adjacent road as an example of new visual impact.

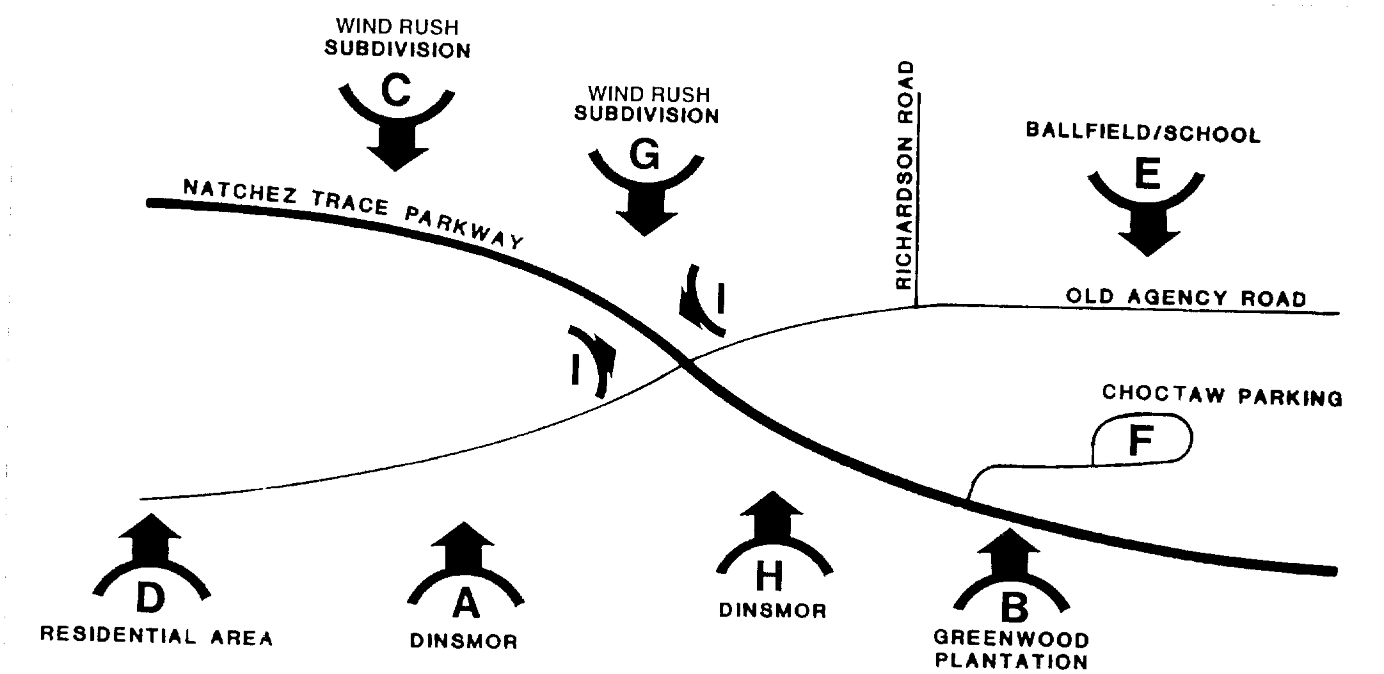


Figure B-62. Viewpoints selected for visual impact assessment adjacent to the roadway corridor.

forested areas, enclosed views down narrow driveways, and open meadows. A significant visual resource which would be lost under Alternative 1 includes a section of historic tree canopy along Old Agency Road and an enclosed view in that location (due to the removal of the tree canopy) (see figure B-63).

The VPP inventory scores of Fill 'd' are described below to demonstrate the inventory process on this project. Fill 'd' extends from Station 848+00 to 854+00, with a maximum height of 8 ft (2.4 m), and an approximate square footage of 2,700 sq ft (250.8 sq m) in Alternative 1 (see figure B-64). Fill 'd' is significantly larger in Alternative 2, extending from Station 845+00 to 854+00 at a maximum height of 28 ft (8.53 m), with an approximate square footage of 18,000 sq ft (1,672.2 sq m) (see figure B-65). The fill is in the value range with a numerical score of 3 for the magnitude variable in Alternative 2, and a 2 for magnitude in Alternative 1, when viewed from the Natchez Trace (NT).

The fill is visible from Natchez Trace Parkway, in the immediate foreground and foreground distance zones, and from the Dinsmor subdivision (H), in the foreground distance zone, in both alternatives. In alternative 1, the fill is also visible from the proposed "Old Trace" pedestrian/interpretive area(s) (I) in the foreground distance zone. In Alternative 2, the fill is visible from Old Agency Road (OAR) in the immediate foreground distance zone.

The angle of view scores for Fill 'd' are as follows: In Alternative 1 and 2, the angle of view from Natchez Trace in the immediate foreground and foreground distance zones are 2 and 1 respectively. The angle of view from the Old Trace in Alternative 1 is 2, direct. The angle of view from Dinsmor is 3, direct.

In Alternative 2, the angle of view from the Old Agency Road is 2. The angle of view from Dinsmor is 3, direct. The duration of view/visibility scores vary. In both alternatives, the duration of view/visibility is 3 from the immediate foreground at Natchez Trace, as the fills are in view for more than 6 sec at 60 mph (96.6 km/h) and a 1 from the foreground view from Natchez Trace. In Alternative 1, the fill receives a 2 when viewed from the Old Trace, because of the viewing time of pedestrians. The fill receives a 2 from Dinsmor, because the new access road which would be between Dinsmor and the fill would somewhat reduce the visibility of this new fill associated with Natchez Trace.

In Alternative 2, the fill receives a 2 when viewed from Old Agency Road because of the existing trees which would largely screen the view of the fill from the vehicles traveling on that road. The actual *duration of view* from Old Agency Road is estimated to be 4 sec. The fill receives a 3 when viewed from Dinsmor because of its high visibility. Computer enhanced photos, figures B-66 through B-72, show the existing views and the two alternatives viewed from the Dinsmor subdivision (location A) and from the Old Agency Road (location B). These images are helpful in assessing accurate scores for the various elements in each alternative.

The total fill scores are 77 for Alternative 1, and 71 for Alternative 2, indicating that the total visual impact of fills is greater in the at-grade alternative than in the bridge alternative, even though the fill at the actual structure is a larger impact in Alternative 2.

Tally Total Values

The scores for the other visual elements were tallied for the unit. After the alternative is selected, the scores for each element can be used to determine VPL's. Each of the categories of new visual elements are totaled for the alternatives below:

	Alternative 1	Alternative 2
Cuts	80	57
Fills	77	71
Views	71	71
Adjacent access roads	113	87
Bridge	0	43
Adjacent development	141	110
Total	482	439

The inventory of significant visual resources which will be lost, inventoried for both alternatives, resulted in the following:

	Alternative 1	Alternative 2
Vegetation	46	35
Enclosed views	31	7
Clearings	16	16
Total	93	58

Total and Net Visual Change

By adding the above visual elements at their positive/neutral or negative values, the Total Visual Change and Net Visual Change for each alternative can be calculated:

	Alternative 1	Alternative 2
a. Total negative visual elements	305	292
b. Total neutral, positive visual elements	177	147
c. Total positive elements lost	85	50
d. Total negative elements lost	8	8
Total Visual Change (TVC)	575	497
Net Visual Change (NVC)	-205	-187

The formula for TVC is: **a + b + c + d**
(305 + 177 + 85 + 8 = 575 for Alternative 1 and
292 + 147 + 50 + 8 = 497 for Alternative 2).

The formula for NVC is : **b + d - a - c**
(177 + 8 - 305 - 85 = -205 for Alternative 1 and
147 + 8 - 292 - 50 = -187 for Alternative 2).

The Total Visual Change indicates that Alternative 1 will have the biggest total impact on the project area, while the Net Visual Change indicates that this alternative also has the largest, overall negative visual impact in the area. While these calculations address the impacts which would result directly from these two alternatives, the local jurisdiction can utilize the information generated by the VPP.

The identification of significant visual resources in the area, for example, can be addressed as additional projects are proposed.

Field Check Preliminary Visual Priority Levels

After the preliminary inventory scores and alternative evaluation findings are completed, each score was checked in the field, from the viewing location, to insure appropriateness and accuracy. On this project, a much more detailed inventory was developed between the preliminary and final inventory stage.

SUMMARY—USE OF VPP IN ALTERNATIVE ANALYSIS

The TVC and NVC can be used as input for weighing visual resources in the alternative selection process, along with other resource, safety, and economic considerations involved. After the alternative has been selected, the visual element scores can be used to direct mitigation needs.

The total impact scores for fills is larger in Alternative 1, even though the largest fill, required at the bridge in Alternative 2 (from Station 845 to 854), is significantly larger than the fill required in Alternative 1. The total impact of associated access roads is also higher in Alternative 1, due to the closing of Old Agency Road and the construction of a new roadway to the south of Natchez Trace.

The summary of visual analysis factors is useful in comparing the total visual impacts of the two alternatives. The VPP process shows the context of each visual concern, for example, a view from one adjacent property when combined with the other significant visual issues. These findings can now be used in conjunction with comparing costs, local transportation impacts, and other factors associated in choosing the best alternative for this section of the Natchez Trace. When the alternative has been selected, the VPP findings can be used to design mitigation along the roadway to minimize the visual impacts.

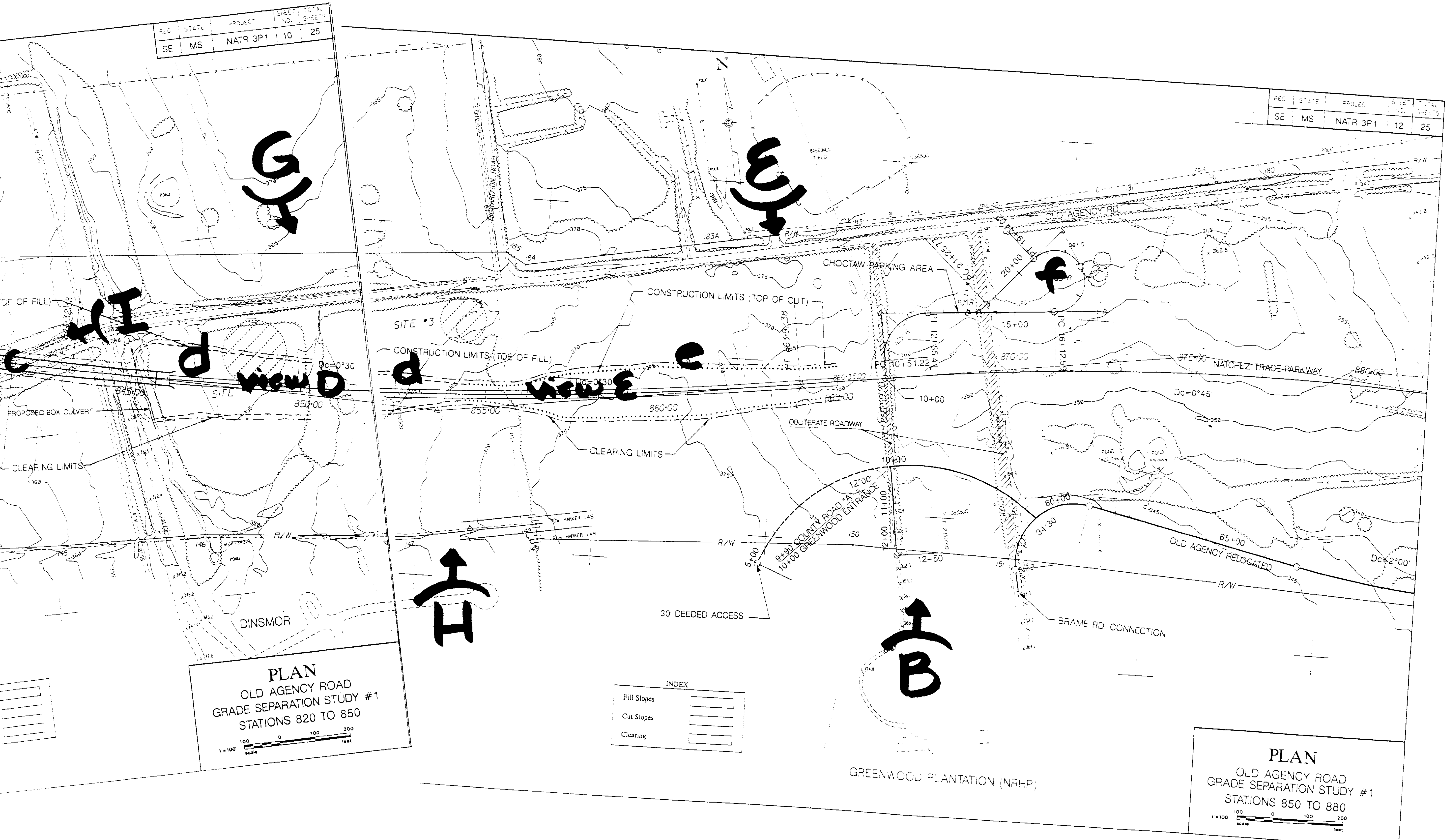
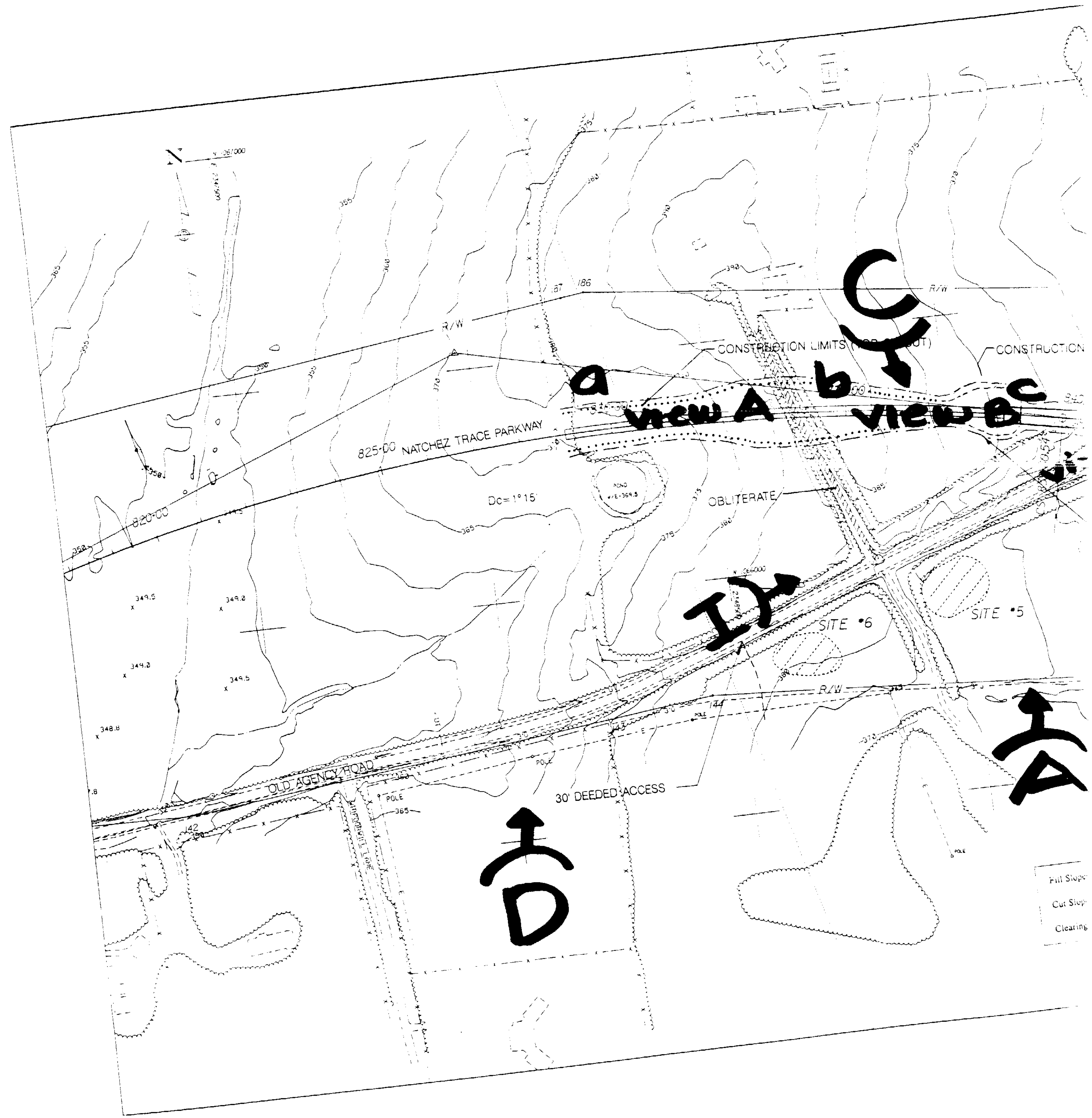
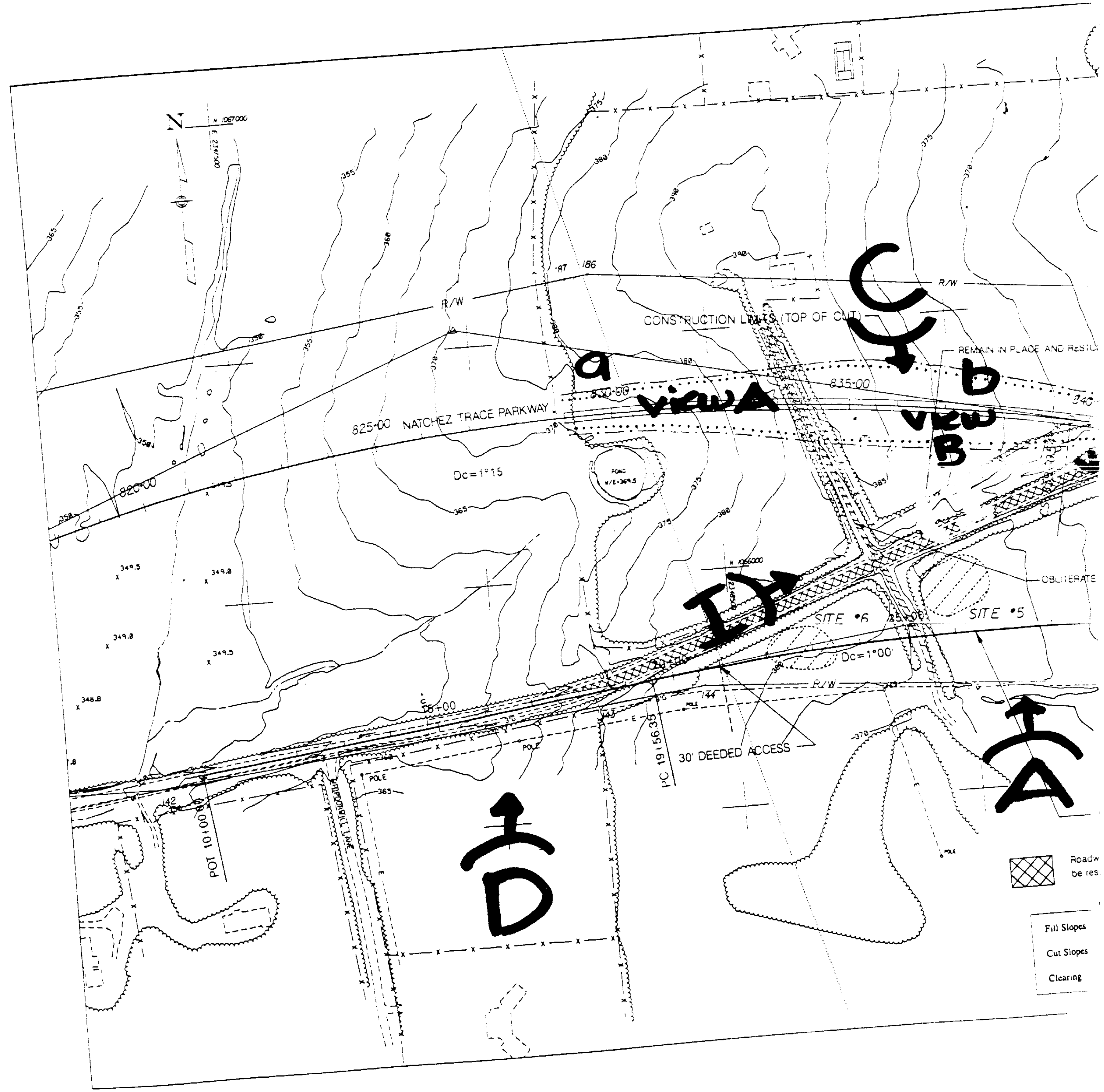


Figure B-64. VPP analysis of Alternative 1.



825+00 NATCHEZ TRACE PARKWAY
820+00
CONSTRUCTION LIMITS
CONSTRUCTION
R/W
OBLITERATE
Dc=1°15'
SITE #6
SITE #5
OLD AGENCY ROAD
30' DEEDED ACCESS
POLE
view A
view B
a
b
c
A
C
D
Fill Slope
Cut Slope
Clearing



NATCHEZ TRACE PARKWAY
CONSTRUCTION LIMITS (TOP OF CUT)
REMAIN IN PLACE AND RESTO
OBLITERATE
SITE #6
SITE #5
Dc=1°15'
Dc=1°00'
30' DEEDED ACCESS
PC 19+56.35
POT 10+00.00
825+00
820+00
835+00
View A
View B
A
B
C
D
Fill Slopes
Cut Slopes
Clearing

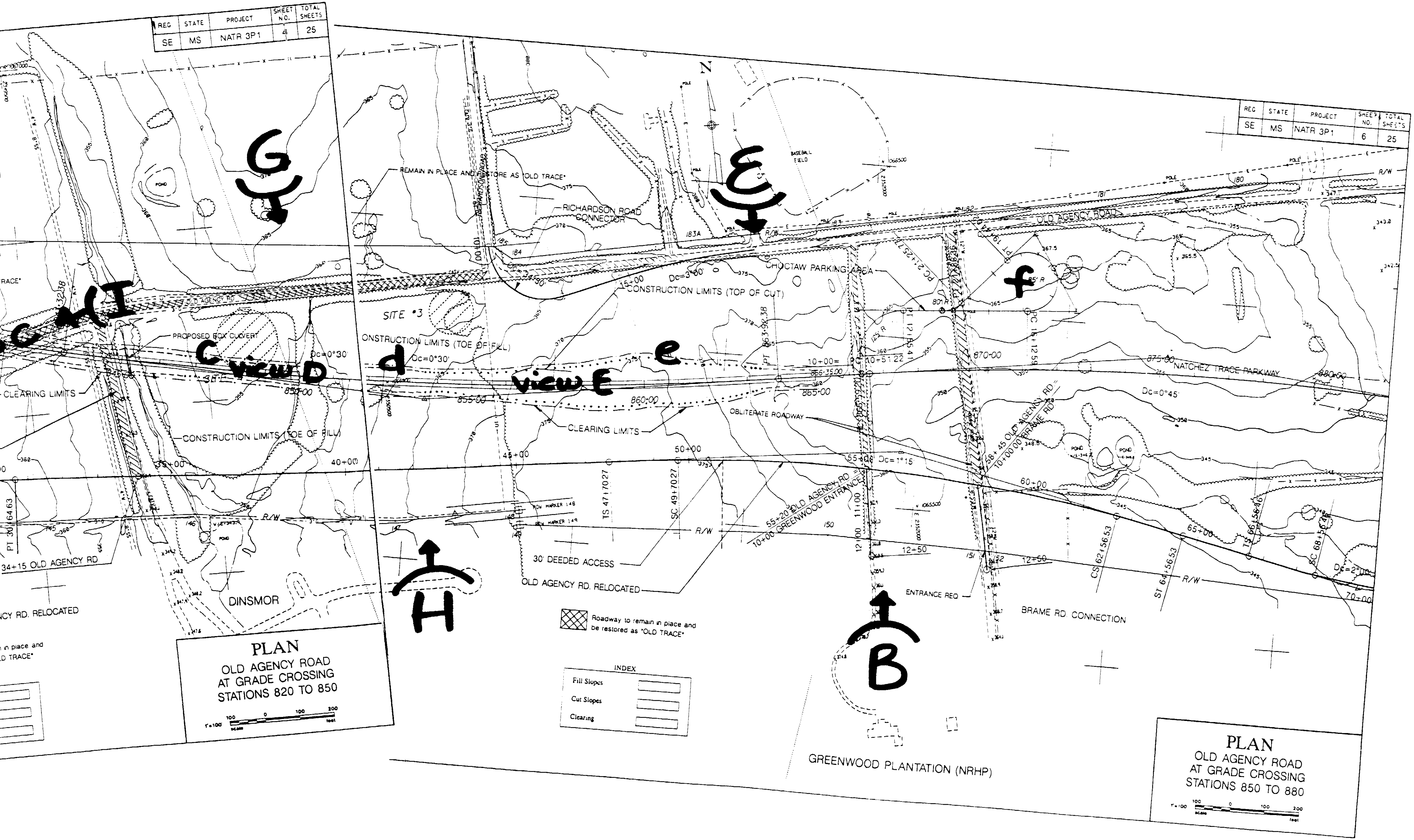


Figure B-65. VPP analysis of Alternative 2.

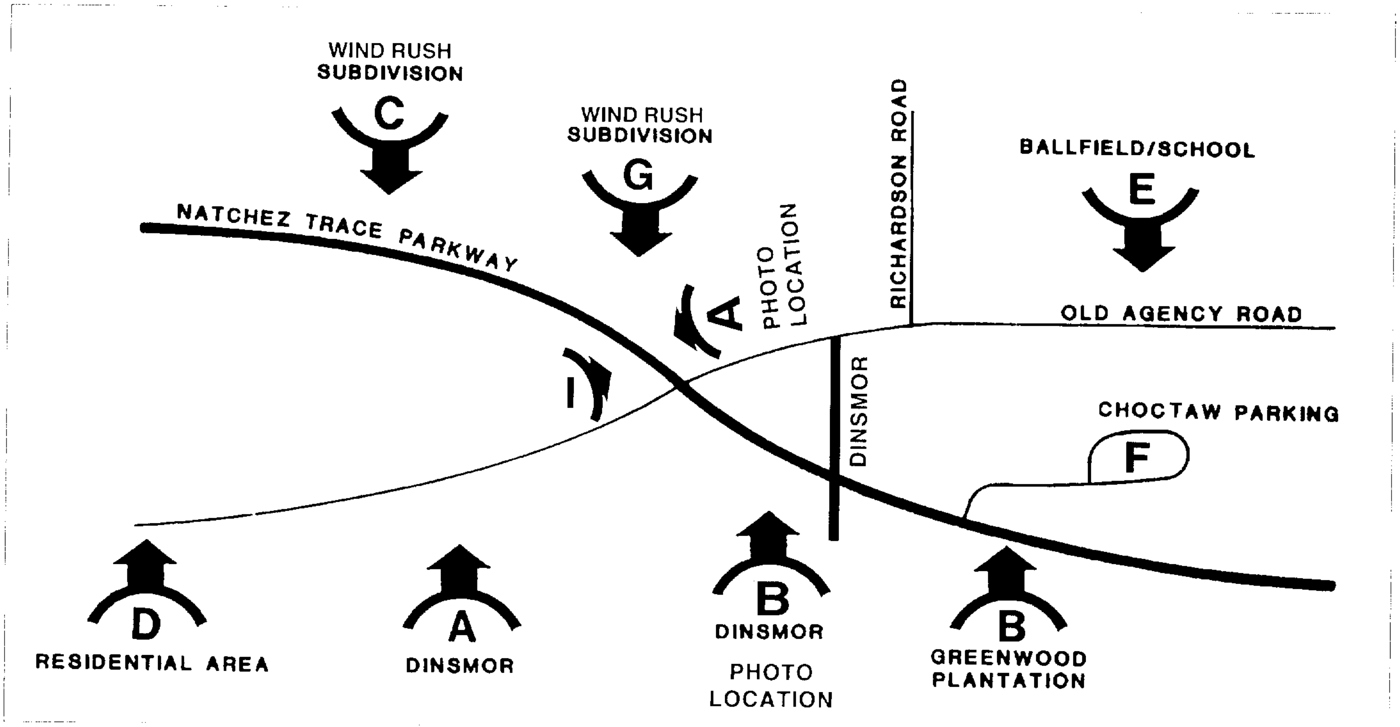


Figure B-66. Map showing site and locations.

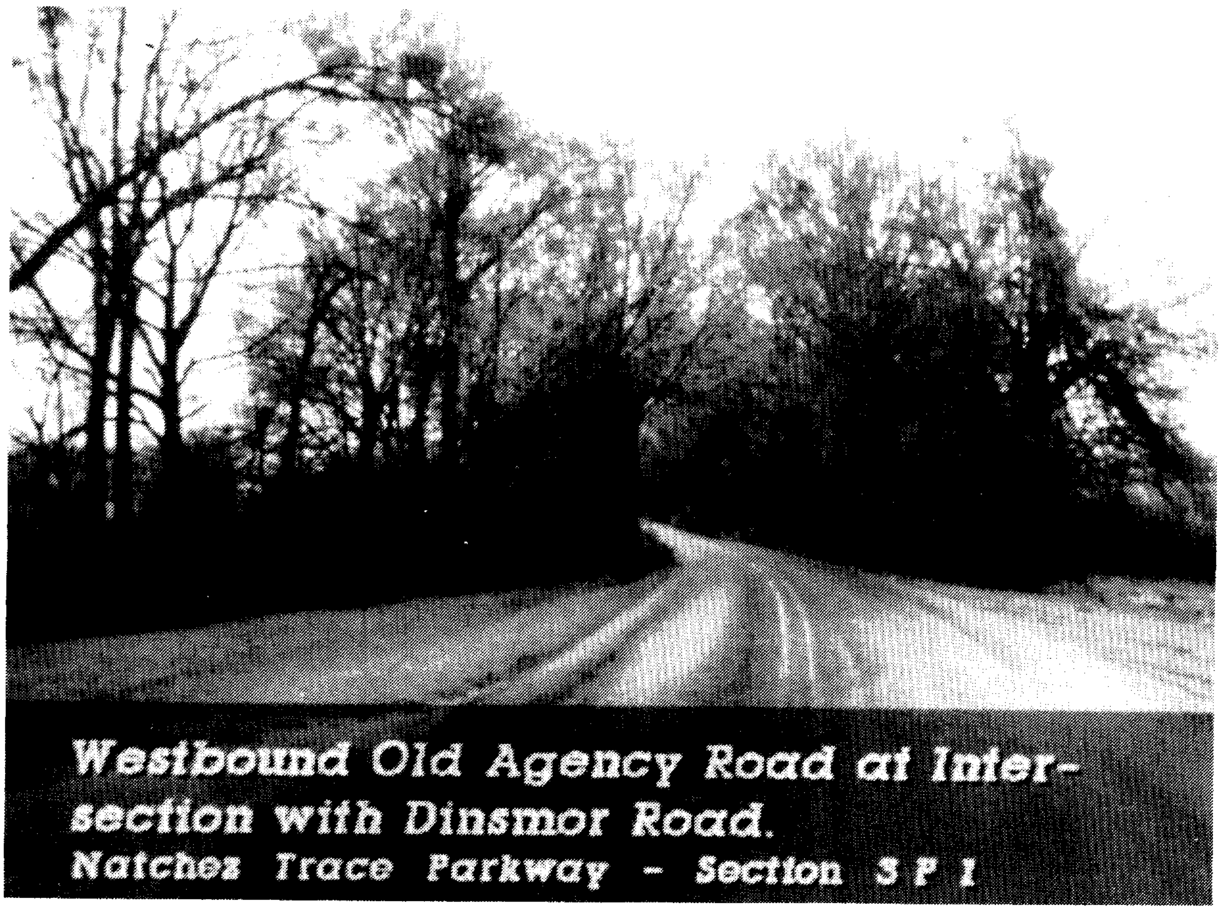


Figure B-67. Existing site from location A.

Figure B-68. Alternative 1—At-grade from location A.

Figure B-69. Alternative 2—Bridge from location A.

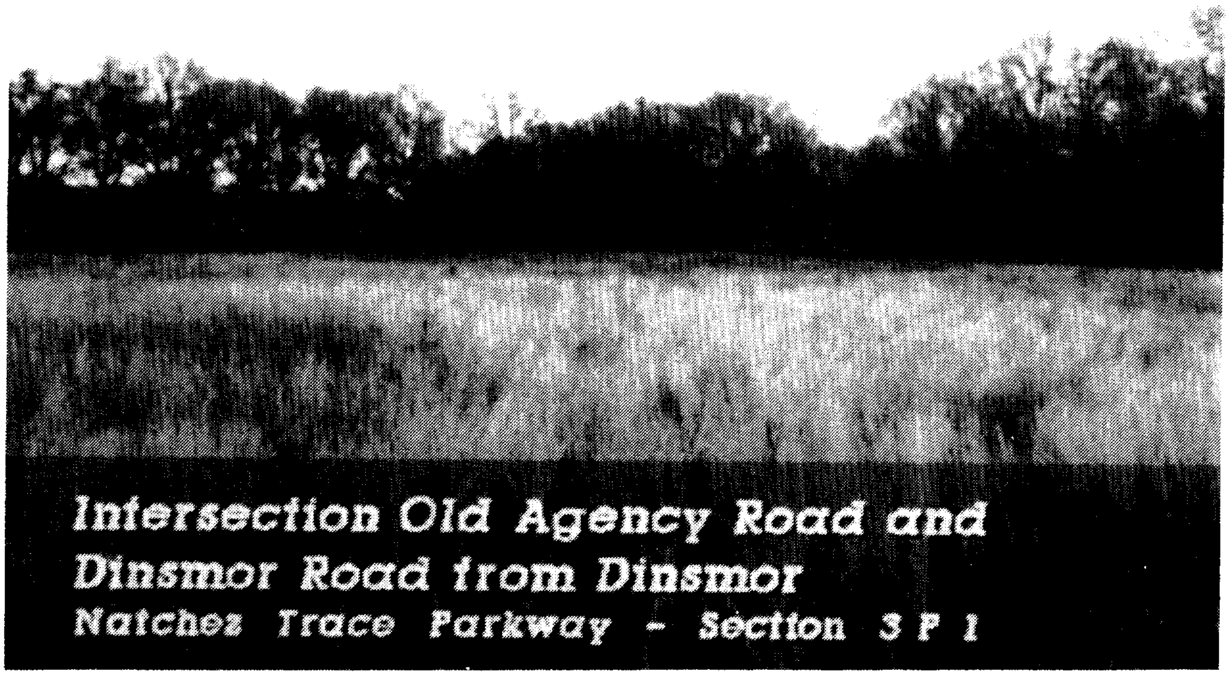


Figure B-70. Existing site from location B.

Figure B-71. Alternative 1—At-grade from location B.

Figure B-72. Alternative 2—Bridge from location B.

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Choosing by Advantages (CBA) A Decision-Making System

Those who recommend *Choosing By Advantages (CBA)*, and those who mention that they use it, are sometimes asked, "What is Choosing By Advantages? Where did it come from?" The following responds to these questions.

What is CBA?

There are many ways to describe *Choosing By Advantages*. Some say it is a **method** of decision making. Most decision makers and facilitators describe it as a **system** of decision making. Some describe it as a "whole technology ", or "a way of life."

The CBA system includes principles, definitions and models—in addition to methods. It includes a wide variety of methods, with different methods for different types of decisions. The CBA system is for individuals, groups, organizations, and communities. It is for everyone who participates in the decision-making process. Virtually all decisions—from the simplest to the most complex--call for the use of CBA methods.

The CBA process includes both mentally choosing (deciding) and physically choosing (doing). Because it includes both deciding and doing, it is called *Choosing By Advantages*, rather than Deciding By Advantages. For this same reason, some call it a management system.

In CBA, the Art of Decision Making includes three areas: sound decision making, congruent decision making, and effective decision making. The following definitions illustrate these three areas:

Sound Decision Making

Doing the right things. (This is where CBA training begins).

Congruent Decision Making

Doing the right things right—the first time, every time, and on time.

Effective Decision Making

Doing the right things right—the first time, every time, and on time—in a manner that is acceptable to various stakeholders who may have conflicting values and preferences.

Where Did CBA Come From?

The evolution of decision-making methodology, from primitive decision making to *Choosing By Advantages*, can be divided into the following time periods, or eras:

- Primitive Decision Making
- The Frontier Era
- The Proposal-Evaluation Era
- The Impact-Evaluation Era
- Choosing By Advantages

Each era produced a variety of methods, and these methods are still being used today. Valid principles and sound methods from each era are included in the CBA system. Many unsound methods were also produced, and they are excluded.

Primitive Decision Making

Decision making is a natural process. But there are many variations of the natural process. Commonly, in response to thoughts, feelings, observations, or whatever triggers the need for a decision, people naturally, automatically:

1. Make assumptions to fill in data gaps, and
2. Jump to a conclusion.

In the primitive era, assumptions were based on traditions and superstitions, in addition to past experience and present imagination. This method might have been adequate for a complex, rapidly-changing, modern society. The emergence of science moved decision making methodology into the frontier era.

The Frontier Era

In this era, the natural process was continued, but it was improved. In the natural process, people often combine a small amount of data from outside their minds. Then, they treat the combination as if it all comes from outside. The frontier era improved what was inside, as well as outside. Many old superstitions were replace by new scientific findings. However, frontier methods did not always produce better decisions, and they did not make the process visible.

People wanted to participate in the decision-making process. And when they recognized that government officials were using primitive and frontier methods for major decisions, they said: "Wait. Before you decide how to spend our taxes, we want you to **propose** and **evaluate** all major projects and programs, and we want to see the rationale for each decision." This moved decision-making methodology into the proposal-evaluation era.

The Proposal-Evaluation Era

Proposal-evaluation methods were very limited. For example, one method of evaluating proposals simply weighed the market-valued benefits of the proposal against the direct costs. These methods produced conflict—not effective participation. Those who were proponents of the proposal lined up on one side, those who were opponents lined up on the other side, and they shouted at each other. To make matters worse, proposal-evaluation methods did not evaluate alternatives. People said: "Before you decide, we want to see all the social, economic, and environmental impacts—both positive and negative—of all the relevant alternatives. This moved decision-making methodology into the impact-evaluation era.

The Impact-Evaluation Era

During the impact-evaluation era, the decision-making process, and many of the resulting documents, were horribly complex. Some environmental impact statements were hundreds of pages long and incomprehensible. Methods were developed that did not qualify as sound methods. One that is widely used today is called Weighting-Rating-and-Calculating. The central activities of this method are:

1. Assign numerical **WEIGHTS** to the factors that are important in the decision. (Research has shown, conclusively, that this is a critical mistake.)

2. Display the attributes of the alternatives, and **RATE** each alternative in each factor. (Rating alternatives, or their attributes, is also a critical mistake.)

3. For each alternative in each factor, multiply the weight of the factor times the rating of the alternative to **CALCULATE** an individual score. (This activity multiplies mistakes times mistakes.)

4. Choose the alternative with the greatest total score.

The need to correct these and other mistakes, coupled with the need to simplify, clarify, and unify the decision-making process, is moving decision-making methodology into the era of *Choosing By Advantages*.

Choosing By Advantages

The development of the CBA system required several decades of designing, testing, and improving—building on the best of what had developed before. Many individuals and groups— mostly in the USDA Forest Service—participated in this development process. The result is a decision-making system that answers four vital questions:

1. How can we make sound decisions?

2. How can we simplify sound decision making?

3. How can we clearly show that our decisions are sound?

4. How can we make our decisions congruent and effective?

The CBA methods have been used successfully for a wide variety of decisions—from very simple to very complex. The results of these applications, and many careful examinations of the logic of the CBA process, have shown that the CBA system is sound, clear, simple, and effective.

Some CBA methods, but not all, are natural methods. All CBA methods base decisions, either implicitly or explicitly, on the importance of advantages—where an advantage is defined as a favorable difference between the attributes, or characteristics, of two alternatives. All disadvantages (unfavorable differences) are included by transforming them into advantages. Consider the following disadvantages, for example: "Route B is three miles longer than A." This becomes, "Route A is three miles shorter than B."

Only those methods that base decisions implicitly on the importance of advantages are natural methods. Basing decisions explicitly on the importance of advantages is a skill that has to be taught. In this regard, CBA is like reading, writing, mathematics, and other skills required in a modern society. Therefore, education is key to successful use of the CBA system. CBA workshops are available from:

The Institute for Decision Innovations
2877 North 1050 East
Ogden, Utah 84414
Telephone: (801) 782-6168

The following page is an outline of a three-day sound decision-making workshop. Similar workshops are available for congruent decision making and effective decision making.

(OUTLINE OF A 3-DAY SOUND DECISION-MAKING WORKSHOP)

INTRODUCTION: WHAT IS CBA?

PART I. SOUND DECISION MAKING: NON-MONEY DECISIONS

1. DECISIONS MUST BE ANCHORED TO THE RELEVANT FACTS
   - The Bridge-Design Experiment
   - Critical-thinking Skill for Sound Decision Making
2. DECISIONS MUST BE BASED ON THE IMPORTANCE OF ADVANTAGES
   - Key Definitions
   - Comparison Displays
   - The Two-List Method
3. DECISIONS AND DECISION METHODS DO MATTER
4. DIFFERENT DECISIONS REQUIRE DIFFERENT METHODS
5. SIMPLIFY COMPLEX DECISIONS BY TAKING FEWER STEPS
   - The Tabular Method
   - Special Methods for Complex and Very Complex Decisions
6. SIMPLIFY SIMPLE DECISIONS BY TAKING FEWER STEPS
   - The Simplified Tabular Method
   - TheSimplified Two-List Method
   - Instant CBA
   - Very Simple Methods for Very Simple Decisions
7. SIMPLIFY ALL DECISIONS BY CORRECTLY USING CORRECT DATA
   - The Sound Decision-Making Model
   - Preference Curves and Preference Charts

PART II. SOUND DECISION MAKING: MONEY DECISIONS

8. MONEY DECISIONS REQUIRE SPECIAL METHODS
9. DIFFERENT CONTEXTS REQUIRE DIFFERENT METHODS
   - Context One
   - Context Two
   - Context Three
   - Context Four
   - Allocation Decision Making

PART III. THE ART Of DECISION MAKING

THE CBA MODEL OF THE ART OF DECISION MAKING

IMPLEMENTATION AND OPERATION OF THE CBA SYSTEM

CONCLUSION: HOW TO BECOME AN ARTIST IN THE ART OF DECISIONMAKING

APPENDIX E—PERFORMANCE INDEXING

Process Map makes use of a performance indexing scheme similar to the Objectives Matrix developed at the University of Oregon. Conceptually, here's how it works in basic steps:

1. Select the measures.

2. Enter the available data for the first measure.

3 Specify a goal somewhat above what has been achieved to date.

4. Specify a minimum level of achievement, below which no performance level is acceptable.

5. Convert goal and minimum performance level numbers into a 10 point scale, (where the total is a 10 and the minimum is a 0) thus creating an indexed scale.

6. Repeat steps 2 through 5 for the other measures.

7. Assign weights to the measures, with higher weights assigned to those measures which are relatively more important.

8. As new measurement data becomes available, Process Map will automatically calculate each new data point number on its particular indexed scale, multiply it by the weight assigned to its particular measure, and add these totals to create a time-trended overall performance index. Now, performance trends can be viewed overall and different measures can be compared with each other on a common scale.

The benefits of performance indexing are significant. By forcing goals to be set, measurements can proceed in a context of improvement as opposed to measurement for its own sake. By assigned relative weights to the goals, the performance mission becomes very sharply defined; what's important becomes clear and relative priorities have been set. By focusing on time trends instead of single data points, an orientation towards continuous improvement is fostered. By developing the performance index in a participative fashion, multiple ideas can be welded together, understanding of good measurement promoted, and commitment developed.

By using the performance index graphically on a regular basis, progress reviews and update meetings can take on more of a problem-solving orientation as opposed to an "explain what the numbers mean" session. And by automating the calculations required for indexing, measurement becomes a useful tool instead of a laborious number-crunching exercise.

APPENDIX F—LIST OF ABBREVIATIONS

B — Background

BLM — Bureau of Land Management

CBA — Choosing By Advantages

CTIP — Coordinated Federal Lands Highway Technology Implementation Program

EA — Environmental Analysis

EIS — Environmental Impact Statement

F — Foreground

FHWA — Federal Highway Administration

I — Intermediate Foreground

M — Middleground

NPS — National Park Service

NVC — Net Visual Change

SCS — Soil Conservation Service

SMS — Scenery Management System

TVC — Total Visual Change

VMS — Visual Management System

VPL — Visual Priority Level

VPP — Visual Prioritization Process

VRM — Visual Resource Management

Angle of View--the horizontal and/or vertical angle between the observer's direct line of sight and the line of sight to view the element, ranging from direct to peripheral.

Aspect—the orientation of the element to the observer, ranging from facing direct to facing away.

Background—distance zone farthest from the observer, normally more than 5mi (8.1 km).

Character—the distinctive natural, cultural, social, and historical resources of a geographical area including the "feeling" of the area.

Character Zones—sections with similar visual resources within an area.

Characteristic Landscape—visual resources typical for the character zone.

Distance Zones—areas within a specified distance of the observer, normally described as Immediate Foreground, Foreground, Middleground, and Background. It is based on variables such as speed, aspect and angle of view.

Duration of View--the amount of time the observer can view the elements and is based on speed, aspect and angle of view.

Elements—visual resources that are natural, cultural, social or historical, such as vegetation, walls, rock formations, utility poles, historical buildings, etc.

Foreground—distance zone near the observer, normally 300-700 ft (91.4-213.4 m).

Magnitude—the size or scale of the element.

Middleground—distance zone between foreground and background, normally 700 ft-5 mi (213.4 m-8.1 km).

Mitigation—the size or scale of the element.

Net Visual Change—a measure of the predicted difference in visual resources resulting from a proposed project. The total score of all the negative visual resources subtracted from the total score of all the positive visual resources within unit.

Numerical Score—numbers which stand for the value of a variable tabulated on the inventory forms and typically are 1, 2, and 3.

Retention—a Forest Service Visual Objective intended to keep construction unnoticeable to observers upon completion of the project.

Significant—being important enough for mitigation based on visual management objectives, environmental laws and viewer opinion.

Silhouette—background of element either vegetation, sky, or no background based on angle of view.

Proposed Visual Element/Resource—elements that will be new to the area due to construction, such as, cuts, fills, bridges, retaining walls, view areas.

Total VisualChange—the total numerical score when the total score of all the negative visual resources are added to the total score of all the positive visual resources. This total is for the visual unit and is based on changes that the project will cause.

Variables—six items used to determine relative importance of elements to the visual goals of the area. The six items are: distance from viewer, magnitude, angle of view, duration of view, silhouette and aspect.

Values—definition of the three portions of each variable for each numerical score, such as the value of 0-600 sq ft (55.7 sq m) for the variable-Magnitude. The range will vary with each project.

View Points—specific location of observer when viewing elements for determination of values for variables, such as, distance from viewer, duration of view, silhouette, angle of view and aspect.

View Sheds—the total view of an element or area from all the potential observer locations.

Viewing Public—any observers of the elements including drivers, hikers, picnickers, campers, property owners, workers.

Visual Units—sections within a land management area that have similar visual resources.

Visual Priority Level—the relative importance of the element/unit compared to the other units. This is based on the various subtotals, such as, the elements total score, units total score, the net visual change, the total visual change. There are normally three levels with the highest scores being in priority level 1 (most relative importance) to the lowest scores being in level 3 (least relative importance).

UNIT VPP INVENTORY-NEW VISUAL ELEMENTS

UNIT NO.____________________

STATION	MAGNITUDE				ANGLE: HORIZONTAL				ANGLE: VERTICAL				DURATION/ VISIBILITY				SILHOUETTE				ASPECT				SUB TOTAL	TOTAL/ ELEMENT
	I	F	M	B	I	F	M	B	I	F	M	B	I	F	M	B	I	F	M	B	I	F	M	B		
CUTS																										
FILLS																										
WALLS, RAILING, GUARDRAIL																										
BRIDGES																										
STRUCTURES																										
																									UNIT TOTAL	

(NEGATIVE, POSITIVE, OR NEUTRAL?)

UNIT VPP INVENTORY-LOSS OF SIGNIFICANT VISUAL RESOURCES

UNIT NO.____________________

STATION	MAGNITUDE				ANGLE: HORIZONTAL				ANGLE: VERTICAL				DURATION/ VISIBILITY				SILHOUETTE				ASPECT				SUB TOTAL	TOTAL/ ELEMENT
	I	F	M	B	I	F	M	B	I	F	M	B	I	F	M	B	I	F	M	B	I	F	M	B		
VEGETATION																										
WALLS																										
STRUCTURES																										
ENCLOSED VIEW																										
OPEN VIEW																										

UNIT TOTAL ____

(NEGATIVE, POSITIVE, OR NEUTRAL)

PP INVENTORY - NEW VISUAL ELEMENTS

UNIT NO.

STATION:	ELEMENT NUMBER		MAGNITUDE Sq. Feet	MAGNITUDE Score	ANGLE HORIZONTAL Angle	ANGLE HORIZONTAL Score	ANGLE VERTICAL Height	ANGLE VERTICAL Score	DURATION/ VISIBILITY Seconds	DURATION/ VISIBILITY Score	SILHOUETTE Description	SILHOUETTE Score	ASPECT Aspect	ASPECT Score	SUB TOTAL	TOTAL/ ELEMENT
2202 - 2215	1E	I	86,401	3	9	3	66.5	2	8	3					11	21
comments: CUT - 1300' total length		F	86,401	3	9	3	66.5	2	7	2					10	
		M		0		0		0		0					0	
		B		0		0		0		0					0	
2202 - 2215	1W	I	85,348	3	9	3	66	2	8	3					11	18
comments: CUT		F	85,348	3	22	1	66	2	3	1					7	
		M		0		0		0		0					0	
		B		0		0		0		0					0	
2215 - 2225	2E	I	53,676	3	11	2	54	2	7	3					10	18
comments CUT - 1000' total length		F	53,676	3	16	2	54	2	6	1					8	
		M		0		0		0		0					0	
		B		0		0		0		0					0	
2215 - 2225	2W	I	44,739	2	3	3	45	2	7	3					10	27
comments: CUT		F	44,739	2	5	3	45	2	12	2					9	
CUT		M	44,739	2	5	3	45	2	5	1					8	
		B		0		0		0		0					0	
2225 - 2236	3E	I	67,667	3	0	0	0	0	0	0					3	6
comments: FILL - 1100' total length		F	67,667	3	0	0	0	0	0	0					3	
		M		0		0		0		0					0	
		B		0		0		0		0					0	
2225 - 2236	3W	I	62,420	3	0	0	0	0	0	0					3	10
comments: FILL		F	62,420	3	0	0	0	0	0	0					3	
		M		0		0		0		0					0	
		B		0	15	2		0	8	2					4	

UNIT VPP INVENTORY - NEW VISUAL ELEMENTS
UNIT NO.

STATION:	ELEMENT NUMBER		MAGNITUDE Sq. Feet	MAGNITUDE Score	ANGLE HORIZONTAL Angle	ANGLE HORIZONTAL Score	ANGLE VERTICAL Height	ANGLE VERTICAL Score	DURATION/ VISIBILITY Seconds	DURATION/ VISIBILITY Score	SILHOUETTE Description	SILHOUETTE Score	ASPECT Aspect	ASPECT Score	SUB TOTAL	TOTAL/ ELEMENT
		I		0		0		0		0					0	0
comments:		F		0		0		0		0					0	
		M		0		0		0		0					0	
		B		0		0		0		0					0	
		I		0		0		0		0					0	0
comments:		F		0		0		0		0					0	
		M		0		0		0		0					0	
		B		0		0		0		0					0	
		I		0		0		0		0					0	0
comments:		F		0		0		0		0					0	
		M		0		0		0		0					0	
		B		0		0		0		0					0	
		I		0		0		0		0					0	0
comments:		F		0		0		0		0					0	
		M		0		0		0		0					0	
		B		0		0		0		0					0	
		I		0		0		0		0					0	0
comments:		F		0		0		0		0					0	
		M		0		0		0		0					0	
		B		0		0		0		0					0	
		I		0		0		0		0					0	0
comments:		F		0		0		0		0					0	
		M		0		0		0		0					0	
		B		0		0		0		0					0