Attachment 1

Excerpt from:
Determining Existing Visibility Impairment in the Mt. Zirkel Wilderness Area, Daniel W. Ely, Colorado Department of Public Health and Environment, Air Pollution Control Division, presented at the conference on Aerosols and Atmospheric Optics: Radiative Balance and Visual Air Quality, sponsored by the Air & Waste Management Association and American Geophysical Union, Snowbird, Utah, September 26-30, 1994.

Endnotes and references have been deleted from this excerpt.

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FACTORS INFLUENCING THE ZIRKEL RA STUDY

Away From a Large-Scale Study

During much of the time since the USFS announced its intention to certify impairment at MZWA, the Air Division has been reluctant to get involved in a multi-million dollar visibility study. The Air Division perceived that a "large-scale study" had a number of undesirable aspects.

Expensive. The Navajo Generating Station Visibility Study (NGSVS) is rumored to have cost approximately $20 million. When combined with the costs of the WHITEX study and Project MOHAVE the amounts of money aimed at understanding the influence of local power plants on the Grand Canyon National Park may be approaching $30-$40 million.

Time Consuming. The Air Division was concerned that a large-scale study could take 2-4 years based on the studies around the Grand Canyon National Park (e.g., WHITEX, NGSVS and Project MOHAVE) and a strong message from the Ninth District Court's review of the NGS case was that this level of study was not necessarily needed. A very focused scientific study of shorter duration could fulfill the objectives of a larger study.

Unattainable Aspirations. The state of the science to determine a particular source's quantitative contributions to a visibility impairment problem is such that most studies are not definitive. This belief was strongly underlined by the two National Academy of Sciences reports: Protecting Visibility in National Parks and Wilderness Areas and Haze in the Grand Canyon: An Evaluation of the Winter Haze Intensive Tracer Experiment. It seemed to the Air Division and a number of the ZAQS Collaborative participants that a small-scale study (e.g., modeling, limited source sampling and limited aerosol, visibility, and meteorological monitoring) would essentially yield the same policy results as a large-scale study.

Largely Irrelevant. Choosing to generate large amounts of information that the NAS stated would likely be "uncertain" has not seemed like the best public policy decision to the Air Division. In addition, the Air Division carefully weighed the words of the Ninth District Court ruling on the NGS case that indicated that the Congressional intent in carrying out this program has never depended on a high level threshold of certainty. Instead the court, quoting the NAS study, found that:

> NAS acknowledged that Congress did not "require EPA to show a precise relationship between a source's emissions and all or a specific fraction of the visibility impairment within a Class I area." (pp. 9-10)

The National Academy of Sciences correctly noted that Congress has not required ironclad scientific certainty establishing the precise relationship between a source’s emissions and resulting visibility impairment:

> [As NAS noted the] phrase “may reasonably be anticipated” suggests that Congress did not intend to require EPA to show a precise relationship between a source’s emissions and all or a specific fraction of the visibility impairment within a Class I area. (pp. 21-22)

Uncertainty is Here to Stay. The NAS study and the Navajo court decision have created a strong dual argument that not only is a large-scale study likely to result in less than definitive answers but the level of certainty sought by such studies is not needed in the regulatory process. The regulatory agency must assemble a reasonable set of technical information to justify its decision making and may do so under conditions of scientific uncertainty. The two NAS studies and the NGS court decision strongly influenced the thinking of the Air Division early in the negotiation process regarding how much additional information needed to be collected.

Science Can’t Answer the Question. "What to do?" is never a scientific question. Science can rarely provide information so certain that it commands action. It is not the scientist who defines the degree of certainty needed in a given situation. The Air Division looked to Congress, EPA’s established agency policy, evaluations of the state-of-the-science (such as the NAS), the courts and the Colorado legislature for guidance on what to do. The Air Division found little to recommend a large-scale effort.

"Bogged-Down." The federal land manager, EPA, local government, and the environmental groups all wanted the Air Division to act quickly and a large-scale study seemed counter to those desires. Specific concerns have been expressed to the Air Division by environmental groups that once one gets involved in a comprehensive study, there is a strong temptation to do more studies and more studies as each one in turn raises as many questions as it provides answers. This seemingly endless cycle of study may stray into areas of uncertainties that are far from the core regulatory questions and "bog down" the process.

Toward a Larger-Scale Study

By the end of 1993 the Air Division was convinced that the *only way* to move ahead was to join in a public/private partnership with industry. Such arrangements are more and more common throughout the country and have a number of advantages including the elimination of ‘dueling studies’ that often frustrate decision makers. A relatively modestly sized $2-3 million study is being planned with the USFS and the owners of the Craig and Hayden power stations and will develop information that can be used both for reasonable attribution and, if necessary, feed into BART as well. The study will be completed by July 1, 1996. The author believes that the Air Division did undergo an evolutionary shift in emphasis from one set of factors to another set as it became more evident what was necessary for it to carry out its responsibilities. What were some of the factors that influenced a change toward embracing the larger study? Below is a discussion of some of theses factors that in combination may have influenced the State's actions and may affect any other state attempting to respond to a federal land manager certification.

Lack of Consensus. Recognizing the contentious nature of past visibility studies, the Air Division believed it was worth trying to put together a consensus study through the ZAQS Collaborative. While it recognized that there would likely be disagreements about any later regulatory decision making, the Air Division very much wanted to develop a collaborative common-ground information base as a platform for decisions with all the participants of the ZAQS Collaborative. The Air Division tried to bridge the gap between environmental groups that believe current information was sufficient and potentially affected industry that wants a large study. Various approaches were attempted for nearly a year and the efforts were not successful.

Potential Cost of Control Equipment. The potential cost of additional air pollution control equipment on the two power plants named as suspected sources of visibility impairment in the USFS letter of certification is likely to be considerable. The potentially affected utilities have argued that given this potential it is reasonable and fair to conduct a study of the situation that consists of a year of field monitoring as well as analysis of the data and modeling. The Air Division has recognized that the more costly a decision might be to an affected party, the more reasonable it appears to attempt to be more certain about the outcome -- even if this is not legally necessary.

"Good Science." The electric utilities have consistently stated they want a well planned, peer reviewed study based on sound science and a year of "real" site-specific data -- as opposed to only modeled results. The Air Division has found it awkward to argue against this. To do so appears that the Air Division is somehow against "good science."

Buy-in of the Scientific Community. Visibility studies that have potential regulatory implications have often been controversial. Some have spawned considerable scientific disputes. The Air Division has considered that a factor in a successful outcome to this regulatory process may be the buy-in of the visibility community to the scope and technical aspects of the reasonable attribution study. Several visibility scientists have cautioned the Air Division against moving ahead unilaterally without gaining scientific input at the risk of having the credibility of the study effort seriously undermined from the moment it begins. The Air Division has recognized that scientific input would likely lead to a larger-scale study.

Money for Studies. Money has created different dynamics than those that existed when EPA, federal land managers and potentially affected electric utilities conducted studies of the Navajo and Mohave power plants. Monetary resources of the federal government were applied to these situations in significant amounts to conduct studies, with or without industry assistance.

In the Mt. Zirkel Wilderness situation, the electric utilities and the Air Division each knew that the other would do a separate study if they did not do one together. The electric utilities stated that $2-4 million had been set aside to spend over the next 2-3 years. The Air Division determined that on their own they could put together approximately $20,000 to $50,000 this year and possibly another $50,000 the next. While the value of information is not always its cost, this large factor of 10 to 50 times more money to spend on buying information provides a considerable advantage. The Air Division saw that a risk was that, while it did not have to answer every question raised about any potential findings of its studies to stand the test of being "reasonable" in its decision making, a separately funded industry study could create enough doubt about the much smaller State study as to substantially undermine it.

Dueling Studies, the Overzealous Bureaucrat and Scientific "Due Process." The Air Division perceived further risks in separate industry and regulator studies. It could not shape nor have input into the industry sponsored study. In addition, if the Air Division reached a reasonable attribution determination based on its small-scale study before the much expanded industry study was complete, there was an opening created for the industry to stop the regulatory process. Industry could argue before state legislative and administrative appeal bodies that the Air Division was being overzealous given that a great amount of additional "good science" would become available in just a few more months. The Air Division's decision could be frozen until the results of the larger study were complete. The Air Division has acknowledged that a larger study can produce a lot more information, can assist with BART if necessary, and, given the potential for large control costs, seems to satisfy the need for scientific "due process."

Attitudes toward FLMs in the Western U.S. A number of Colorado state legislators and industry representatives have stated that they believe the federal land managers (FLMs) are hypocritical. They believe that the FLMs also produce air pollution, often in or near Class I areas, that may affect visibility in the Class I area and are not held accountable for it, yet these very same FLMs can certify visibility impairment and name existing stationary sources as suspects. This has led to a section of SB 94-217 calling for the Air Division to review FLM activities. In addition, a number of these same people also hold the belief that the USFS' certification of visibility and aquatic ecosystems in the Mt. Zirkel Wilderness was based on inadequate science. This has been an additional reinforcing argument for their point that the reasonable attribution study should be based on "good science" and scientific "due process."

"All Politics Is Local." This famous phrase, attributed to former Congressman Tip O'Neill, has some application in this situation. While the Air Division believes that a small study is all that may be needed to meet a legal challenge to any regulatory decision that may be made later, the Air Division has had to consider whether a federal district court judge is really, ultimately, the entity a regulatory decision by the Colorado Air Division must satisfy as being reasonable. The Air Division must also contend with the Colorado legislature, the Air Quality Control Commission (to which the Air Division's decisions can be appealed), local government in the affected area, local media, and the people of the State of Colorado. The Air Division has had to consider how to position itself in order for a potential regulatory decision to be carried through to some ultimate conclusion without being overturned or its visibility program undermined.

Timing and "Longer is Shorter." The Air Division has been concerned with the amount of time a large-scale study will take. To better illuminate the validity of this concern, the Air Division outlined five different levels of study and estimated how long each would take. Given the Division's limited monetary resources and the need for adequate planning and scientific review of even a small-scale study, it was determined that the large-scale study would take only 6-12 months longer than a study at the opposite end of the spectrum. The Air Division began to believe that taking some additional time to complete the study process and to develop a common-ground information base with industry may actually take less time than doing the Air Division's small-scale study. The reason is that the smaller effort would have to be undertaken within an adversarial atmosphere and would be very likely to draw the legislature's interest, administrative appeals, lawsuits and be continually attacked. While a decision based on the larger effort may generate appeals and lawsuits as well, the probability of this occurring is diminished and the ease of defending a decision increased -- leading to a result faster than if a smaller-scale study was performed. Within the Air Division, the phrase "longer is shorter" was born to summarize this scenario.

CONCLUSIONS

There was an expectation by the author that after the NAS reports and the NGS process that the script was already largely written for what would happen after certification occurred at the Mt. Zirkel Wilderness. The author believed an agreement with industry on a small scale study was highly likely and that this would lead to a negotiated outcome, as occurred with NGS. The author was not alone in this belief. It is possible such a scenario may have occurred if the State of Colorado did not have a delegated visibility protection program and EPA was the controlling regulatory authority. The realities of implementing the program at a local level, however, make it impossible for the Air Division to act as if it were EPA. Reasonable attribution assessments are by nature case-by-case constructions, and it appears that a state and the federal government may face varying challenges in carrying out this program in the post-NGS era. Finally, it is important to note that in endorsing the larger study the Air Division is in no way stating that it believes the legal hurdles established by Congress, EPA policy and the courts should be changed nor is the Air Division saying that the information required for a reasonable attribution decision is defined by the study that has been chosen. What should be recognized is that the choice of a larger study than originally envisioned has been necessary in order for the State to make "reasonable progress" toward the national visibility goal and that there is an argument to be made that this is the path that is most likely to produce regulatory decision making in a timely fashion.

Attachment 2

Figure 2.1.1.
Mt. Zirkel Visibility Study measurement locations in the mesoscale modeling domain.

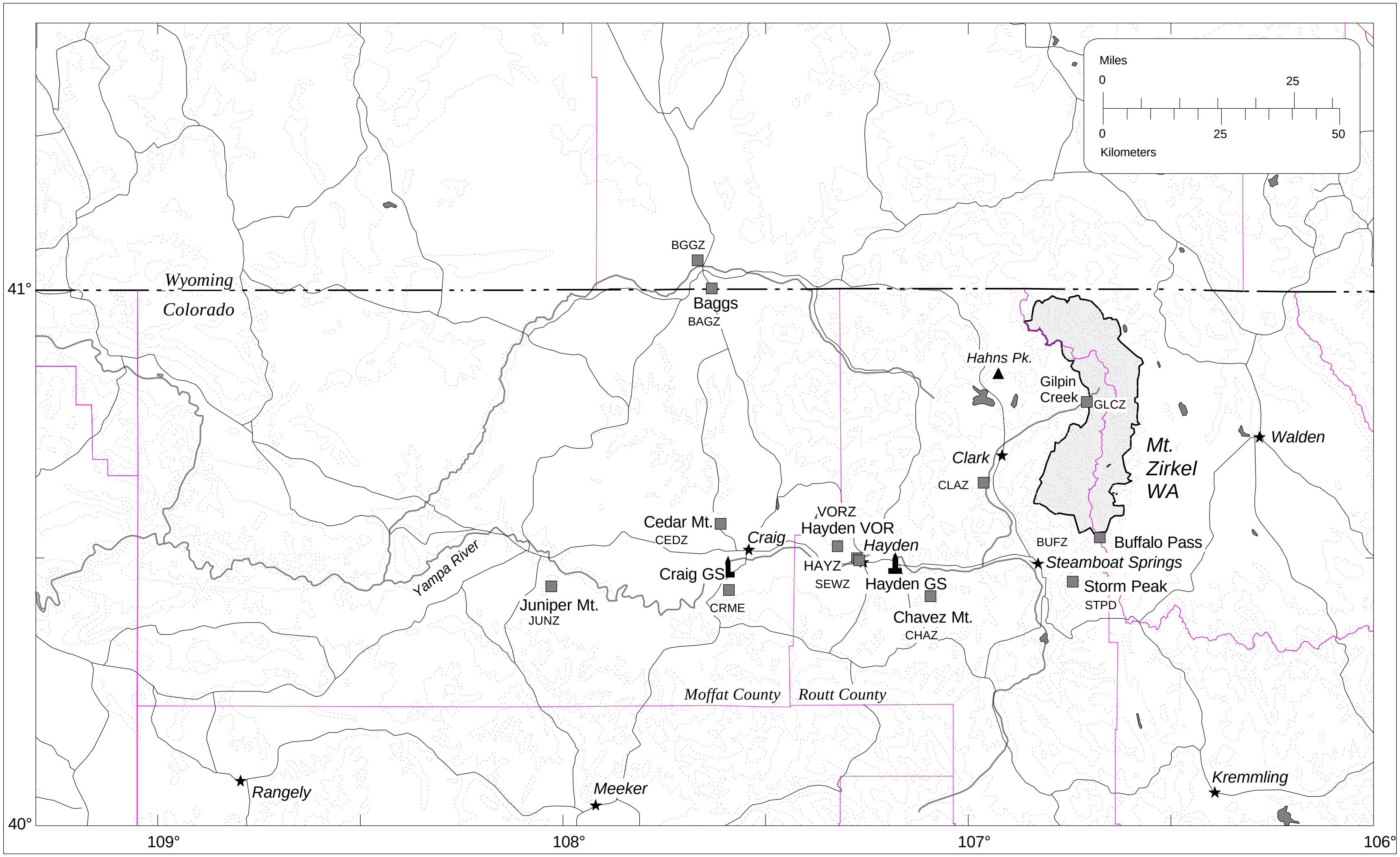

Figure 2.1.1. Mt. Zirkel Visibility Study measurement locations in the mesoscale modeling domain.

Attachment 3

Table 2.1.1
Measurements in the Mt. Zirkel Visibility Study

Table 2.1.1

Measurements in the Mt. Zirkel Visibility Study

ID	Site	Latitude (degrees)	Longitude (degrees)	Elev. (m ASL)	ANNUAL[a] 35mm[1]	Vid[2]	Met[3]	Pro[4]	Neph[5]	Aeth[6]	Aer[7]	SO_2[8]	INTENSIVE[b] Aer[9]	SO_2[10]	NH_3[11]	NO_3[12]	Sulf[13]	TEC[14]	O_3[15]	MNeph[16]
BAGZ	Baggs Visibility	41.004	-107.633	2030			AR		AR				DR	DR						
BGGZ	Baggs Profiler	41.056	-107.668	1930			NO	NO												
BUFZ	Buffalo Pass Visibility	40.538	-106.676	3224	AR				AR	DR	DR	DR	DR	DR	DR	DR	DR	AR		AR
CEDZ	Cedar Mountain -Craig Station	40.564	-107.611	2250		AR														
CHHZ	Chavez Mountain -S. Wilderness	40.429	-107.093	2469		AR														
CHNZ	Chavez Mountain -N. Wilderness	40.429	-107.093	2469		AR														
CHZZ	Chavez Mountain -Hayden Station	40.429	-107.093	2469		AR														
CLAZ	Clark Profiler	40.641	-106.963	2176			NO	NO												
CRAI	Craig BLM Camera	40.526	-107.554	1966	BL															
CRAZ	Craig Met Tower	40.453	-107.592	1875			AR													
GLCZ	Gilpin Creek Visibility	40.792	-106.708	2850	AR		AR		AR		DR	DR								
JUNN	Juniper Mountain - North	40.447	-108.029	2399	AR															
JUNS	Juniper Mountain - South	40.447	-108.029	2399	AR															
JUNW	Juniper Mountain - West	40.447	-108.029	2399	AR															
JUNZ	Juniper Mountain Visibility	40.447	-108.029	2399		AR	AR		AR		DR	DR	DR	DR	DR	DR				
SEWZ	Hayden Waste Water	40.496	-107.269	1950			ST	ST	AR				DR	DR						
MOZI	Storm Peak-Wilderness	40.456	-106.743	3200	FS	AR														
SCDH	Storm Peak-Yampa Valley	40.456	-106.743	3200	CO	AR														
VORZ	Hayden VOR Visibility	40.522	-107.323	2150			AR		AR				DR	DR	DR	DR			AR	

Notes:

[a] Annual measurements nominally from 12/01/94 through 11/30/95. Start dates differ by site and measurement. Aerosol filter measurements taken from 02/06/95 through 11/30/95.

[1] 35mm = 35 mm color slides at 0900, 1200, 1500 MST

[2] Vid = Time-lapse video during daylight hours

[3] Met = Surface, wind speed, wind direction, temperature, relative humidity

[4] Prof = Hourly radar profiler and radio acoustic sounding system (RASS)

Investigator codes are:

AR = Air Resource Specialists
BL = U.S. Bureau of Land Management
CO = Colorado Department of Public Health and Environment
DR = Desert Research Institute
FS = U.S. Forest Service
NO = National Oceanic and Atmospheric Administration, Boulder, CO
ST = Sonoma Technology Inc.

[5]Neph = Hourly OPTEC NGN-2 integrating nephelometer for light scattering

[6]Aeth = Hourly Magee Scientific aethelometer for light absorption

[7]Aer = $PM_{2.5}$ filter measurements for particle mass, light absorption,
elements, ions, and carbon. 0600-1800 MST annual.
0600-1200 and 1200-1800 MST intensive operating periods.

[8]SO_2 = Filter measurements for gaseous sulfur dioxide. 0600-1800 MST annual. 0600-1200 and 1200-1800 MST, all intensive operating periods.

[b] Intensive operating period measurements acquired from:
02/06/95 through 03/02/95 (winter)
08/03/95 through 09/02/95 (summer)
09/15/95 through 10/15/95 (fall)

[9]Aer = $PM_{2.5}$ filter measurements for particle mass, light absorption,
elements, ions, and carbon. 0600-1800 MST annual.
0600-1200 and 1200-1800 MST intensive operating periods.

[10]SO_2 = Filter measurements for gaseous sulfur dioxide. 0600-1800 MST annual. 0600-1200 and 1200-1800 MST, all intensive operating periods.

[11]NH_3 = $PM_{2.5}$ filter measurements for total ammonia, gaseous ammonia, and total particle ammonium. 0600-1200 and 1200-1800 MST, all intensive operating periods.

[12]NO_3 = $PM_{2.5}$ filter measurements for total nitrate, gaseous nitric acid, and total particle nitrate. 0600-1200 and 1200-1800 MST, all intensive operating periods.

[13]Sulf = Hourly high sensitivity sulfur dioxide and sulfate, all intensive operating periods.

[14]TEC = Hourly standard sensitivity sulfur dioxide (TECO 43a). Summer and fall intensive operating periods.

[15]O_3 = Hourly ozone. Summer and fall intensive operating periods.

[16]MNeph = Continuous TSI three-color integrating nephelometer. Summer and fall intensive operating periods.

Attachment 4

The First Section of the Final Report of the
Mt. Zirkel Visibility Study:
Introduction – Study Purpose and Technical Approach

1.0 INTRODUCTION

This section provides an opening overview of the report. The purpose of the study is defined, and the technical objectives are outlined. The technical approach to achieving each of these objectives is briefly summarized. Also included is a guide to the organization of this report as well as of other materials used in conducting the study but not contained in the report. In addition, terms used in the study are defined.

1.1 Study Purpose and Technical Objectives

The Mt. Zirkel Wilderness Area (MZWA) in the Routt National Forest of northwestern Colorado is one of 156 Class I areas in the United States in which visibility is protected. In Class I areas, such as national parks and wilderness areas, industrial activities are not permitted and emissions from new sources outside the Class I boundaries must cause no adverse impact. Current regulations, promulgated by U.S. EPA in 1980, address visibility impairment that is "reasonably attributable" to an existing industrial source or a group of sources (these are often called "plume blight" regulations). Uniform, regional hazes caused by a multitude of sources located near and far from Class I areas are considered under the 1990 Clean Air Act Amendments and are to be treated by visibility transport commissions (VTC). A VTC exists for the Grand Canyon National Park, but no VTC has been established to evaluate regional haze in northwestern Colorado.

Ely *et al.* (1993) assembled available technical information on visibility, air quality, and meteorology in and near the MZWA, including color slides, meteorological data, and emission inventories. The designated land manager for the MZWA, the U.S. Forest Service (USFS), used this information to certify that occasions existed during which visibility was significantly impaired and named the Craig and Hayden coal-fired power generating stations as possible sources. The State of Colorado determined that information was insufficient to reasonably attribute observed visibility impairment to specific sources, and the Mt. Zirkel Visibility Study (MZVS) was commissioned to obtain this information. Potential contributors include sources in the Yampa Valley, which is west of the MZWA and contains the Craig and Hayden generating stations and the Steamboat Springs, Hayden, and Craig population centers, and more distant emitters in Colorado, southern Wyoming, western Utah, and outlying areas.

The purpose of the MZVS (Blumenthal *et al.*, 1995; Watson *et al.*, 1995) is to determine, using scientifically sound principles and established methods and procedures: 1) the extent of visibility impairment, if any, within the MZWA; 2) whether the cause of or contribution to any visibility impairment within the MZWA may be reasonably attributed to emissions from any source or group of sources; and 3) the relative contribution of emissions from each source or group of sources to visibility impairment. Specific technical objectives of the MZVS are to:

1. Obtain a documented data set of specified precision, accuracy, and validity that supports modeling and data analysis efforts.
2. Document the frequency, intensity, and character of haze in the Mt. Zirkel Wilderness, within the Yampa Valley, and outside of the Yampa Valley and relate these to meteorological conditions.

3. Quantify the contributions from scattering by gases, absorption by gases, scattering by particles, and absorption by particles to different levels of light extinction in the Mt. Zirkel Wilderness.
4. Quantify contributions from particulate chemical components to light extinction.
5. Describe the behavior of generating station plumes in the Yampa Valley.
6. Estimate contributions to light extinction in the Wilderness from different emission sources within and outside of the Yampa Valley.
7. Reconcile results from different modeling and data analysis methods, and assign confidence levels to source contribution estimates.

1.2 Technical Approach

There is no single, foolproof method for attaining these objectives. Emission rates, air flow in complex terrain, and chemical transformations of emitted pollutants in the atmosphere are complicated phenomena that are not entirely understood. Even with complete understanding of the processes involved, it is not technically or economically feasible to obtain measurements that fully describe all of the relevant atmospheric variables in space and time.

The MZVS program plan (Watson *et al.*, 1995) examined several previous visibility and particulate source apportionment studies, as well as existing information from the study area. The plan specified measurements, data analyses, and modeling methods that address each of the first six technical objectives. Several different data analysis and modeling methods were identified for each objective, and each of these methods was to be evaluated with respect to its applicability in the study area, completeness and uncertainty of available data, and its relevance to each study objective.

Measurements were taken as part of the MZVS, as well as acquired from existing meteorological, air quality, and visibility monitoring networks. To attain the first technical objective, these measurements were organized into a consistent and documented data base and subjected to several tests to determine their validity, precision, and accuracy. Validation tests are applied to determine which data can be used for other objectives and the uncertainties that they impart to data analysis and modeling. The following measurements were submitted to several comparison and validation tests: nephelometer measurements for light scattering; aethelometer measurements for light absorption; radar profiler and radioacoustic sounding system (RASS) measurements of upper air winds and temperature; meteorological tower measurements of winds, temperatures, and relative humidities; filter-based measurements of aerosol and precursor gas composition; and continuous measurements of sulfur dioxide. All but the following measurement methods had been applied in prior quantitative source apportionment studies: 1) high time-resolution (every 15 minute) particle sulfur concentrations at levels below 0.1 $\mu g/m^3$; and 2) isotopic abundances of S^{32} and S^{34} in potential primary source emissions as well as in secondary particle sulfate measured at receptors. These methods had high risk of failure, but very high value for attaining the source apportionment objective if they succeeded. The climatology of the 12/01/94 through 11/30/95 study period was examined to determine the extent to which conditions found during that year can be extrapolated to earlier and later years.

The second technical objective of documenting the frequency, intensity, and character of the haze was addressed by visually examining photographs and videos as well as instrumental light scattering measurements. Frequencies of visual and instrumental haze occurrences were compiled for each measurement location. These were compared with each other and with simultaneous light scattering and extinction measurements from other Class I areas. Visual records and relative humidity measurements allow weather-related excursions in light extinction to be separated from haze caused by air pollution. Comparisons of simultaneous visibility measures near the Mt. Zirkel Wilderness, in the Yampa Valley, and outside the Yampa Valley allowed effects of regional and local emissions on visible haze to be discerned. From these analyses, several haze events were identified for more detailed examination to attain subsequent objectives.

The third technical objective of estimating the relative contributions of scattering and absorption was attained by summing the contributions from clean air (Rayleigh) scattering determined from atmospheric temperature and pressure, fine particle scattering determined by nephelometry, and fine particle absorption determined by densitometry measurements of particle deposits on Teflon-membrane filters. Nitrogen dioxide, the major contributor to absorption by gases, has been shown to be a minor contributor even in urban areas where concentrations are high, and its contribution to light extinction is assumed to be negligible in the study area.

The fourth technical objective of attributing light extinction to chemical components was addressed by estimating extinction efficiencies for each of the major aerosol components measured on daytime filter samples of six- and twelve-hour duration. These estimates make use of multi-wavelength nephelometer measurements to infer particle size distributions, relationships between particle size and relative humidity established in this and other studies to estimate particle growth from liquid water absorption, and the Elastic Light Scattering Interactive Efficiencies (ELSIE) (Sloane *et al.*, 1991; Lowenthal *et al.*, 1995) light scattering model to determine the change in extinction associated with changes in chemical concentrations.

The fifth technical objective of documenting generating station plume behavior was addressed by drawing examples from the time-lapse videos of the plumes during daylight hours, estimating transport and mixing within the Yampa Valley from vertically stratified meteorological measurements, identifying variations in generating station emissions of primary particles and sulfur dioxide, applying the CALMET/CALPUFF dispersion model to daily emissions and meteorological measurements for the entire study period, and examining continuous sulfur dioxide, light scattering, and light absorption measurements near the Wilderness boundary.

The sixth objective of source apportionment presented the greatest challenge to this study. The attainment of the second technical objective identified cases representing different emissions, transport, and aerosol transformation situations. Both primary particles, those directly emitted from sources, and secondary particles, those formed from directly-emitted gases, were believed to be major components of suspended particles that cause light extinction (Watson *et al.*, 1995). Both Yampa Valley and more distant emitters were suspected of contributing the suspended particle concentrations. Emissions, especially intermittent emitters such as fires, were tabulated for the Yampa Valley and a larger domain that included large parts of Colorado, Wyoming, and Utah. Examples of emissions from coal-fired generating stations, vehicle exhaust, residential coal and wood combustion, geothermal springs, wildfires, and suspended dust were acquired and chemically characterized. Source characterizations included measurements of isotopic abundances in sulfur as well as elemental, ionic, carbonaceous, and sulfur dioxide abundances.

An aerosol evolution model (Robinson and Whitbeck, 1985) was applied to the generating station profiles to determine how the abundances of sulfur dioxide, sulfate, and elements might change with time under dry and moist conditions. The Chemical Mass Balance receptor model (Watson *et al.*, 1990) was used with these "aged" and unaged profiles to estimate source contributions for the all of the six- and twelve-hour average aerosol samples that were chemically characterized. Short-term (an hour or two) increments in light scattering and absorption near the Wilderness were determined to estimate maximum impacts from plumes originating in the Yampa Valley, especially when light scattering excursions corresponded to short-term excursions in continuous light absorption and sulfur dioxide. The CALMET/CALPUFF (U.S. EPA, 1995a, 1995b) wind field and air quality models were applied, using emission rates and meteorological data from the MZVS, to independently estimate source contributions from Yampa Valley and regional sources during five multi-day visibility episodes that illustrated different types of events. Nonlinearities associated with emissions changes were examined for perception by calculating changes in contrast along sight paths associated with views from the Wilderness, and by equilibrium modeling of ammonium nitrate concentrations when sulfate, ammonia, and nitric acid precursors are reduced (Kim *et al.*, 1993a, 1993b).

The final technical objective of reconciliation was approached by combining information from each of the previous analyses. Several episodes were selected for detailed analysis, especially ones in which different combinations of source contributions were observed. A conceptual model was formed that explained these episodes, and the ability of each of the simulation models to simulate these episodes was critically examined. The best estimates of each source contribution were selected, with objective and subjective estimates of the uncertainties of these contributions.

Attachment 5

Table 5-6 from the Craig FGD Study
Craig FGD Upgrade Option Cost Summary – Units 1 and 2
Combined (Current $'s)

Table 5-6. Craig FGD Upgrade Option Cost Summary[1] - Units 1 & 2 Combined (Current $'s)

Option #	Total Capital Requirement MM $	Level.Cost/yr. (Current $s) $MM/year	Incremental[2] SO_2 Removed tons/yr.	Level.Cost Effectiveness (Current $) $/ton SO_2 removed	Level. Incremental Cost Effectiveness[3] (Current $s) $/ton SO_2 removed	Total Present Value[4] for 20-yr. Plant Life (1998 MM$'s)
Baseline	0	-----	0	-----	0	0
1	10.6	1.58	2947	536	536	14.2
2	12.0	1.88	4279	440	231	16.9
3	27.5	4.49	6834	659	1020	40.4
4	25.2	11.5	6834	1690	3770	104

[1] Expected accuracy +/- 30% for these rough order of magnitude cost estimates based on the level of design information, vendor budgetary Quotations, and contingency of 20% added to estimates. Rounding errors may occur in the transfer of data from Appendix F to this table.

[2] Incremental SO_2 tons/year is the additional quantity of SO_2 removed for each option relative to current SO_2 removal rates.

[3] Incremental cost effectiveness is a calculation of the added cost for the additional tons removed compared against the next highest level of control, i.e., 2 vs. 1, 3 vs. 2, and 4 vs. 2. Includes SO_2 allowance credits.

[4] Represents the present worth (at 6% discount rate over the 20-year projected service life). Caution should be used when comparing Present value numbers since all of the options have different Benefits (removal efficiencies). P/A for 20 yrs. & 9.2% discount rate = 8.999. Multiply P/A times Level. $/yr. = Present Value. See Section 3 for additional explanation of cost development criteria and methods.

Note: All levelized and present value cost estimates include an SO_2 allowance credit of $100/ton for each additional ton removed.