T&B Systems
environmental research associates
859 2nd St, Santa Rosa, CA 95404
(707) 526-2775 fax (707) 579-5954

MONITORING AND QUALITY ASSURANCE PLAN UPPER GREEN RIVER WINTER OZONE STUDY

Prepared for

State of Wyoming
Dept. of Environmental Quality, Air Quality Division
Cheyenne, WY 82002

Prepared by

T&B Systems, Inc.
Santa Rosa, CA 95404

Meteorological Solutions, Inc.
Salt Lake City, UT

Environ International Corporation
Novato, CA 94945

and

Sonoma Technology, Inc.
Petaluma, CA 94549

August 14, 2007

T&B Systems
environmental research associates
859 2nd St, Santa Rosa, CA 95404
(707) 526-2775 fax (707) 579-5954

MONITORING AND QUALITY ASSURANCE PLAN UPPER GREEN RIVER WINTER OZONE STUDY

Prepared for

State of Wyoming
Dept. of Environmental Quality, Air Quality Division
122 W. 25th Street
Herschler Bldg – Flrs 3W & 4W
Cheyenne, WY 82002

Prepared by

T&B Systems, Inc.
Santa Rosa, CA 95404

Meteorological Solutions, Inc.
2257 South 1100 East, Suite 203
Salt Lake City, UT 84106

Environ International Corporation
Golden Gate Plaza
101 Rowland Way
Novato, CA 94945

and

Sonoma Technology, Inc.
1360 Redwood Way, Suite C
Petaluma, CA 94549

August 14, 2007

TABLE OF CONTENTS

Section **Page**

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION AND PROJECT OVERVIEW

This monitoring and quality assurance plan provides the basis for the collection of air quality and meteorological data for the Upper Green River Winter Ozone Study (UGWOS), sponsored by the Wyoming Department of Environmental Quality (WDEQ). While research in nature, the monitoring methods and objectives described in this plan are consistent whenever possible with EPA quality assurance guidance for the collection of air quality and meteorological data (US EPA 1995, and 1998) and the most recent guidance for the collection of meteorological data for regulatory modeling applications (US EPA, 2000).

Recent high ozone events observed in this area have raised concerns regarding potential adverse health and ecological effects associated with monitored concentrations greater than the U.S. Environmental Protection Agency's ozone standard (set at an 8-hour average concentration of 0.08 ppm) and the significantly increased federal regulatory requirements that would be associated with any potential future violation of the EPA ozone standard. The situation is made even more critical by the fact that EPA's Science Advisory Board is currently considering the need to lower the ozone standard between 0.060 and 0.070 ppm which would make a violation (currently defined as a three year average of the annual fourth highest daily maximum 8-hour ozone above 0.08 ppm) considerably more likely: preliminary measurements from the Jonah monitoring site show an average fourth highest 8-hr ozone of 0.071 ppm for 2005 – 2006.

Ozone formation in the Upper Green River Basin is unusual in that the highest concentrations have been recorded during the late winter and early spring (February to April) when sun angles are relatively low and temperatures are generally below freezing. This is in stark contrast to ozone exceedances in other areas, which occur during the warm summer months when abundant solar radiation and high temperatures act to increase precursor emissions and enhance the atmospheric reactions that result in ozone formation near the earth's surface (i.e., within the planetary boundary layer).

Due to the pressing need to manage ozone air quality in the Upper Green River Basin and the limited amount of information currently available about the nature and causes of these unusual events, the WDEQ has funded this comprehensive field study during the 2007 late winter – early spring season. Data from this study will be used to develop a conceptual model of ozone formation. The conceptual model will be used along with the field data to develop accurate meteorological and air quality numerical simulations of the ozone events. Both the conceptual and numerical models will in turn be used to develop effective air quality management strategies needed to adequately protect public health and the environment in accordance with applicable State and Federal laws.

2. SAMPLING PROGRAM DESCRIPTION

There are two levels or modes of field measurements in UGWOS: *continuous* and i*ntensive*. Continuous measurements will be ongoing from the start of the field study February 1, 2007 and continue until the scheduled end date, anticipated March 30, 2007. More extensive measurements will be conducted when the meteorological conditions are conducive to producing high ozone levels. These periods are hereafter referred to as Intensive Operational Periods (IOPs). IOPs will be initiated on a forecast basis and, as such, the field crew is committed to the project for its duration. Each IOP can last up to five days, and three such IOPs will be conducted over the study period. IOP measurements comprise the main core of the study in which the three-dimensional air quality and key meteorological features will be described. The surface ozone measurements are expanded to bound the major well field development, and measure the maximum air quality impacts.

2.1 Operational Forecasts and Readiness Protocol

The current conceptual model of the meteorological conditions conducive to the formation of high ozone levels in the Pinedale-Jonah fields during the winter and early spring is characterized by clear skies, light winds and a stable atmosphere. These conditions occur during periods when the synoptic weather is dominated by high pressure over the western Rockies, Intermountain area and the northern Great Basin. The primary broad scale characteristics dominating the Green River basin during the high probability events are weak pressure gradients within the context of a subsidence-dominated air mass.

In an effort to formulate the conceptual model, the synoptic scale weather patterns prior to occurrences of escalated ozone values in the study area during the winters of 2005 and 2006 were examined. Although many different nuances of the general pattern were encountered, the basic characteristics of the conceptual model did emerge. Figures 2-1 through 2-4 present composite views of the 700 mb and 500 mb configurations for all of the days with surface 8-hour averaged ozone concentrations greater than 60 ppb. **Figure 2-1** shows the ridging pattern of the 500 mb height contours; **Figure 2-2** presents the wind speed isotachs at 500 mb; **Figure 2-3** shows the ridging pattern of the 700 mb height contours; and **Figure 2-4** demonstrates that there was warmer air aloft just above the surface, indicating air mass subsidence.

Recognition of the onset and establishment of the conceptual model characteristics in advance is the key to the operational forecasting solution for the UGWOS field measurements operations. National Weather Service numerical synoptic-scale models such as the North American Mesoscale model (NAM) and the Global Forecast System model (GFS), coupled with regional NWS Forecast Discussion guidance, will provide the experienced MSI and T&B Systems weather forecasters with the basis for daily long and medium range operation forecasts. An additional factor that may prove critical in operational forecasting is the presence of sufficient snow cover to provide the radiation component needed for ozone chemistry. Local observations will provide this information on a day-to-day basis.

The effects of day-to-day variability in local-scale meteorological factors on ozone levels is not clearly understood owing the to the limited measurements in the project area. Our knowledge and ability to refine the forecasts will improve as the program progresses. Discussions with local DEQ and BLM personnel and our initial observations suggest that high levels of ozone may occur more frequently than the current monitoring network is capable of detecting. The mesonet being deployed for the study will provide significant expanded areal ozone coverage.

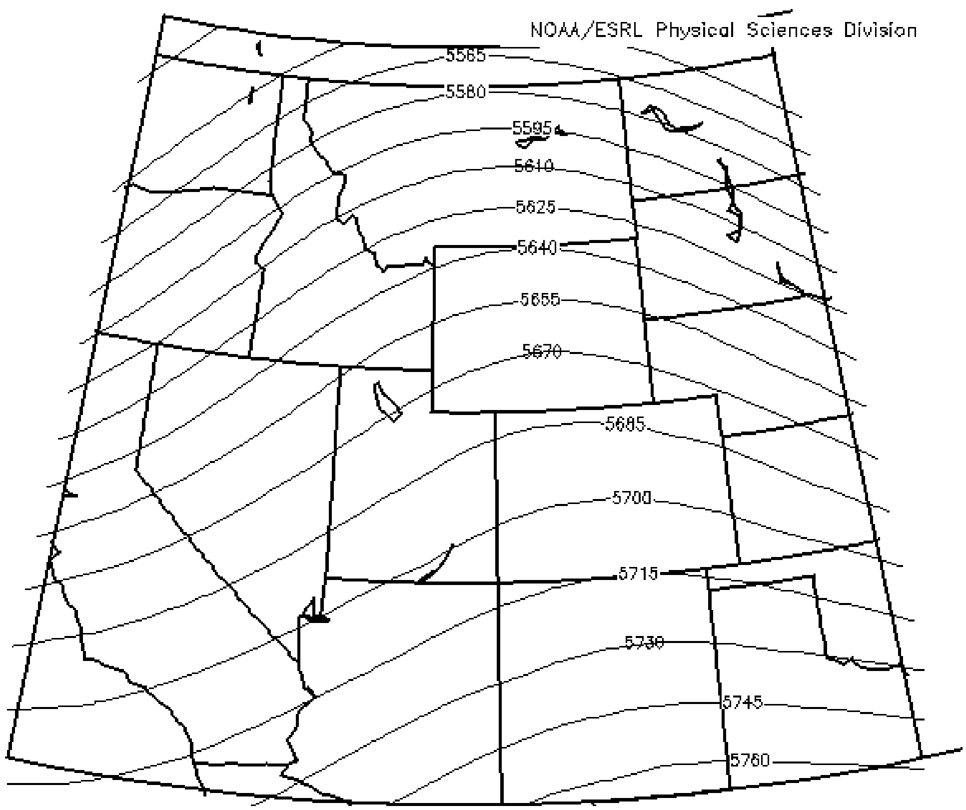


Figure 2-1. Composite 500 mb Heights During High Ozone Periods

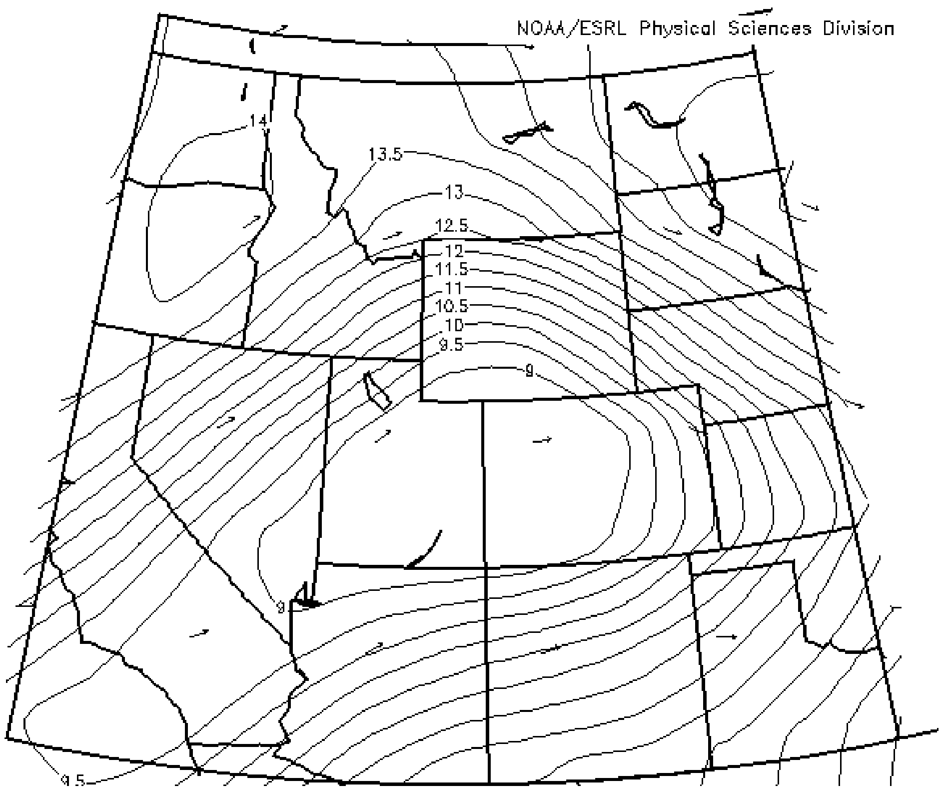


Figure 2-2. Composite 500 mb Winds During High Ozone Periods

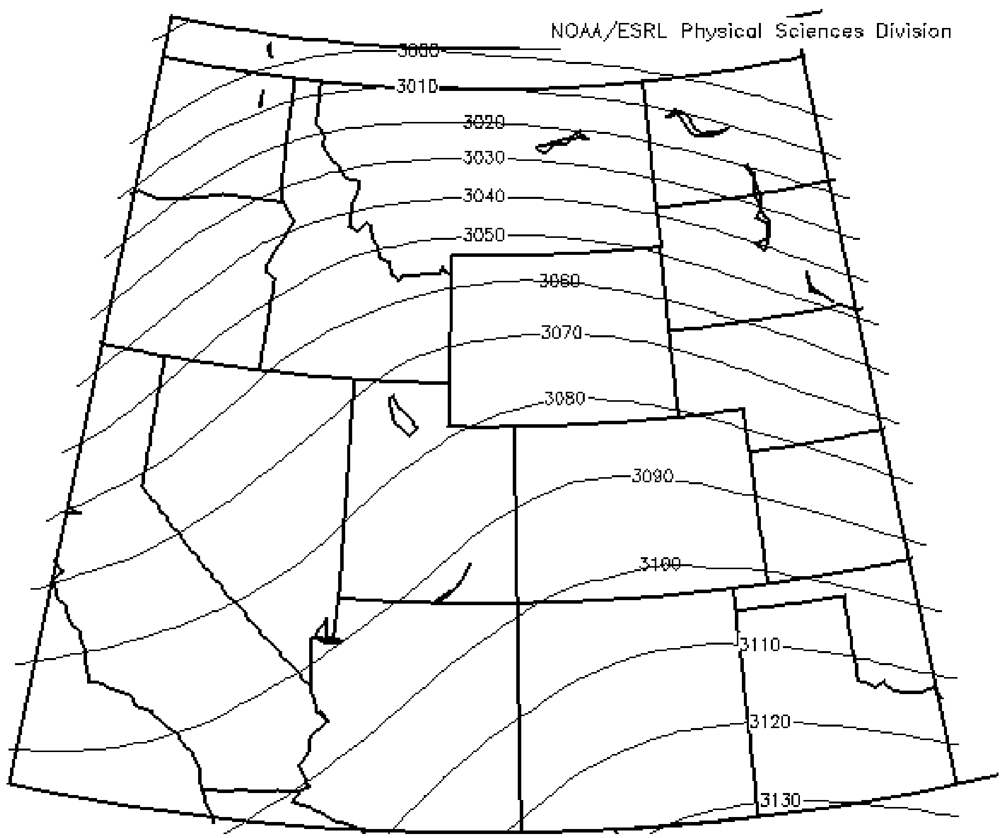


Figure 2-3. Composite 700 mb Heights During High Ozone Periods

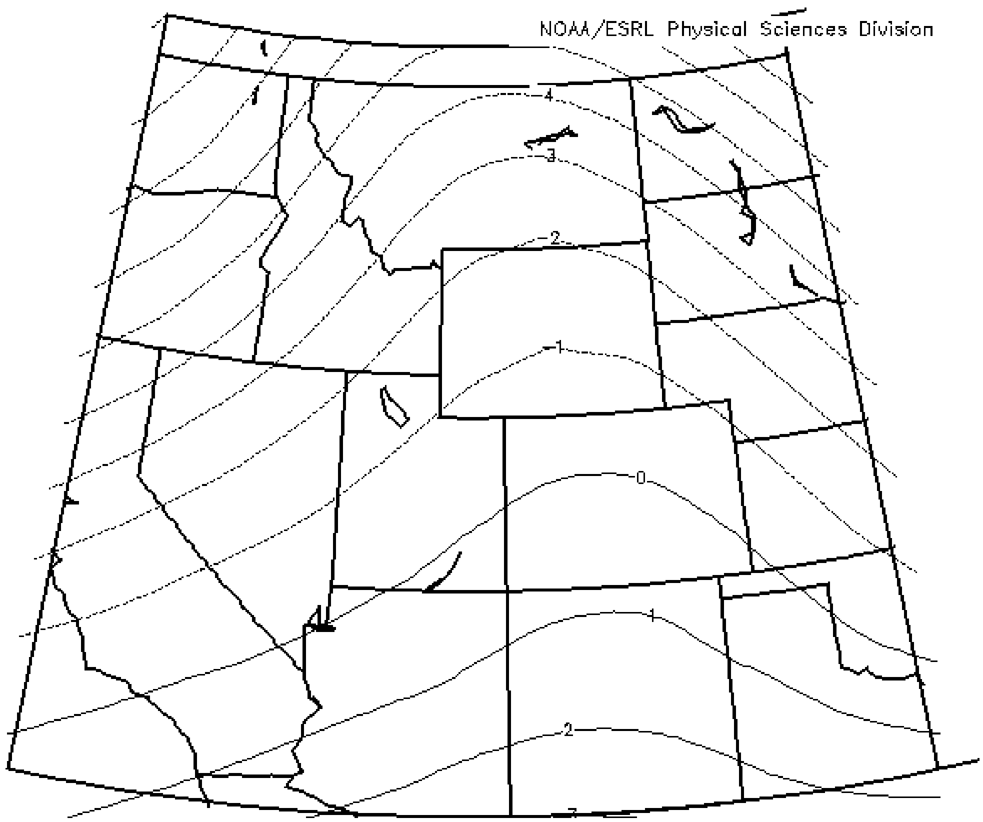


Figure 2-4. Composite 700 mb Temperature During High Ozone Periods

A number of products and data will be routinely archived. Products include: the daily Riverton NWS rawinsondes, the GOES sounding data for Afton and Rock Springs, the Weather Modification, Inc. project soundings from Farson, and the NAM and GFS model generated simulated soundings for points within the Pinedale area. Short-term daily operational forecasts will be aided and refined as all this near real-time information is obtained. We will also be evaluating the usefulness of the Rapid Update Cycle model (RUC), the Weather Research and Forecasting model (WRF) and the RAMS model from CSU in our short-term operational forecasting mode and possibly incorporate them into our daily forecasts.

An operational forecast will be issued by 10 MST each day that will include both the short-term and long-term weather forecasts. All project participants will be required to provide any changes in their operational readiness daily to the Field Project Manager and that information will be included as well. This forecast will be posted on a project web site accessible to all participants. If conditions are developing that are conducive to the development of high ozone, an alert will be issued.

A “GO” alert will be issued at the 10 MST forecast at least 48 hrs before an IOP is to begin. Field crews will begin making preparations to debark to the field the following morning. A final

GO or NO GO will be issued by 17 MST that afternoon. If the forecast remains a GO, the crews will deploy as scheduled.

The field crews will meet in Pinedale the following evening for a briefing and to coordinate setting up for the IOP. All equipment will be deployed and/or checked for readiness the following day. In this manner, an IOP can begin within 48 hours of the initial GO forecast. To aid in that critical operational forecast, we have contingency plans to launch a rawinsonde to measure local winds, temperature and humidity the first morning in the field before the complete network is deployed.

We do not anticipate having to deploy the field crew when inclement weather hampers travel to and from the project area. It should be noted that the major characteristics of the meteorology that can lead to high ozone levels in the Pinedale-Jonah area are a stable atmosphere, clear skies, and light low-level winds. These conditions take some time (at least 48 hours after a storm frontal passage) to develop. Moreover, we expect operational conditions to occur during periods when the synoptic weather pattern in the western states is relatively stationary as opposed to short-waves of high and low pressure patterns, so it will not be necessary to start operations on the heels of a storm system.

2.2 Continuous Measurements

Project-specific measurements to be continuously obtained over the complete field program period include surface and winds aloft, and supplemental surface ozone measurements. Surface meteorological measurements will be taken from the 8-site meso-network (mesonet), the radar wind profiler site, and from Wenz Field (Pinedale airport). At the latter site, continuous surface ozone measurements using a designated EPA equivalent analyzer will be made. Surface wind, temperature, and relative humidity will also be collected at the Pinedale site. At a site on the south mesa, both surface and aloft winds and temperature will be made employing a radar wind profiler, RASS, miniSodar, and surface meteorological station. Although the ozone monitors will be removed from the mesonet sites between intensive operations, the surface wind measurements will continue unattended, if security allows. Both incoming and reflected UV radiation will be measured at the Boulder site, with measurements beginning prior to the first IOP.

Other participants in the field program will be operating a trace CO analyzer and an aethalometer continuously from the Boulder site as well.

2.3 Intensive Monitoring

During periods when high ozone levels are forecast, more intensive measurements will be initiated. The key components of the intensive monitoring periods (IOPs) are:

- Operation of the 8-station network of ozone measurements
- VOC and carbonyl measurements
- Tethered sounding operations
- Ozone/rawinsonde operations
- Aircraft measurements

2.3.1 Mesonet Ozone Measurements

MSI staff will deploy to the field from their office in Salt Lake City immediately following issuance of the final GO. The 2B ozone monitors, which will be at the Wenz Field office between IOPs, will be span-checked, reassembled in enclosures with freshly-charged batteries, and deployed to the sites. Their operation on-site will be checked using the 2-B ozone generator and zero-scrubber, and any zero and span adjustments made. The data system time will be reset as required.

During the IOPs the sites will be visited every two to three days to download data and ensure appropriate operations. At these visits, batteries will be checked and swapped with freshly charged batteries if needed. At the completion of each IOP, the ozone analyzers will be span and zero checked.

All steps of the deployment and on-site operations will be documented and logged by the MSI technicians. Mesonet monitoring will begin with the first intensive. It was initially planned that the 2B analyzers would be brought back and stored at Wenz Field after the end of an IOP. If, however, the 2B samplers appear reliable enough to be operated between IOPs, continuous ozone sampling may be possible at key sites. In this case, WDEQ will be responsible for servicing the sites in between IOPs. The priority will always be to insure that equipment is operational for the IOPs.

2.3.2 VOC and Carbonyl Measurements

VOC and carbonyl measurements will be conducted at each of the three existing WDEQ monitoring sites within the study area – Jonah, Boulder and Daniel. The VOC and carbonyl measurements will be collocated and sampled simultaneously as three-hour integrated samples. On intensive study period days, samples will be taken from 0400-0700, 0900-1200 and 1400-1700 hours.

VOC measurements will be made using 6-liter SUMMA canisters connected to Xontech Model 910A canister samplers. Ambient air will be pumped to the canisters for a three-hour period. Carbonyl measurements will be made by pulling ambient air at 1 LPM through DNPH cartridges with an ozone scrubber inserted upstream of the cartridge. Both types of samplers are outfitted with timers that enable automatic start/stop operation. Ambient air needed for the samplers will be obtained from borosilicate glass intake manifold ports at each monitoring shelter.

Research team technicians stationed at the three monitoring sites to conduct tethered-ozonesonde soundings during intensive study days will be responsible for loading canister/cartridge media into the samplers, confirming sample run times, removing samples and filling out the affiliated documentation. Exposed sample media will be collected at the end of each intensive study day and brought to the project field office at the Pinedale Airport for packaging and shipment to EAS laboratory for analysis. Field sample sheets will accompany samples and the required chain-of-custody documentation will accompany each shipment. Samplers will be cleaned prior to the start of the measurement program and tested for contamination. A field blank will be submitted for each site during intensive study periods.

2.3.3 Tethered Sounding Operations

Vertical profiles and aloft measurements of ozone and temperature will be initiated daily during IOPs at 3 sites (Daniel, Boulder, and Jonah). The first sounding will be taken at 9:00 to characterize the stable period of the diurnal cycle. Measurements will be ongoing thereafter through 16:30 to characterize the daytime boundary layer. The anticipated schedule of soundings will be an up/down sounding taken hourly beginning at 09 MST and continuing until 17 MST as warranted and/or feasible. Soundings will be terminated when it becomes apparent that air quality conditions are not developing as forecast, or conditions such as wind speeds preclude safe operations.

The EC-cell ozone sampler will be compared with the EPA designated equivalent analyzer, which will be simultaneously operating at each sounding site each time the balloon is elevated and retrieved. Balloon tethering height will be determined using an optical range-finder as well as the recorded altitude in the sonde GPS system.

It should be noted that on the first day of an IOP, there will be preparation time required to prepare the balloon and line assembly. Thus, the first sounding will be delayed until midmorning. At the completion of each sampling day, the balloons will be tethered at the ground and covered with tarps.

It will be up to the tether balloon operator to determine when flying conditions become impractical due to higher winds. In these conditions, the balloon will be brought to the ground and secured until lower wind speeds allow further flights.

Tethered sounding sites will be manned by MSI and T&B Systems. T&B Systems has the overall responsibility of this task.

2.3.4 Aircraft Sampling

Ozone, fine particulate loading, and temperature will be measured using a single-engine airplane. A typical flight sampling mission will be comprised of measurements at constant levels and spiral ascents and descents to provide vertical profiles. Vertical profiles will be made from as near to ground level as safety permits to approximately 4000 ft-agl. If the daytime boundary level is shallower than 4000 ft, the spirals may be to a lower height.

Two three-hour sampling flights are planned each intensive sampling day, beginning the first day of an IOP. Preliminary flight plans will be developed prior to takeoff. The morning flight will take place approximately 07:30 -10:30 MST. The afternoon flight will take place approximately 13:30 –16:30 MST. An experienced T&B Systems air quality scientist will be onboard observing the measurements in real-time. Based on those observations and the winds aloft measurements, the flight plan may be modified. For example, if a polluted layer is observed the primary mission of that sampling flight may be to map the areal extent of the polluted layer. Flight patterns will initially be as follows:

- The morning flights will concentrate on characterizing the near-surface ozone conditions, and will consist of a series of spiral soundings connected by relatively low level flight. Flights during both the morning and the afternoon will begin with a sounding near the radar profiler site. The study area will then be characterized by conducting similar spiral soundings near the Haystack Butte, La Barge, Big Piney, and Daniel sites, with connecting legs at a constant level of approximately 500 ft agl, to characterize as best as possible concentrations at or below the inversion layer.
- The goal of the afternoon flights will be to map the extent of any plume of high concentrations. The initial spiral sounding near the radar profiler site will determine the

height of maximum concentrations. Based on available upper level wind data from the ozonesonde measurements and radar profiler/sodar data, a series of constant level traverses perpendicular to the prevailing winds will be conducted at progressively farther downwind distances.

The flight patterns for the aircraft measurements are intended to be dynamic in nature, with changes made as data are collected and analyzer from all of the study measurement platforms. This task is the responsibility of T&B Systems.

2.3.5 Ozone/Rawinsondes

Free ascending balloon-borne measurements of ozone, temperature, relative humidity, and winds will be made three-times daily from Wenz Field during IOPs. Scheduled sounding times are 07, 13, and 17 MST. The early morning sounding will document the vertical structure of the atmosphere during the most stable period over the diurnal cycle. This sounding will closely correspond to the 12 GMT world-wide sounding schedule and data set. The afternoon sounding will characterize conditions when the atmosphere is generally most unstable and the mixed layer has fully developed. The midday sounding will be document the timing of the growth of the boundary layer. Soundings will extend to at least 500 mb or ~ 18,000 ft. Optimally, data will be gathered to 300 mb which is approximately 30,000 ft.
This task is the responsibility of T&B Systems.

2.3.6 Supplemental Monitoring and Data Collection

<u>UV Radiation</u>
In addition, T&B Systems will be operating direct and reflected UV radiation sensors (radiometers) at the WDEQ Boulder site. The sensors will be checked and the data downloaded at the beginning and end of each IOP. Sensor checks will consist of a zero reading and comparison of the sensors output while orientated identically. The radiometer will be continuous operational but unattended between IOPs.

<u>Archiving of NOAA Products</u>

Archiving of data that is not already archived on the web and readily available will occur on a daily basis. The items that will be archived for the period from February 1 through March 31, 2007 are listed below:

- MSI routinely archives 00Z and 12Z surface and upper air maps for 700 mb, 500 mb and 850 mb.
- MSI routinely archives data from all rawinsonde sites in the United States for both 00Z and 12Z time periods.
- MSI routinely archives Visual and IR, US east and west satellite images every 15 minutes.
- Vorticity information provided by the NAM model will be archived twice daily. The 00Z and the 12Z analysis vorticity data will be archived for a 13 by 13 grid surrounding the Pinedale area. Additionally, all data from the analysis period will be archived for the data point nearest Pinedale. This will provide another point for which a sounding may be plotted.

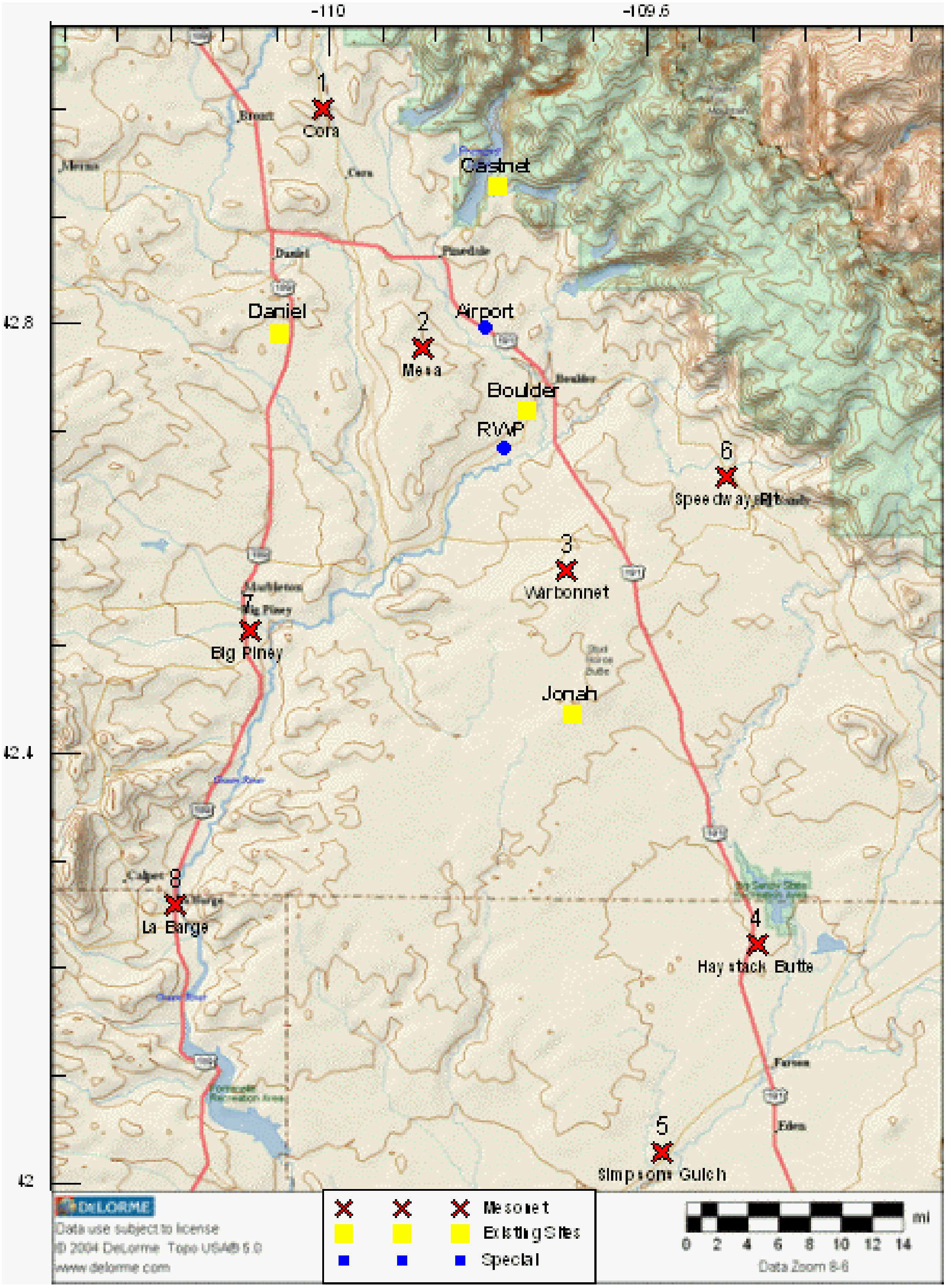
- Vorticity graphics at 500 mb produced by NCEP from both NAM and GFS will be archived on a daily basis for the analysis runs at 00 and 12Z.
- GOES derived soundings will be archived on a daily basis. Archival will include plots and data listings.

In addition to the above, the following data are currently archived on the web and available for analysis:

- Snowpack - available at NOAA's National Operational Hydrologic Remote Sensing Center
- Total Column Ozone - A web site from NASA provides historical ozone global charts, and Dobson Unit measurements for any lat/long on any particular day.
- Local Camera Images - The current local camera images from Daniel, Jonah and Boulder can be viewed on line at the WDEQ site, and there is also a 2 week image archive here which consists of an image at 9:00 12:00 and 15:00 MST each day. Archived images can also be requested from Air Resource Specialists, Inc. or InterMountain Labs.

3. MONITORING SITE DESCRIPTIONS

Figure 3-1 presents a map of the UGWOS site locations. **Tables 3-1 and 3-2** present coordinates and site selection rational (monitoring objectives), respectively, for each of the sites. More details regarding the sites can be found in the metafiles contained in **Appendix A**.



Proposed Monitoring Network – UGWOS
Red Flags = Mesonet Sites, Red Xs = Upper Air Sites, Yellow Boxes = Existing Sites

Figure 3-1. Map of UGWOS Site Locations

Table 3-1. Network Locations and Identifiers. (All Lat/Longs are WGS 84)

	Latitude	Longitude	Elevation
OZONE/MET SITES			
Site 1: Cora Area (BLM)	43 00.399N	110 00.543W	7558'
Site 2: The Mesa (BLM)	42 46.638N	109 53.019W	7543'
Site 3: Warbonnet (BLM)	42 34.212N	109 42.125W	7425'
Site 4: Haystack Butte (WY)	42 13.323N	109 27.762W	6758'
Site 5: Simpson Gulch (BLM)	42 01.697N	109 34.914W	6691'
(FAA Tower)			
Site 6: Speedway Pit (WY)	42 39.433N	109 29.944W	7206'
(Big Sandy Area)			
Site 7: Big Piney (USFS)	42 30.836N	110 06.124W	6818'
Site 8: La Barge (Privat)	42 15.512N	110 11.638W	6609'
WIND PROFILER SITE			
RWP: M&N Yard	42 40.657N	109 48.474W	6933'
TETHERSONDE SITES			
Boulder	42 43.120N	109 45.225W	7078'
Daniel	42 47.484N	110 03.886W	7084'
Jonah	42 26.184N	109 41.754W	6848'
PINEDALE AIRPORT (WEINZ FIELD)			
Airport	42 47.890N	109 48.296W	7109'

Table 3-2. Major Objectives of Mesonet Sites

Site	Objective
Cora	Boundary site upwind from prevailing winds
Mesa Site	Representative of conditions on top of the Mesa
Warbonnet	Representative of middle and southern Pinedale Anticline
Big Sandy Reservoir	Replacement site for Jonah – parallel monitoring period
Speedway Pit	Representative of east foothills
Marbleton/Big Piney	Western boundary site – principal drainage from source region
La Barge	Southwestern boundary site
Simpsons Gulch	Southern boundary site

4. MONITORING EQUIPMENT DESCRIPTION

The following section describes the monitoring equipment that will be used for UGWOS. Monitoring quality objectives (MQOs) are presented for each of the monitoring methods.

4.1 Mesonet Ozone Monitoring

All equipment used at the mesonet ozone monitoring sites will be housed in a 70 to 100 quart portable cooler. This includes a 110 amp-hour deep cycle 12-Volt battery with will power all equipment and allow continuous monitoring for a least one week. A small 5-watt light bulb will also be located in the cooler to provide sufficient heat to keep temperatures in the cooler within the operating ranges of all equipment.

The following equipment will be at each of the mesonet sites:

2B Model 202 Ozone Analyzer
The 2B Ozone Monitor will be used for the mesonet Monitoring. This monitor has a low power consumption (12v DC, 0.33 amp, 4.0 Watt) relative to conventional instruments allowing operation with deep cycle batteries. Additionally, it does not require a temperature-controlled environment.

The 2B Technologies Model 202 Ozone Monitor™ is designed to enable accurate and precise measurements of ozone ranging from low ppb (precison of ~1 ppbv) up to 100,000 ppb (0-100 ppm) based on the well established technique of absorption of light at 254 nm. "Absorption spectroscopy" is a chemical analysis technique made possible by the phenomenon that a given molecule absorbs light at selected wavelengths. The wavelengths absorbed are characteristic of each molecule's atomic features. The amount of light radiation absorbed by a substance depends on two factors: the number of molecules in the path of the light, and the characteristics of the molecule (e.g., absorption cross-section). Measurement of changes in the light intensity as it passes through the molecules, and the use of calibration and reference data, enable the determination of the number of molecules encountered.

Accuracy (performance checks)	±5%
Precision (performance checks)	±5%
Resolution	0.001 ppm
Lower Quantifiable Limit	0.002 ppm

RM Young Model 05305 Wind Monitor AQ
For surface monitoring of wind speed and wind direction at the mesonet sites, we will employ an RM Young 05305 Wind Monitor AQ wind speed and direction sensors. These sensors employ a propeller anemometer. The sensors can be mounted on existing structures or on 2-meter tripods, typically on the roof of existing buildings **(Figure 4-1**), resulting in measurement heights ranging form 2 to 10 meters. All sensors will be oriented to true north using either the GPS walkoff method or solar alignment method for orienting wind speed sensors.

Figure 4-1. Roof Mounting (left) and Existing Tower Mounting (right) of Wind Sensors

Monitoring quality objectives for the supplemental surface wind measurements are presented below.

Accuracy (instrument specifications)	
Horizontal Wind Speed	±(0.2 m/s + 5% of observed)
Horizontal Wind Direction	±5 degrees
Precision (performance checks)	
Horizontal Wind Speed	±0.1 m/s
Horizontal Wind Direction	±2 degrees
Output Resolution	
Horizontal Wind Speed	0.1 m/s
Horizontal Wind Direction	1.0 deg.
Starting Threshold	0.5 m/s

Campbell Scientific 109-L Temperature Probe

The temperature within the cooler will be monitored using a Campbell Scientific 109 temperature probe. The 109-L Temperature Probe is a thermistor designed for use specifically with the CR200-series dataloggers and has a measurement temperature range of -50° to +70℃.

Campbell Scientific CR206 Data Logger

All data will be stored using a Campbell Scientific CR206 data logger. Both 5-minute and 60-minute averages will be stored, though the 5-minute data will be used primarily for QC purposes. Based on the number of measurements an statistics being record, the CR206 can operate for a period of up to approximately two weeks before it is necessary to download data. The CR206 data logger is equipped with a 915 MHz radio, allowing remote accessing and downloading of data.

4.2 Ozone/Rawinsondes

To profile ozone concentrations from the surface to the tropopause, we will use balloon-borne ozonesondes, with measurements placed at the Pinedale airport. The ozonesonde systems has three primary components, described below:

Sippican W-9000

The Sippican W-9000 system consists of a SIPPICAN ZEEMET W-9000 GPS based navaid receiver/data system for measuring winds and the SIPPICAN Mark II Microsondes radiosonde packages.

The SIPPICAN ZEEMET W-9000 receiving station interfaces with a personal computer and printer. This is a state-of-the-art wind finding system employing GPS technology. The UHF receiver operates in the 400 MHZ range. SIPPICAN software enables the interface with the SIPPICAN W-9000 receiver and reduces the thermodynamic pressure, temperature and humidity (PTU) and navaid/wind data. During each flight, the technician is able to monitor both raw and reduced data in near real time. The software also includes graphics and plotting capabilities that allow the technician to review results during and at the end of each flight. Both raw and reduced data are stored on the hard disk in subdirectories identified by the flight name. All data files are copied to both primary and backup diskettes immediately after each flight.

SIPPICAN Mark II Microsondes

The SIPPICAN Mark II Microsondes are 10 x 19 x 15 cm and weigh 250 grams with a water-activated 18V battery. The radiosonde UHF transmitter sends its modulated signals in the 400 MHZ range. The Microsondes are calibrated at the factory in a computer-controlled environmental chamber. Calibration coefficients are stored in read-only-memory (ROM) within each sonde and are automatically transmitted to the receiver in 1.5 sec intervals. Temperature is measured using a bead thermistor and relative humidity using a carbon hygristor. The SIPPICAN W-9000 is an automatic wind finding system that is based on tracking the sonde using the GPS satellite network. The Microsonde incorporates a low-noise integrated circuit GPS receiver. Winds aloft are calculated from the change in balloon position (determined from navaid) with time. Height is obtained directly from GPS positioning and, unlike older systems, pressure is now a derived parameter, calculated from the hydrostatic equation, using measured height, temperature, and humidity.

Accuracy (instrument specifications)	
Horizontal Wind Speed	± 0.5 ms^{-1}
Horizontal Wind Direction	Unknown
Temperature	± 0.2° C
Relative Humidity	± 2.0%
Output Resolution	
Horizontal Wind Speed	0.1 m/s
Horizontal Wind Direction	1.0°
Temperature	0.1° C
Relative Humidity	1.0%

EN-SCI Corporation KZ-ECC Ozonesondes

EN-SCI Corporation KZ-ECC ozonesonde system will be used in conjunction with the SIPPICAN W-9000 Mark II Microsondes radiosonde package. The KZ-ECC atmospheric ozone sounding system is designed for ozone measurements from balloon platforms, but for this project will be used both from balloon platforms and, in a modified package, for continuous surface sampling at fixed locations (see Section 3.2.1.4). Ozone is measured with an electrochemical concentration cell (ECC) ozonesonde coupled through an electronic interface to a SIPPICAN W-9000 Mark II radiosonde (described in detail in the meteorological measurements proposal).

The ECC ozonesonde is of a simple design consisting of a rigid mainframe on which is mounted a motor-driven Teflon/glass air sampling pump, a thermistor for measuring pump temperature, an ozone sensing ECC, and an electronics box containing interface circuitry which couple the ozone sensor to the radiosonde. The mainframe is mounted in a lightweight weatherproof polystyrene flight box that is taped and wired to the radiosonde during flight.

The ozone-sensing cell is made of two bright platinum electrodes immersed in potassium iodide (KI) solutions of different concentrations contained in separate cathode and anode chambers. The chambers are linked with an ion bridge that, in addition to providing an ion pathway, retards mixing of the cathode and anode electrolytes thereby preserving their concentrations. The electrolytes also contain potassium bromide (KBr) and a buffer whose concentrations in each half-cell are the same. The driving electromotive force for the cell, of approximately 0.13 V, is provided by the difference in potassium iodide concentrations in the two half cells. Sample air is forced through the ECC sensor by means of a non-reactive pump fabricated from TFE Teflon impregnated with glass fibers. The pump is designed to operate without ozone-destroying lubricants. Pumping efficiency for each pump varies from pump to pump and is also dependent on ambient air pressure. The sampling flow rate is calibrated at the factory and checked in the field before launch. The ECC ozone concentration calibration is also determined prior to launch.

When ozone in air enters the sensor, iodine is formed in the cathode half cell according to the relation

$$2KI + O_3 + H_2O \rightarrow 2KOH + I_2 + O_2. \qquad (1)$$

The cell converts the iodine to iodide according to

$$I_2 + 2e \rightarrow 2I^- \qquad (2)$$

during which time two electrons flow in the cell's external circuit. Measurement of the electron flow (i.e., the cell current), together with the rate at which ozone enters the cell per unit time, enables ozone concentrations in the sampled air to be derived from

$$p_3 = 4.307 \times 10^{-3}(i_m - i_b)T_p t \qquad (3)$$

where p_3 is the ozone partial pressure in nanobars, i_m is the measured sensor output current in microamperes, i_b is the sensor background current (i.e., the residual current emanating from the cell in the absence of ozone in the air) in microamperes, T_p is the pump temperature in Kelvin, and t is the time in seconds taken by the sonde gas sampling pump to force 100 ml of air through the sensor.

Sensitivity	2-3 ppb by volume ozone in air
Response Time	15 seconds for 67% of change; 60 seconds for 85% of change
Noise	less than 1% of full scale
Estimated Measurement Uncertainty	less than ± 10% of indicated value

As an integral part of the ozonesonde operations, a Dasibi EPA designated equivalent ozone analyzer and meteorological instrumentation will be installed at the ozonesonde launching site, within the hanger office building at the Pinedale Airport. This equipment is described below:

<u>Dasibi Model 1000 Series Ozone Analyzer</u>
Ozone at the Pinedale airport will be measured with either Dasibi Model 1003 or Model 1008 UV photometric ozone analyzers (EPA equivalent numbers EQOA-0577-019 and EQOA-0383-056, respectively). Sampling will made through Teflon lines, which will be of sufficiently short length to meet EPA requirements for sample residence time. Interior temperature will also be monitored.

Accuracy (performance checks)	±5%
Precision (performance checks)	±5%
Resolution	0.001 ppm
Lower Quantifiable Limit	0.002 ppm

<u>RM Young Model 05103 Wind Monitor</u>
For surface monitoring of wind speed and wind direction at the Pinedale airport site, we will employ an RM Young 05103 Wind Monitor wind speed and direction sensors. MQOs for this sensor are similar to those for the model 05305 sensor presented above with the exception of the starting threshold, which is 1.0 m/s.

4.3 Tethered Soundings

Tethersondes will be used to make vertical measurements of both the ozone and temperature at three sites, providing ozone profiles at a total of four sites, including the ozonesonde presented above. The tethersonde packages will be simple, cost-effective balloon borne instruments and will use the portable ozone saturation sampler developed by T&B Systems for the Clark County Regional Ozone and Precursors Study (CCROPS). Details of its development can be found in the CCROPS final report (Bush et al., 2006).

The saturation sampler is based on the potassium iodide (KI) bubbler detection principle described above for the ozonesondes in Section 4.2. A prototype system was developed in 2003, and tested at the South Coast Air Quality Management District monitoring site in Santa Clarita. **Figure 4-2** shows the collected data with 5-minute average values at 30-minute intervals, along with the hourly average data from the local ozone monitor.

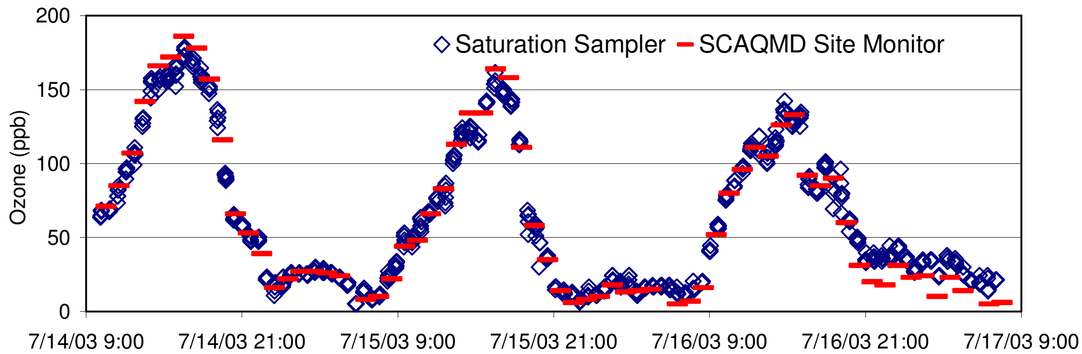


Figure 4-2. Comparison of Saturation Sampler Versus SCAQMD Ozone Data at the Santa Clarita Site in 2003

Data are recorded by a simple multi-channel 8-bit data logger that recorded the cell temperature and current over a nominal range of equivalent ozone concentrations from 0 to 250 ppb, with 1 ppb resolution. This design formed the basis for the samplers built and deployed during the 2005 CCROPS, where 13 samplers were deployed.

Accuracy (performance checks)	±10%
Precision (performance checks)	±10%
Resolution	0.001 ppm
Lower Quantifiable Limit	0.002 ppm

We recognize the harsh environment in which the sonde packages will be operating. We have tested and operated the samplers to ambient temperatures in excess of 50°C, but have not operated them below about 10°C. Therefore, to address any questions about the viability of the method in a cold environment, we performed tests of the package in a simulated environment. The package was prepared for operation at room temperature and placed in a freezer that brought the ambient temperature down to –21°C. The system was allowed to operate for 8 hours. During operations, the internal temperature of the sampler, which is recorded by the sampler logger, was maintained at an operational level and both the anode and cathode solutions maintained their integrity and did not freeze. The resulting data output was normal. To further ensure the success of the method we will be adding a small heater in the form of a 3-watt light bulb or chemical warmer to the sampler. This will remove any questions about the temperature integrity of the system and allow operations over the desired time periods.

The four dimensional position of the sonde (latitude, longitude altitude and time) will be recorded on a Garmin GPS receiver mounted in the base of the sampler, along with the sampler's battery pack. Data collected from both the sampler and the GPS system will be merged based on sampling time to create a high-resolution sample system with data collected in one-second-scan intervals. The sampler packages, with GPS receivers, will be suspended below helium filled spherical balloons and raised and lowered human power. Further information of the sonde package system is described in "Innovative Procedures for the Performance Auditing of Radar Wind and RASS Profilers" (Baxter, 2002), presented at the Sixth Symposium on Integrated Observing Systems in Orlando Florida.

While the accuracy of the ozone sonde measurement system has been well documented in past programs, and the detection principle for ozone is based on fundamental physical principles, we will still implement appropriate quality control checks using a certified ozone transfer standard to verify the accuracy of the measurements. Furthermore, checklists and detailed procedures will be followed in the preparation of the systems, operation in the field, and data processing and validation, to create a traceable link between the collection of the data and the final reported validated data set.

While the saturation monitor does record temperature, the probe is mounted internally to measure the air temperature in the pump system, an integral measurement to the calculation of ozone concentration. We will add a second probe to the exterior of the package, with the data recorded in the existing sampler's data logger. The sampler's internal logger has two spare channels specifically for this type of added measurements.

4.4 Aircraft Sampling

The sampling instrumentation for the aircraft that we are proposing is identical to that which used during the 2005 CCROPS (T&B Systems, 2006). Ozone sampling is based on the wet cell KI technique implemented by EN-SCI Corporation for tropospheric and stratospheric ozone profiling, as described in Section 4.2. The sample pump/cell system is housed in a small case with the output signal from the sampler recorded on a Campbell CR1000 data logger. This data logger allows the recording and parsing of a serial data stream from a Global Positioning System receiver as well as recording analog signals of pressure, ambient temperature, detection cell temperature and the calculated values of ozone based on the sampled parameters. Data are sampled and recorded at 2-second intervals. A set of AA batteries provides power and the capability for the entire system to measure ozone continuously for over 8 hours. The sample inlet is through a length of FEP Teflon tubing to a region of the aircraft in free airflow. The temperature probe will be placed near the sample inlet. The preparation time prior to a flight requires approximately 20 to 30 minutes to install, pre-flight and assure that the systems were operational. **Figure 4-3** shows the installation of the package behind the pilot seat in the Piper Super Cub used for the 2005 CCROPS study, with the sample line is run out the open window to the mounting on the strut. For this study, we are using a Cessna 172 based out of the Pinedale airport.

In addition to sampling for ozone, $PM_{2.5}$ sampling will also be included in the aircraft measurements using a DustTrak 8520 optical light scattering instrument. Test flights of the system showed that the aircraft readings were in no way affected by the aircraft exhaust, as evidenced by $PM_{2.5}$ reading of zero.

Figure 4-3. Ozone Sampling Package Mounting in Back Seat of Aircraft

4.5 VOC Sampling

VOC samples will be collected using SUMMA canisters outfitted with flow controllers set up for 3-hour integrated samples. Carbonyl samples will be collected using DNPH-coated cartridges outfitted with ozone scrubbers and connected to constant flow pump systems over the same time period as the canisters. VOC samples will be analyzed using Method TO-14 with an expanded PAMS list of compounds (see **Table 4-1**). Carbonyl samples will be analyzed using Method TO-11 for the compounds listed in **Table 4-2**. Analysis will be performed by Environmental Analytical Services, Inc., Santa Barbara, CA.

Table 4-1. Target Compound List for EPA Method TO-14 Toxics in Air (Expanded for PAMS)

Ethene	Cyclohexane	Total Petroleum Hydrocarbons:
Acetylene	2-Methylhexane	Total Non-Methane Hydrocarbons
Ethane	2,3-Dimethylpentane	Total Gas Non-Methane Organics
Propene	3-Methylhexane	Total Volatile Organic Compounds
Propane	2-Methyl-1hexene	TPH (gasoline)
i-Butane	Tert amyl methyl ether	TPH (diesel)
Methanol	2,2,4-Trimethylpentane	TPH (hexane)
1-Butene	n-Heptane	TPH (toluene)
1,3-Butadiene	Methylcyclohexane	TPH (methane)
n-Butane	2,5-Dimethylhexane	TPH (Jet A Fuel)
t-2-Butene	2,4-Dimethylhexane	TPH (Mineral Spirits)
c-2-Butene	2,3,4-Trimethylpentane	c6+ (hexane)
Ethanol	Toluene	Sample: Composition
3-Methyl-1-butene	2,3-Dimethylhexane	Total Identified
Acetone	2-Methylheptane	Paraffins
i-Pentane	4-Methylheptane	Isoparaffins
1-Pentene	3-Ethyl-3-methylpentane	Aromatics
Isopropanol	3-Methylheptane	Napthlenes
2-Methyl-1-butene	2-Methyl-1-heptene	Olefins
n-Pentane	n-Octane	Oxygenates
Isoprene	Ethylbenzene	Carbon Ranges:
t-2-Pentene	m,p-xylene	C2 (ethane)
c-2-Pentene	Styrene	C3 (propane)
Tert butyl alcohol	o-xylene	C4 (Butane)
2-Methyl-2-butene	1-Nonene	C5 (Pentane)
2,2-Dimethylbutane	n-Nonane	C6 (Hexane)
Cyclopentene	i-Propylbenzene	C7 (Heptane)
n-Propanol	n-propylbenzene	C8 (Octane)
Cyclopentane	a-Pinene	C9 (Nonane)
Methyl tert butyl ether	3-Ethyltoluene	C10 (Decane)
2,3-Dimethylbutane	4-Ethyltoluene	C11+ (Undecane)
2-Methylpentane	1,3,5-Trimethylbenzene	
3-Methylpentane	2-Ethyltoluene	
1-Hexene	b-Pinene	
n-Hexane	1,2,4-Trimethylbenzene	
Diisopropyl ether	n-Decane	
3-Methylcyclopentene	1,2,3-Trimethylbenzene	
Ethyl tert butyl ether	Indan	
Methylcyclopentane	d-Limonene	
2,4-Dimethylpentane	1,3-Diethylbenzene	
Benzene	1,4-Diethylbenzene	
	n-Butylbenzene	
	1,4-Dimethyl-2-ethylbenzene	
	1,3-Dimethyl-4-ethylbenzene	
	1,2-Dimethyl-4-ethylbenzene	
	Undecane	
	1,2,4,5-Tetramethylbenzene	
	1,2,3,5-Tetramethylbenzene	
	Napthalene	
	Dodecane	

Table 4-2. Target Compound List for EPA Method TO-11
Volatile Organic Compounds

Compound
Formaldehyde
Acetaldehyde
Acrolein
Acetone
Propionaldehyde
Butyraldehyde
Methylethylketone
Benzaldehyde
Valeraldehyde
Cyclohexanone
Hexaldehyde

4.6 Upper-air Meteorology

A 915-MHz radar wind profiler (RWP) with a Radio Acoustic Sounding System (RASS), a collocated mini-Sodar, and a surface-based meteorological system (if one does not already exist at the site) will be used to collect the upper air meteorology data. These instruments provide vertically and temporally resolved boundary layer winds, virtual temperature (T_v), and boundary layer depth (i.e., mixing height) data. In particular, the RWP provides continuous (hourly or sub-hourly) wind data with a vertical resolution of 60 m at heights from about 120 m up to about 3000 m agl. The mini-Sodar fills in data beneath the RWP measurements by providing continuous (hourly or sub-hourly) wind data with a vertical resolution of 5 m at heights from about 15 m up to about 200 m agl. The RASS provides continuous (hourly or sub-hourly) T_v data with a vertical resolution of 60 m at heights from about 120 m up to about 1,500 m. The exact height coverage at any given time depends on atmospheric conditions. Continuous (hourly or sub-hourly) boundary layer depth can be derived from the RWP and mini-sodar reflectivity data and from the RASS T_v data. In addition, the RASS T_v data can be used to determine atmospheric stability. Examples of selected data products are shown in **Figures 4-4** through **4-6**. The instruments are shown in **Figure 4-7**.

Accuracy (instrument specifications)	
Horizontal Wind Speed	0.5 m/s
Horizontal Wind Direction	±5°
Maximum Altitude	200 meters
Sampling Height Increment	5 meters
Minimum Sampling Height	15 meters
Transmit Frequency	4500 Hz.
Averaging and Reporting Interval	1 to 60 minutes

As part of the operations, we will design and implement sampling strategies for the RWP/RASS and mini-sodar, including programming the data acquisition systems to operate the instruments under configurations that produce the highest quality data for the typical atmospheric conditions found in the Upper Green River Basin.

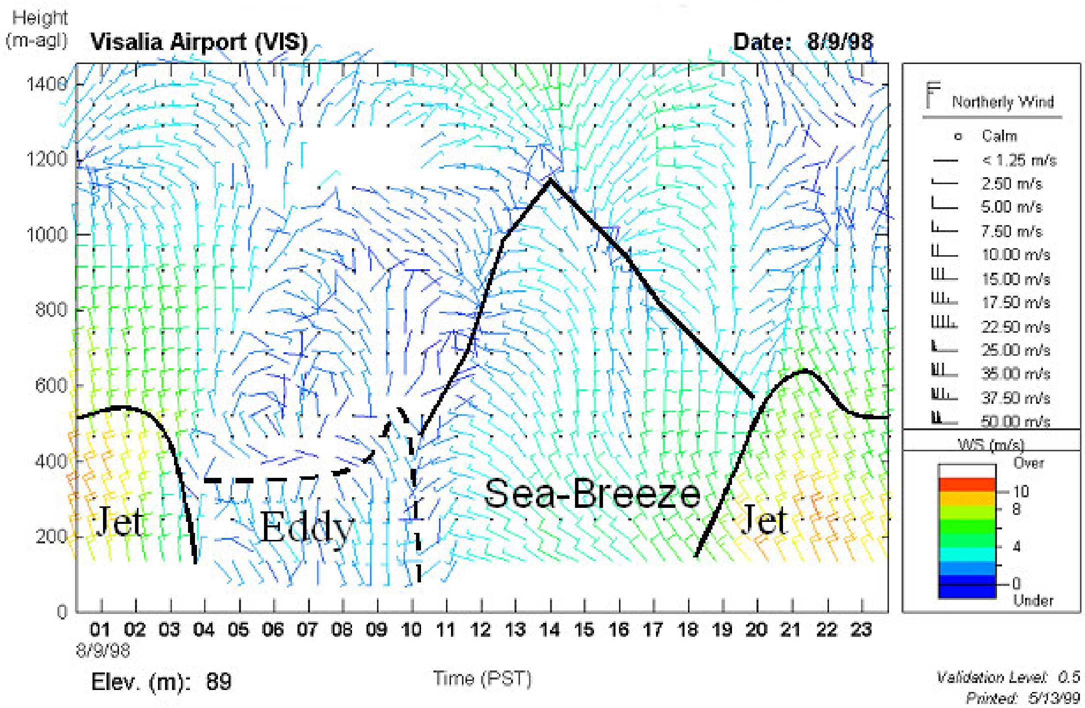


Figure 4-4. Example of a Time-height Cross-section of RWP Data Showing Complex Wind Patterns

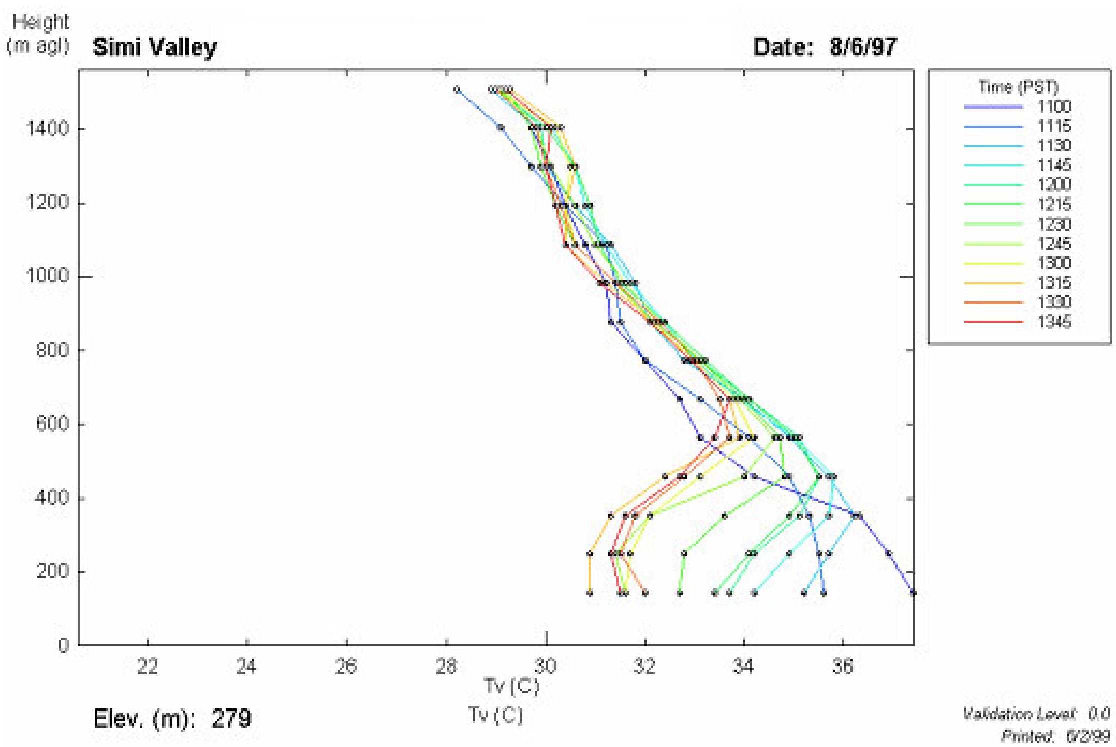


Figure 4-5. Example of Vertical Profiles of RASS T_v Showing how the Measurements Capture the Rapid Evolution of Atmospheric Stability

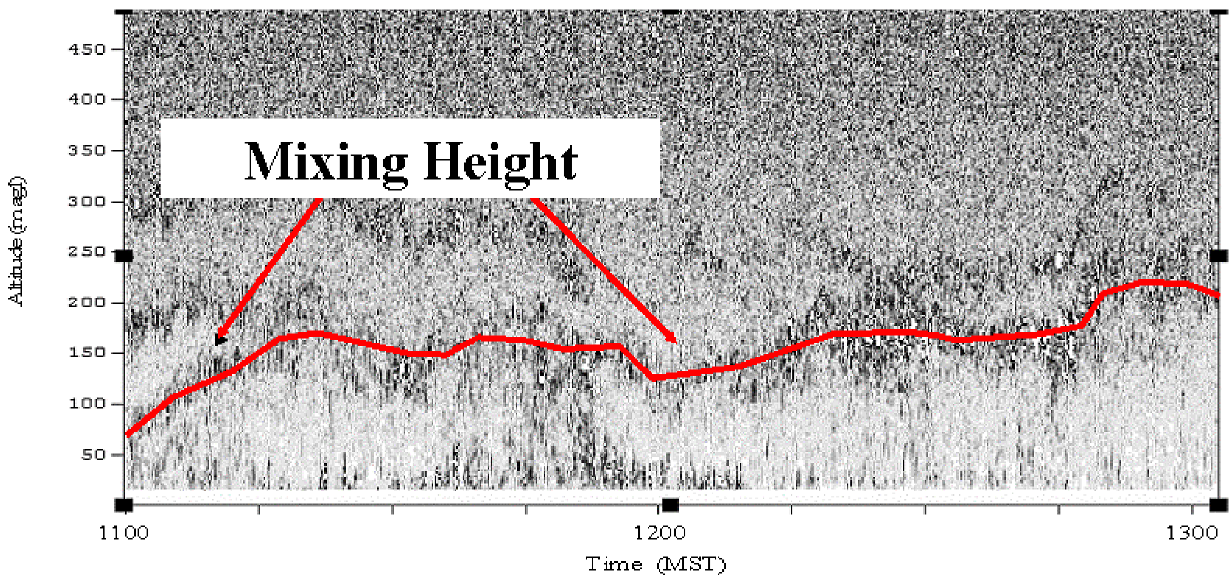


Figure 4-6. Example of Sodar Backscatter Data, Showing How Measurements Capture the Daytime Mixing Height Under Cold Wintertime Conditions

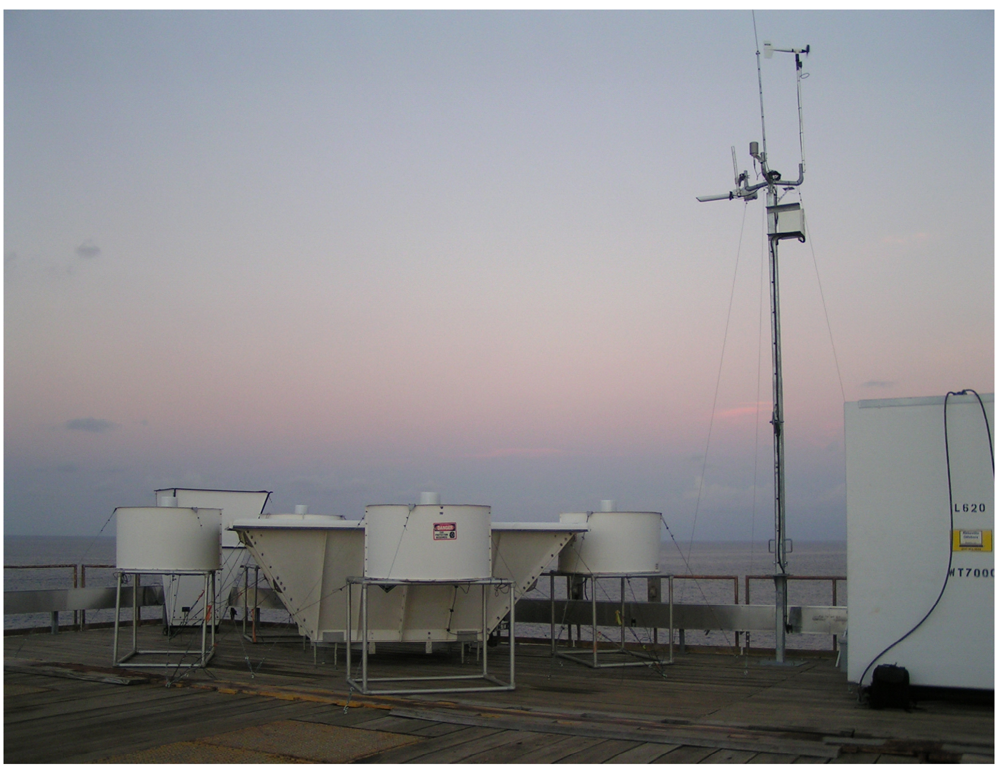


Figure 4-7. RWP, RASS, Mini-Sodar, and Surface Meteorological Equipment Operated by STI from June 2005 through October 2006 for Texas Air Quality Study II (Texaqs-II) Field Program

4.7 Additional Measurements

Total UV Radiation

UV radiation will be measured using two Eppley Total UV Radiation (TUVR) sensors – one facing upward to the sky and one facing downward to the ground. The Eppley Ultraviolet Radiometer consists essentially of a selenium barrier-layer photoelectric cell with a sealed-in quartz window, a bandpass filter to restrict the wavelength response of the photocell to the designed range, generally 295-385 nm (i.e. adhering closely to the generally accepted limits for solar ultraviolet radiation reaching the earth's surface, even at altitudes as high as l5,000 feet) and virgin teflon diffusing disk. The purpose of this disk is twofold, - to reduce the light intensity at the filtered photocell (and thus to increase its stability with exposure time) and also to improve the adherence of the instrument to the Lambert cosine law (and is shaped with this object in view).

These sensors will be installed at the Boulder site. For the UGWOS, the sensors will be connected to a Campbell Scientific CR10X data logger maintained by T&B Systems.

5. DATA REPORTING

5.1 Data Management Plan

A primary study objective is to produce an adequately validated data set from the field measurements that is well defined and documented within the desired completion time. The overall goal of the data management effort is to create a system that is straightforward and easy for users to obtain data and provide updates.

Each data provider will be responsible for reviewing and validating their collected data. The raw data will be validated to level 1 as described in "The Measurement Process: Precision, Accuracy, and Validity" (Watson, 2001) before being submitted to the database. This includes flagging values for instrument downtime and performance tests, applying any adjustments for calibration deviation, investigating extreme values and applying appropriate flags. Flags used for UGWOS are presented in **Table 5-1**. Each data provider will be responsible for documenting the validation process so that it could be provided to the data manager and other analysts if needed.

In addition, each data provider will be responsible for furnishing information regarding the monitoring equipment used in the field study and any additional site information to the data manager as requested to enhance the overall documentation of the study. In particular, participants will provide the Monitoring Quality Objective (MQOs) defining the quality of all data submitted as "valid." These MQOs contain the following:

- Accuracy
- Precision
- Lower quantifiable limit
- Resolution
- Completeness

If cases exist where data do not meet the primary MQOs but is still deemed useable and can be defined with a secondary set of MQOs, these additional MQOs and the dates to which they apply will also be submitted.

Table 5-1. Data Flags

Flag	Description
V	Valid. Data meets primary MQOs.
S	Valid, but does not meet primary MQOs. Secondary MQOs in effect.
I	Data invalid.
M	Missing. Measurement not taken.

Once the data have been validated to level 1, the data will be prepared for submittal to the database in a form that clearly define the time reference, averaging period, parameter names and units. The time reference for the database is **local standard time (Mountain Standard Time)** and the averaging period reference will be standardized to **hour beginning (0 – 23)**. The data will be submitted as ASCII comma delimited text files or excel spreadsheet files, with data columns well defined to clarify site identification, parameters, instrumentation, units, and time reference.

Data will be submitted in a format similar to that of the final database structure, as outlined below. This basically has a second column for each measured value for an accompanying QC code. Data flagged as invalid or missing will be given a value of -9999. In the event that data for a given measurable is either all valid (meeting primary MQOs) or all missing, participants need not supply the flag column, though this must specifically stated.

5.1.1 Preliminary Database Management Design

T&B Systems will be responsible for assimilating the submitted data into an integrated relational Microsoft ACCESS database and is managing the data for subsequent distribution and analysis. The database will consist of both information and data files. The goal is to make the database very usable by data analysts and all participants.

The following describes the preliminary design for the database. The database will include an inventory spreadsheet file to help users track and ensure that all of the data were submitted and processed in a timely and consistent manner. All data files submitted will be examined to verify unique names for all sites, instruments, and parameters so that no orphan or duplicate records exist in any of the tables. A system will also be designed for identifying the version and or modification date of all data files.

The data will have the following flat format:

<u>Surface Hourly Meteorological Data</u>

SITE, DATE, HOUR, WS, WS_QC, WD, WD_QC, TP, TP_QC, and any additional met parameters and QC codes, if collected.

<u>Ozone 8-hour averaged:</u>

SITE, DATE, HOUR, O3_8HR, O38HR_QC

<u>Hourly Surface Air Quality:</u>

SITE, DATE, HOUR, OZONE, O3_QC, NO, NO_QC, NOx, NOx_QC, NOy, NOy_QC, PAN, PAN_QC and any additional air quality parameters if collected and QC codes.

<u>NMHC VOC:</u>

SITE, DATE, HOUR, START_TIME, END_TIME, CANNISTER_ID, QC_CODE, PARAMETER1, PARAMETER2, PARAMETER3,..PARAMETERn, notes

<u>Upper level meteorological and air quality data</u>

The episodic rawinsonde, ozonesonde, pibal, and glider data will be stored together in a file with the following format:

SITE, DATE, TIME, HEIGHT, PRESSURE, PRESSURE_QC,

O3, O3_QC, WS, WS_QC, WD, WD_QC, TP, TP_QC, RH, RH_QC

Radar Profiler and SODAR data will be stored in both a flat file format and a CDF (common data format) or similar tabular format. CDF files are used for plotting the data. Participants should include both flat files and CDF files with their data submissions. The final flat format will be as follows:

SITE, DATE, HOUR, TIME, HEIGHT, WS, WS_QC, WD, WD_QC

The data will be formatted into the final database with the following unit configurations and naming conventions:

- Parts per million for O3, NOx, NOy
- Meters per second for wind speed (as a general rule, metric units will be used)
- Degrees Celsius for ambient temperature
- Percent for relative humidity
- Parts per Billion Carbon for non-methanated hydrocarbon species
- Watts/m^2 for radiation

- SITE = Alpha-numeric site code identifier
- DATE = (MM/DD/YY)
- HOUR= Nearest whole begin hour (HH) (MST)
- TIME, START_TIME or END_TIME = Time stamp of data (HH:MM:SS) (MST)
- HEIGHT = Elevation in meters above MSL
- QC_CODE, WS_QC, WD_QC, O3_QC, etc =
  "V" (valid), "M" (missing), "I" (invalid), "S" (secondary MQOs)
- NOTES = any additional information

The level 1 data files along with the documentation files will be available for download on an FTP server.

5.2 Data Reporting

Data files of all data collected during the study will be presented to WDEQ by June 15, 2007. The ENVIRON/T&B team will review the validated data collected during the field study and prepare descriptive summaries in a report format for delivery to WDEQ. We will prepare summaries of air quality and meteorological conditions during the study period. In addition, we will prepare more detailed descriptive analyses of the air quality and meteorology measured during each high ozone event captured by the intensive operating periods. As part of our Level 1 data validation procedures, we will carefully examine all of the measurements. This process typically provides insight into the critical processes that determine the extent of pollution loading such as atmospheric stability, wind shears (low-level jets, etc), layers aloft, and boundary layer development (growth rate, peak mixing heights), including the nocturnal boundary, convective boundary, and residual layer. The meteorology leading up to and during periods with high ozone levels and the diurnal behavior of ozone aloft during these periods will be characterized. Supporting the analyses discussion, products that will be produced in this phase of the study include but are not limited to:

1. Time-series plots of continuous measurements such as ozone, ambient temperature, radiation;
2. Vertical profiles of ozone, temperature, and winds;

3. Horizontal mapping of ozone, precursors, ambient temperature, and winds—both at the surface and aloft;
4. Time-height cross sections of ozone, potential temperature, winds, and mixing heights.
5. Time-height cross sections of transport statistics including scalar transport distance, vector transport distance, and recirculation factors
6. Wind roses at the surface and select levels aloft,
7. Pollution roses at the surface and select levels aloft, and
8. Summary tables of 1-hour and 8-hour averaged ozone as well as statistical summaries showing hourly averages and maximums.

A final report will be prepared presenting:

- The above-mentioned information and associated analyses in an easy to digest format.
- A summary of field operations via tables showing the times of balloon-borne soundings, the times of ground and airplane sampling, VOC samples, and supplemental measurements. A measure of the associated data capture rates will be included. Problems encountered during the field operations will be discussed.
- Details of the database design including descriptions of the metafiles; field descriptors; and the accuracy, precision, lower limits, resolution, and completeness of each measurement.

A draft version of the report will be presented to WDEQ by June 30, 2007. Voluminous tables and figures will be incorporated into electronic appendices as appropriate. All report materials will be made available via a project web site with access restricted in accordance with WDEQ policies and procedures.

6. QUALITY ASSURANCE PROGRAM

6.1 Project Management

Mr. Till Stoeckenius will serve as overall project manager and co-principal investigator. Dr. Greg Yarwood will serve as ENVIRON's Principal in Charge for the proposed project, insuring that any and all ENVIRON resources needed for the timely and on-budget completion of the project are made available.

Mr. Don Lehrman will serve as manager of all field operations and co-principal investigator, overseeing the day-to-day project activities and providing the primary interface with team members on project related issues.

Additional key staff will be assigned to each project task as shown in **Figure 6-1**. Quality assurance will be lead by Mr. David Bush. Mr. Bush has extensive experience in this area, having served as the external quality assurance officer for a number of large air quality studies. He will also be closely involved in field study operations. Mr. Robert Baxter will also be involved in field study operations and will lead the data archiving task. Mr. Baxter has managed numerous field studies including the Clark County (Las Vegas) CO Saturation and PM_{10} studies. Key staff from T&B Systems, MSI and STI will be responsible for the deployment, operation, and data gathering from the specific instrumentation programs they are assigned to.

Study personnel responsibilities and contact information is presented in **Table 6-1**.

A UGWOS study web site has been developed to assist in communications between study participants. This web site can be found at http://70.133.103.202/UGWOS. The web site contains the following web pages:

- Study Overview - This page presents a brief overview of the study, the study objectives, and study schedule.
- What's New? – This page serves as "document control" for the web site, providing a complete history of all modifications to the web site. Anytime the web pages are expanded or modified, a brief summary and the date of the modification is posted.
- Project Status – This page provides information regarding the readiness of participants' monitoring efforts. The page is particularly important during the early stages of the study period for helping to maintain the study schedule.
- Study Forecast – This page provides for the communication of study-specific information regarding forecasted ozone conditions, and serves as the alert for IOPs and episode-mode monitoring efforts.
- Monitoring Sites – This page provides a description of the UGWOS measurements and a map of the measurement locations.
- Project Participants – This page provides a list of the UGWOS participants, a summary of each participant's study responsibilities, and contact information for key individuals.
- Planning Documents – This page requests and posts measurement quality assurance documentation. This is discussed in more detail below.

- Preliminary Analysis – This page provides participants with a means to present preliminary analysis of collected data. This in turn provides study management with feedback regarding collected data versus study goals, and the means of refining the monitoring effort, if needed.

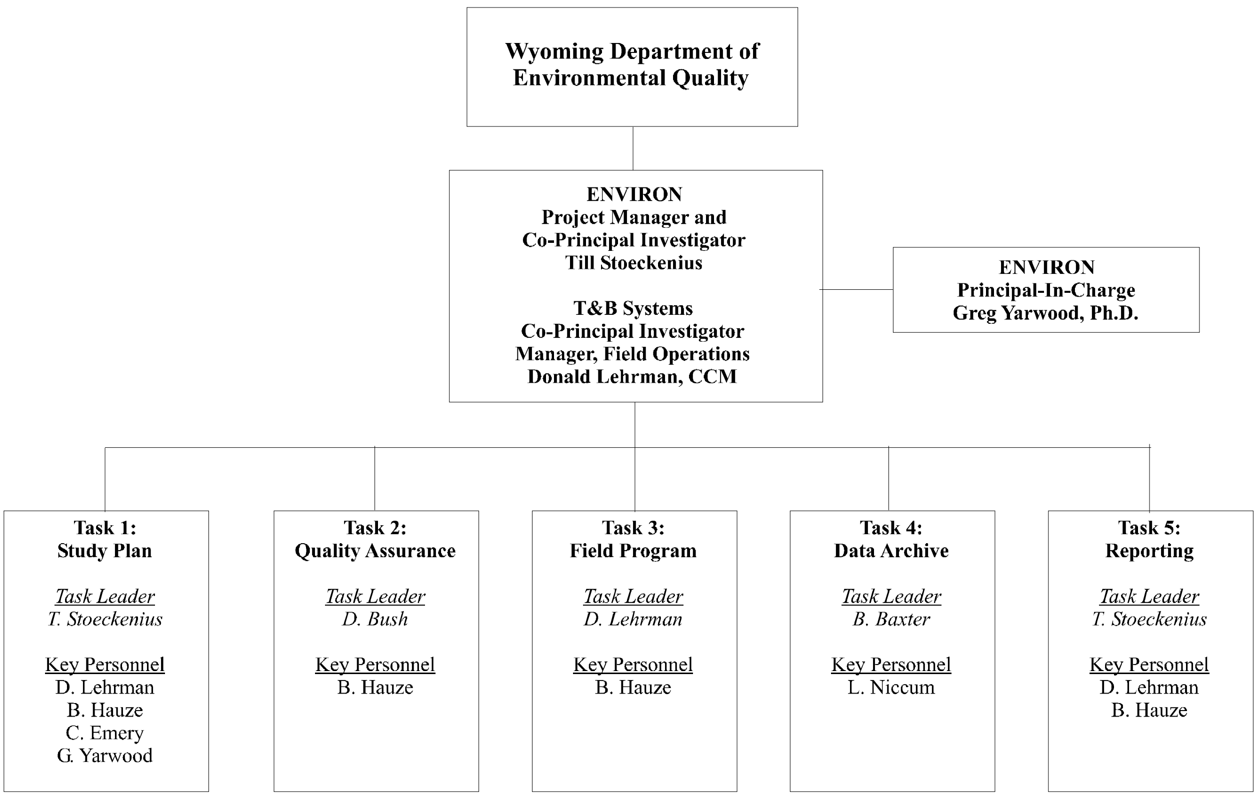


Figure 6-1. Proposed Project Organization

Table 6-1. Project Responsibilities and Contacts

Name	Organization	Key Responsibilities	Phone Numbers
Cara Keslar	Wyoming DEQ	Contract Manager	(307) 777-8684 (307) 421-9953 (cell)
Jennifer Frazier	Wyoming DEQ	Pinedale Support	(307) 231-2387 (cell)
Till Stoeckenius	Environ	Project Manager Principal Investigator	415-899-0709 415-717-0039 (cell)
Don Lehrman	T&B Systems	Field Project Manager Ozonesondes Principal Investigator	(707) 526-2775 (707) 975-4412 (cell) (307) 708-0783 (local cell)
David Bush	T&B Systems	Quality Assurance Aircraft Measurements	(530) 647-1169 (530) 903-6831 (cell) (307) 708-0785 (local cell)
Bob Baxter	T&B Systems	Overall Field Measurements Support	(661) 294-1103 (661) 645-0526 (cell) (307) 708-0784 (local cell)
Bill Knuth	T&B Systems	Tethered Soundings Study Forecasting	(707) 279-1661 (707) 975-4413 (cell) (307) 708-0786 (local cell)
David Yoho	T&B Systems	Tethered Soundings	(661) 294-1103 (661) 212-3008 (cell) (307) 708-0787 (local cell)
Bill Hauze	MSI	Field Support	(801) 474-3826 (801) 450-3776 (cell) (307) 708-0780 (local cell)
Dan Risch	MSI	Forecasting	(801) 474-3826
Casey Lenhart	MSI	Mesonet Site Checks	(801) 474-3826 (307) 708-0781 (local cell)
Mike Peterson	MSI	Tethered Soundings	(801) 474-3826 (307) 708-0782 (local cell)
Clinton MacDonald	STI	Radar Profiler, RASS, miniSodar - Management	(707) 665-9900 (415) 827-0051
Charley Knoderer	STI	Radar Profiler, RASS, miniSodar - Support	(707) 665-9900
Lincoln Sherman	ARS	Trace CO and Aethalometer Measurements at Boulder	(970) 484-7941 (970) 222-5362 (cell)
Michael Butler	IML	Boulder and Daniel Site Operations	(307) 674-7506 (307) 751-3108
Jim Mclellan		Aircraft Pilot Pinedale Airport Support	(307) 367-4395 (307) 537-5488 (home)

6.2 Data Quality Objectives

Specific monitoring quality objects have been presented for each measurement in Section 4 of this document. The overall objectives for the collection of valid data will be as follows:

Air quality data: 80% of the possible data
Meteorological data: 90% of the possible data

For the above calculation, data lost during calibrations, maintenance or audits are considered invalid.

6.3 Assessment And Oversight

6.3.1 Quality Control Procedures

As part of the quality assurance program, detailed quality control procedures have been implemented to assess and maintain control of the quality of the data collected. All equipment will undergo complete checkout and acceptance prior to the start of monitoring on February 1, 2007. This checkout will occur during the week prior to the start of monitoring, during setup and installation of the equipment. This includes a dry run of all measurement methods, during which operating procedures can be refined and fully documented. Standard operating procedures (SOPs) for measurements will be completed prior to the start of monitoring. SOPs can be found in Appendix B.

A summary of key elements of the QC program for each measurement is presented below:

Ozone Analyzers and Samplers
All ozone analyzers and samplers will be routinely checked using a certified transfer standard, following operating procedures consistent with EPA guidelines. This will consist of zero and span checks conducted at the beginning and end of each IOP. These checks will be conducted using a transfer standard certified against T&B Systems primary standard maintained following EPA's guidelines at their office in Valencia, CA. For the mesonet equipment, a 2B model 306 (S/N 2) portable ozone calibrator will be used. Zero/span checks of the mesonet samplers will be conducted at least twice per week during the IOPS, providing precision data. A pass/fail criterion of +/-10% will be used when evaluating the span and calibration data. A zero check and ground truth comparison will be performed on all tethersonde and ozonesonde equipment prior to each flight.

Aircraft Samplers
QA/QC for the aircraft ozone sampler will be similar to that for the other ozone analyzers and samplers. This would include calibrations at the beginning and end of the study, as well as zero check and ground truth comparison each intensive day. In addition, we will periodically conduct soundings coincident with ozonesonde soundings, providing a QA comparison for both aircraft and ozonesonde measurements. In addition, soundings at each of the tethered sounding sites will be conducted each day, providing additional QC data. The DustTrak will be subject to zero and flow checks each intensive day.

Radar Profiler, RASS, miniSodar
The status of the instruments will be checked daily via remote access of the data. If any problems are encountered that could affect data recovery, repairs will be made promptly. The data will be transferred hourly to STI's weather operation center, using a high-speed, two-way

satellite, where it will then be posted to a web site in real time so that team members can use the data to assist in special monitoring and forecasting.

The data will be quality-controlled using the National Oceanic and Atmospheric Administration's (NOAA) Weber-Wuertz quality control algorithm. After objective quality control, a meteorologist will perform subjective quality control of the hourly wind, T_v, and mixing height data using specialized STI data display and editing programs (e.g., GraphXM and LAPMom). The subjective review and editing will produce data that will require no further judgment as to their validity and will be considered ready for modeling and data analysis. Daily reviews will include a general scan of the data to identify instrument problems but will not include data editing.

VOC Sampling
Field blanks totaling approximately 5% of the collected samples will be collected and analyzed. In addition, two of the samplers will be collocated periodically during the study to collect duplicate samples.

Radiation Sensors
The relative calibrations of the two radiation sensors will be periodically checked by aiming both sensors towards the sky and recording the responses. The ratio of the responses should be consistent with that obtained from the calibration certifications that accompany the sensors. In addition, the zero response of each sensor will be checked at the same time by covering the sensor with a UV blocking substance.

6.3.2 Calibrations

The purpose of a calibration is to establish a relationship between the ambient conditions and an instrument's response by challenging the instrument with known values and adjusting the instrument to respond properly to those values. The calibration method for each of the air quality and meteorological variables is summarized in **Table 6-2.**

Calibrations of the ozone instruments will be performed upon initial installation and at the end of the study period. Additional calibrations will be performed on an as-needed basis in the event of equipment repair or replacement. All calibrations will be performed in accordance with manufacturers recommendations and consistent with USEPA guidance (USEPA, 1994, 1995, 2000).

Calibrations and zero/span checks of all ozone monitoring equipment will be conducted using a transfer standard (2B Model 306, S/N 002) certified against a local ozone standard (Dasibi Model 1003-PC, S/N 2437) maintained at the Pinedale airport. This local standard in turn has been certified against T&B System's primary standard maintained following EPA's guidelines at their office in Valencia, CA, as well as against the US EPA Region 8 primary standard maintained at Boulder, CO. The two certifications showed very good agreement.
Ozone data will be adjusted if the calibration slope is off by more than ±5% or if the zero is off by more than ±5 ppb.

All meteorological sensors will be calibrated at the beginning and ending of the study. Wind speed sensors will be calibrated using an RM Young constant rpm motor simulating wind speeds at several points across the sensor's operating range. Wind direction sensors will be calibrated by checking responses in 30° to 45° increments. Calibration of the UV radiometers is provided by the manufacturer.

Table 6-2. Calibration Methods for the Monitored Variables

Measurement Variable	Calibration Method
Ozone (O_3)	Multipoint comparison of ozone concentrations with certified ozone transfer standard
Wind Speed	Rotational rate using a selectable speed anemometer drive
Wind Direction	Alignment using true north and linearity with a directional protractor
Temperature	Water bath comparisons to a certified transfer standard
Relative humidity	Collocated comparisons to a certified transfer standard

6.3.3 Independent Audits

As Part Of The Quality Assurance program, an independent audit program will be implemented that will use an independent entity to verify the site operations and data accuracy. These audits will be performed using personnel independent of the measurement program. This will establish confidence in the data collected and allow the measurement processes to be supported through independent verification. Audits will be performed in accordance with the principles of the US EPA.

The principal audit tool will be system audits of the data collection operations. System audits will address the following:

- Siting
- Adherence to SOPs
- QA/QC procedures
- Documentation
- Data collection and chain of custody

Mr. David Bush and Mr. Bob Baxter will conduct the system audits of all measurement platforms, with audit responsibilities based on independence from the operations of the monitoring efforts. These audits will be conducted during or before the first IOP of the study. Comments and recommendations resulting from the audits will be discussed with measurement personnel at the time of the audit, with a written memo report provided to study management within 48 hours of the audit.

As discussed above, to further verify the accuracy of the ozone measurements, the T&B Systems ozone transfer standard will be compared against the US EPA Region 8 primary standard located in Golden, Colorado. This comparison will consist of a six-point comparison, per US EPA guidance for ozone transfer standards, and will be conducted prior to its use for the UGWOS.

6.4 Data Validation

All data collected for UGWOS be will validated to Level 1 validation (see Section 5). As part of the validation effort, participant's data will be evaluated to verify that they meet the stated MQOs. If data clearly do not meet MQOs, they will be removed from the database as invalid data. If, however, data miss meeting the primary MQOs in a definable way to the point where the data are still considered useful, secondary MQOs will be assigned to the data in question. This use of secondary MQOs will be specifically documented in metafiles associated with the data.

For the radar wind profiler, RASS, and miniSodar, monthly reviews and editing will include Level 1 and Level 2 validation of wind, T_v, and mixing height data. Level 1 validation is a check of internal consistency and reasonableness for each site for each hour (or sub-hour, depending on measurement frequency). Level 2 validation is an external consistency check of the data and is achieved by comparing the data with those collected at nearby locations for each day, including comparisons of wind and temperature data to meteorological data from other sources (e.g., rawinsondes, synoptic weather charts). The final product will include electronic files containing Level 2-validated RWP and mini-sodar wind, RASS T_v, and mixing height data.

7. REFERENCES

Baxter, Robert A. (2002). Innovative Procedures for the Performance Auditing of Radar Wind and RASS Profilers. Presented at the Sixth Symposium on Integrated Observing Systems in Orlando, FL.

Bush, David, R. Baxter, W. Knuth, D. Lehrman, P. Fransioli, D. Yoho, Technical & Business Systems; W. Goliff, Desert Research Institute, Reno; M. Green, D. Dubois, DRI, Las Vegas; D. Fitz CE-CERT, UC, Riverside (2006). Clark County Regional Ozone & Precursor Study Final Report. Prepared for the Clark County Dept. of Air Quality & Environmental Management, Las Vegas, Nevada.

United States Environmental Protection Agency (1995). Quality Assurance Handbook for Air Pollution Measurement Systems Volume IV: Meteorological Measurements. Document EPA/600/R-94/038d. Office of Research and Development, Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, North Carolina.

United States Environmental Protection Agency (1998): Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II: Part I, Ambient Air Quality Monitoring Program Quality System Development. Office of Air Quality Planning and Standards. Draft Revision to Document EPA/600/R-94/038b.

United States Environmental Protection Agency (1999): EPA Requirements for Quality Assurance Project Plans. Document EPA QA/R-5. U.S. EPA Quality Staff Interim Final Report, Research Triangle Park, North Carolina. November.

United States Environmental Protection Agency (2000). Meteorological Monitoring Guidance for Regulatory Modeling Applications. Document EPA-454/R-99-005. Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina.

Watson, J.G., B.J. Turpin, and J.C. Chow (2001). The measurement process: Precision, accuracy, and validity. In *Air Sampling Instruments for Evaluation of Atmospheric Contaminants,* 9th ed., B. Cohen, Ed. American Conference of Governmental Industrial Hygienists, Cincinnati, OH, in press.

APPENDIX A

SITE METAFILES

APPENDIX B

STANDARD OPERATING PROCEDURES