

3. STUDY DESIGN AND IMPLEMENTATION

Several factors helped guide the BRAVO Study design. These include the material presented in Chapter 2 regarding monthly-summarized visibility and aerosol composition at Big Bend, and information developed during the planning of the study (available in Green et al., 2000) concerning transport patterns during periods of poor visibility, the spatial distribution of SO₂ emissions, and the frequency these emissions are transported toward Big Bend. Also helpful was knowledge gained from previous studies, notably the preliminary Big Bend study and Project MOHAVE (Kuhns et al., 1999).

Particulate sulfate has been the compound that contributes most to visibility impairment at Big Bend National Park; thus sources of SO₂ are of particular interest to BRAVO (SO₂ emissions maps are shown in Chapter 4). Particulate carbon (light absorbing and organic compounds) also contributes substantially to haze at Big Bend, so the aerosol-monitoring program was designed to reveal more information regarding the types of sources responsible for carbonaceous aerosol at Big Bend.

Previous studies demonstrated the utility of a large network of particulate sampling sites and chemical analysis of the filter samples to develop data used by spatial analysis methods. BRAVO design included a network of 38 aerosol-monitoring sites. The purposes of the individual monitoring sites for BRAVO are given below. Additional aerosol special studies were conducted (mainly at Big Bend) to address issues raised by the preliminary study.

Additional upper-air measurements were made to help evaluate and calibrate wind field models for input to air quality models. Extensive optical measurements at Big Bend National Park were made to help characterize effects of relative humidity on light scattering and the relative effects of fine and coarse particles on light scattering and light absorption. To help separate the effects from different sources, a source characterization program (sampling and chemical analysis of emissions) was conducted for several source types.

Unfortunately, the study design was constrained by the inability of the United States and Mexico to agree on the design for a joint U.S.–Mexico study. This resulted in a study design that included monitoring and source characterization only in the United States. Earlier versions of the proposed study plan included substantial aerosol and source monitoring and tracer release in Mexico. The final plan includes additional monitoring and tracer release along the U.S./Mexico border to partly alleviate the limitations imposed by conducting a U.S.-only study.

3.1 Selection of the Study Period

On the average, visibility at Big Bend is most impaired during the May to October period. The high haze levels of May were thought to be dominated by a combination of smoke from large fires in Southern Mexico and Central America resulting in high organic and elemental carbon and occasional high sulfate concentrations from distant SO₂. However, in October transport from the northeast is sometimes associated with very poor visibility.

A four-month field program from July through October 1999 was selected to maximize the likelihood of monitoring impact from a variety of potential sulfur source regions, for example northeast Mexico and eastern U.S. including eastern Texas. These regions were of interest because results from the 1996 Preliminary Study showed coal-fired power plants to be a likely, significant contributor to Big Bend haze. Back trajectory analysis showed that this four-month period would maximize the number of occurrences of flow from the significant source areas for SO₂ that are closest to Big Bend National Park. These periods might also be expected to give many episodes of transport from large SO₂ sources in central Mexico and might result in one or more cases of transport from large SO₂ source regions in the Ohio River Valley.

3.2 Use of Synthetic Tracers

3.2.1 Tracer Release

Synthetic tracers (perfluorocarbons) were released from several locations throughout the BRAVO Study. Two major objectives were identified for the use of synthetic tracers:

1. Directly determine transport and dispersion from source areas with the potential for significant visibility impairment at Big Bend National Park by tagging emissions from large, representative, individual sources within the area.
2. Evaluate and improve performance of air quality models used for BRAVO.

As *Carbón* I & II are the largest SO₂ emissions sources that are relatively near to Big Bend in an upwind direction for much of the time, the potential benefits from tagging those power plants were thought to be substantial. Since access to the *Carbón* stacks was not possible, a surrogate tracer release site from the top of a 107 meter (350 feet) tower in Eagle Pass, Texas, approximately 32 km northeast of the *Carbón* plants, was selected as one of the tracer release locations (see Figure 2-2).

The tracer releases were designed in two phases to take advantage of the seasonal flow regimes. The first phase (7/5/99 to 9/13/99) was used to characterize the transport, dispersion, and average transport duration of southeasterly flow common in the study region throughout the summer months, while the second phase (9/17/99 to 11/1/99) was designed to characterize transport and dispersion from sources to the north and east of Big Bend during the early fall months when there is a higher probability of flow from that direction.

Two tracer release locations were used in the first phase: a tower release at Eagle Pass, TX, located on the U.S./Mexico border about 32km northeast of the *Carbón* I & II coal-fired power plants, the largest SO₂ emissions sources relatively near to and frequently upwind of Big Bend, and a stack release from the Big Brown coal-fired power plant in northeast Texas. The Eagle Pass release was intended to provide insight into potential transport from the vicinity of the *Carbón* plants and the release at Big Brown was intended to represent air masses transported from northeast Texas, in particular to characterize the transport and dispersion of several large coal fired power plants in the northern reaches of the lignite belt. One tracer was released continuously at each location -- perfluoro-1,2-

dimethylcyclohexane (oPDCH)¹ at Eagle Pass and perfluoro-iso-propylcyclo-hexane (i-PPCH) at Big Brown. In addition, to provide time markers for assessing transport time, two additional tracers were released at Eagle Pass, but their releases were cycled on and off: perfluoro-1,3,5-trimethylcyclohexane (PTCH) was released during the 12 hours of daytime (8am to 8pm CDT) and not released during the night, and 1,1,2,2,3,4-hexafluoro-3,4-bis(trifluoro-methyl) cyclobutane (PDCB) was released on alternate 24-hour periods (8am to 8am CDT). With the continuous and daytime only released tracers, the concentrations measured at receptors can be designated as resulting from daytime, nighttime, or a known mixture of daytime and nighttime releases based upon the relative concentrations of the two tracers. The alternate day released tracer provides information as to which day the tracers were released and to help resolve ambiguities over the release time of the tracer. If the Eagle Pass releases are representing transport from *Carbón* I/II there should be significant relationships between SO₂ and tracer concentrations. Comparison of SO₂ concentrations with daytime versus nighttime releases can provide information that might be useful in exploring whether the tracer is more likely to mix with the *Carbón* I & II power plant plumes during daytime atmospheric conditions than during nighttime conditions.

During the second phase, continuous tracer releases continued at Big Brown and at Eagle Pass and continuous releases were added at two other locations -- a stack release at the Parish power plant near Houston, to represent air masses originating in southeast Texas, and a surface release in San Antonio, to represent air masses originating in that portion of the State. Constant tracer emission rates during both phases ranged from about 0.1 to 0.5 kg/hr depending on the tracer and release location. The September-October period is the time of year with most frequent transport from these source areas toward Big Bend National Park.

Perfluorocarbons are a class of chemically inert, fully fluorinated hydrocarbon compounds that have characteristics that make them ideal for atmospheric tracer use including low atmospheric background levels, a long atmospheric lifetime, and detection at low levels using electron capture chromatography. Criteria for selection of the tracer compounds included background concentration, cost, and ability to separate the compounds during chromatographic analysis. Design release rates were estimated using dispersion factors extrapolated from an assessment of the Project MOHAVE tracer data applied to the BRAVO Study release locations with transport to Big Bend, and using the estimated precision for the new chromatographic system developed for the BRAVO Study (Pitchford et al., 2000). Automatic systems for precisely controlled release of the perfluorocarbons were developed for use in the BRAVO Study (Watson et al., 2000). These systems included redundant methods to monitor the emission and included microprocessor-control and monitoring of all functions. Daily remote communications with the microprocessor ensured proper operations.

Release rates for the first period of the study are shown in- Table 3-1. oPDCH and i-PPCH were released continuously. PDCB was released on alternate days from 8am to 8am CDT. PTCH was released every day but only from 8am to 8pm CDT.

¹ The isomer, oCPDCH that makes up 45% of the perfluorocarbon oPDCH that was released from Eagle Pass is the material that was analyzed for in the tracer samples.

Table 3-1. Tracer release schedule first phase of study.

Tracer	<u>Eagle Pass</u>	<u>Eagle Pass</u>	<u>Eagle Pass</u>	<u>Big Brown</u>
	oPDCH	PDCB	PTCH	i-PPCH
Release period	7/5/99-11/1/99	7/5/99-9/13/99	7/5/99-9/13/99	7/9/99-11/1/99
Release Rate (kg/hr)	0.155	0.525 alternate days (8am-8am CDT)	0.184 (8am-8pm CDT only)	0.092

Release rates for the second period of the study are shown in Table 3-2. OPDCH at Eagle Pass and i-PPCH at Big Brown continued to be released during this interim period. In early September, PDCB and PTCH releases from Eagle Pass were terminated. Release at San Antonio and Houston began five days later at 8am and terminated at 8am CDT (7am CST) on November 1 along with the releases from Eagle Pass and the Big Brown power plant. The hiatus from terminating PDCB and PTCH at Eagle Pass and initiating release at San Antonio and Houston was planned to allow these tracers to clear the study area. Note that all tracers were released continuously during the second half of the study. The tracer release at the Big Brown power plant was discontinued from 11:05am on October 8 to 2:00pm on October 16 during a period of plant maintenance.

This program provided balance with three tracers representing Mexican emissions and one representing American emissions during the first half of the study when flow is more frequently from the south and three tracers representing American emissions and one representing Mexican emissions during the second half of the study when flow from the east is more likely.

Table 3-2. Tracer release schedule for the second half of the study.

Tracer	<u>Eagle Pass</u>	<u>San Antonio</u>	<u>WA Parish</u>	<u>Big Brown</u>
	oPDCH	PDCB	PTCH	i-PPCH
Release period	7/5/99-11/1/99	9/17/99-11/01/99	9/17/99-10/25/99	7/9/99-11/1/99
Release Rate (kg/hr)	0.155	0.442	0.115	0.092

3.2.2 Tracer Monitoring

At the 21 sampling locations described in Section 3.3, programmable tracer samplers were used to collect 1-hour, 6-hour, and 24-hour duration samples on Amborsorb adsorbent material. Twenty-one metal tubes containing adsorbent located in the sampler lid enabled the sampler to collect up to 21 unattended samples for predetermined start times and durations. Sample air was drawn through the adsorbent tubes by a constant flow pump. The replaceable lid of the sampler contained the 21 tubes and a memory module that stored flow and pump operation-timing data. Use of additional lids allowed the base unit to continue sampling indefinitely. Sample analysis consisted of heating the tube while flushing with a carrier gas to desorb the sampled perfluorocarbon compounds, which were then transported to an electron capture gas chromatograph for analysis (Dietz, 1996).

Concentration uncertainty for 6-hour and 24-hour samples was estimated during the study design to be less than 10% of maximum concentration expected at Big Bend. Sample volume was the same for the 6- and 24-hour samples because the 6-hour sampler pumped at four times the rate of the 24-hour sampler. Concentration uncertainty for the 1-hour samples at Big Bend is higher due to the lower sample volume.

The original BRAVO Study plan called for high-time-resolution tracer sampling (1-hour duration or less) at the Big Bend site, 6-hour duration sampling at six sites in a ~200km arc from Big Bend to the north, and 24-hour duration sampling at 18 sites throughout the Texas area. To succeed, this plan required analysis of samples collected during the early portion of the field program in order to return the limited number of sample lids for reuse in subsequent portions of the field program. Unanticipated technical difficulties with the newly constructed GC-2, the higher-sensitivity tracer analysis system designed for this study, prevented its use during the first half of the study and required mid-study modifications to the sampling plan. The 1-hour sampling was discontinued in early August and restarted in early October. The 24-hour sampling at all sites but Big Bend was similarly discontinued during the center period of the study while an older analysis system (GC-1) with lower sensitivity was used to analyze the 24-hour lids collected during August, and a few 24-hour duration sites were never implemented. These changes were made so that the 6-hour sampling at the six sites at and near Big Bend could be continued during the entire 4-month tracer release period with nearly all 6-hour samples analyzed using GC-2 (only eight 6-hr samples were by GC-1).

One-hour duration tracer samples were collected at the K-Bar site at Big Bend from July 6 to August 4 and again from October 2 to November 6, 1999. About half of the earlier period (16 of 30 sample days) and 90% of the later period (32 of 36 sample days) resulted in 18 or more 1-hour samples each day. Double or triple sampling, used to establish collocated precision for the 1-hour tracer data, occurred on 16 of the sample days.

Six-hour duration tracer samples were collected at six sampling sites from July 1 to November 6, 1999. The best data recovery was for October with all but one site having over 90% of the days with 3 or more samples and all days having at least one sample. September had the poorest performance with only about 60% of the days containing 3 or more samples and about 80% having at least one sample. Big Bend had the highest data recovery of the six

sites with nearly 90% of the days having 3 or more samples. Double and triple samples, used to establish collocated precision for the 6-hour tracer data were collected primarily at the Big Bend site (> 30 days), though a few days of replicate sampling occurred at each of the other sites.

Twenty four-hour duration tracer samples were collected at 16 sites during the tracer release period and at two of the 6-hour sites (Marathon and San Vicente) plus Big Bend during a post-tracer release period that ended November 25, 1999. The data were divided into two periods for the purpose of summarizing data recovery: an early period 7/1 to 8/12/99 and a late period 10/8 to 10/31/99. Data availability is relatively poor for the 24-hour duration sites with only 7 sites having better than 75% data recovery for the early period and 3 sites for the late period (see Figure 3-1). Less than half of the data is available for 6 sites during the early period and 7 sites for the late period. Big Bend is consistently the best of the 24-hour duration sampling sites. Samples were collected there throughout the 4-month tracer release period, with only 18 missing sample period out of 123 possible samples (85% data recovery).

Data quality was assessed with multiple methods: use of collocated data; variation in PFT concentration before tracer release; and a combination of analytical error estimates. Results for the 6-hour sites are shown in Table 3-3. At the Big Bend area sampling sites, few observations of *i*-PPCH (released at the Big Brown plant in northeast Texas) were above background variation. This is due to the infrequent flow from the northeast and dispersion over the large distances to the 6-hour sites from the release location.

3.3 Aerosol and Gaseous Measurements

The network for collection of aerosol and gaseous data included 38 sites located throughout Texas, except for the panhandle area, one site (Wichita Mountains) in Oklahoma and one site (Caney Creek) in Arkansas. IMPROVE sampler modules were used for

Table 3-3. PFT data uncertainty (RMS error) in parts per quadrillion and correlation coefficients for collocated measurements. 80th and 90th percentile concentrations above background given for perspective. Collocated data from Monahans site not included.

	<u>PDCB</u>	<u>ocPDCH</u>	<u>i-PPCH</u>	<u>PTCH</u>
Collocated uncertainty	0.19	0.045	0.019	0.037
Collocated R ²	0.81	0.93	0.72	0.90
Analytical uncertainty ¹	0.22	0.077	0.029	0.099
Analytical uncertainty ²	0.72	0.16	0.032	0.20
Pre-release uncertainty	0.17	0.073	0.037	0.097
80 th percentile concentration	0.78	0.42	0.017	0.13
90 th percentile concentration	2.49	0.87	0.049	0.32

¹ Periods with collocated data, ² All samples

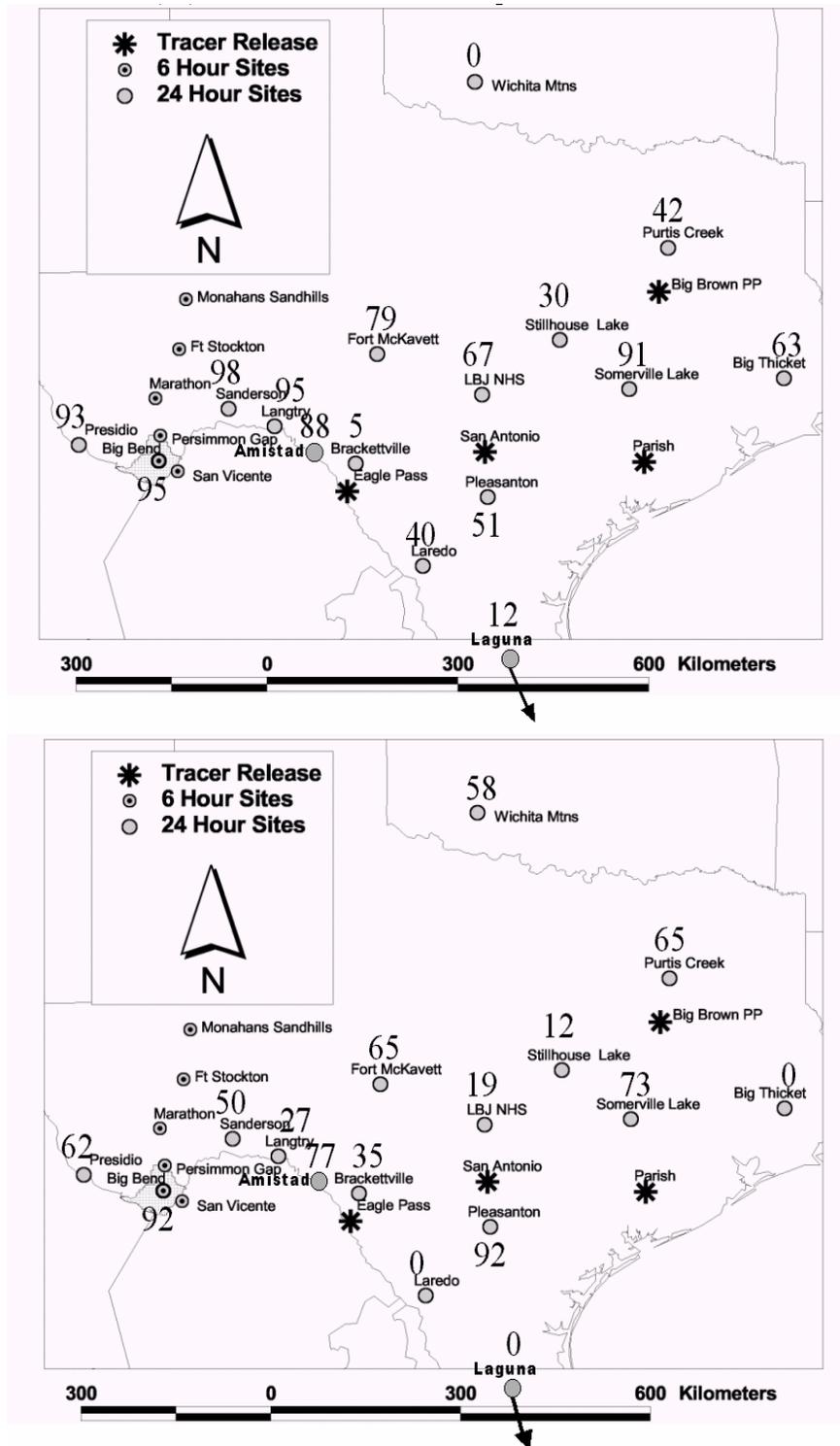


Figure 3-1. Data recovery of 24-hr tracer sample data during the two periods when 24-hr tracer sampling took place. Top shows the fraction (%) of 24-hour tracer samples from 7/1 to 8/12/99. Bottom shows the fraction (%) of 24-hour tracer samples from 10/8 to 10/31/99.

collecting aerosol and SO₂ samples. All sites collected PM_{2.5} on Teflon filters; many sites have additional measurements. Table 3-4 summarizes the number of sites for each type of measurement.

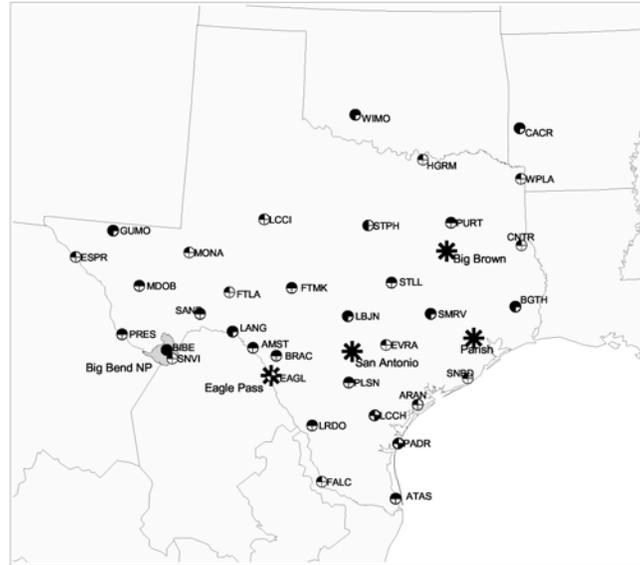
Figures 3-2 and 3-3 show the locations of the monitoring sites and the parameters measured at each site. Table 3-5 gives this information as well, along with site name and latitude, longitude, elevation, and purpose of each site. The purposes of sites included: general gradient sites² in Texas (about 100 km apart); border gradient sites at the Texas/Mexico border; Texas/other U.S. States border sites; coastal gradient sites; Big Bend area gradient sites; Class I areas; and sites predominantly downwind of tracer release locations. Additional aerosol and gaseous measurements were made at Big Bend (K-Bar Ranch). These measurements are summarized in Table 3-6.

Many of the specialized aerosol measurements at Big Bend were made to support an ion balance study, carbon apportionment, and a size distribution study. The ion balance study was designed to identify the form of the sulfate compound, to determine aerosol acidity, estimate particle size distributions associated with each ion component, investigate the possibility of sea salt contributions to the ions at BBNP, and compare ion composition to similar elemental aerosol components from the IMPROVE sampler. The carbon study goal was to identify the major carbonaceous source types that contribute to the aerosol at BBNP by measuring indicator species unique to those source types. The size distribution studies were designed to determine the size information needed for Mie Theory calculations of light scattering and thereby test the closure between aerosol and optical measurements; to determine the water content of the aerosol by comparing dry and moist size distribution measurements; and to assess the extent of the coarse particle scattering bias by nephelometers caused by truncation errors. Results of the special studies are summarized in Chapters 5 and 6.

Table 3-4. Number of measurement sites by measurement type.

<u>Measurement Type</u>	<u>Number of Sites</u>
24-hour PM _{2.5} elements (H, Na-Pb, mass, b _{abs}) (Teflon filter)	34
24-hour SO ₂ and tracer	18
24-hour PM _{2.5} carbon (quartz filter)	7
24-hour PM _{2.5} ions (nylon filter)	4
6-hour PM _{2.5} elements, SO ₂ , tracer	6
24-hour PM ₁₀ elements, ions, carbon	1
12-hour PM _{2.5} elements, ions, carbon	1
Collocated 24-hour PM _{2.5} elements, ions, carbon, SO ₂ , tracer	1
Collocated 24-hour PM ₁₀ elements, ions, carbon	1
Collocated 6-hour PM _{2.5} elements, SO ₂ , tracer	1

² Gradient sites are used to determine locations where concentration changes with distance are large. This information in combination with other data can be used to help infer emission source areas.



24 Hour BRAVO Network Configuration

- ⊕ Fine Particles on Teflon Filter
- ⊙ SO₂ and Tracer
- ⊖ Ion Balance
- ⊕ Carbon
- * Tracer Release Sites

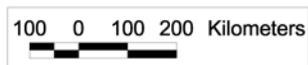
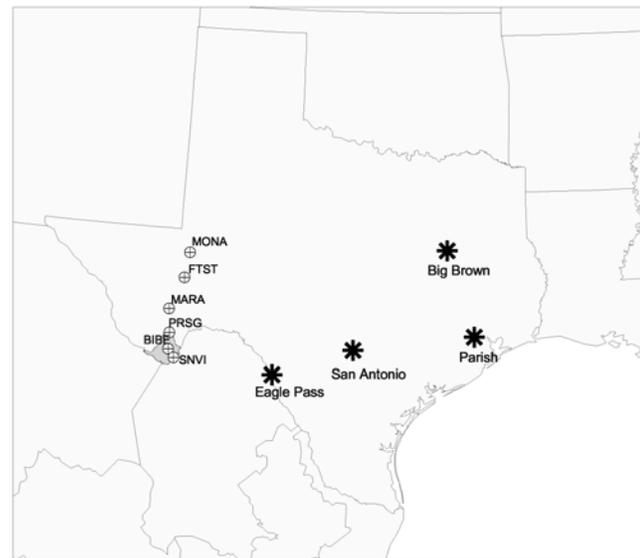


Figure 3-2. Network of 24-hour gas and aerosol sampling locations.



6 Hour BRAVO Network Configuration

- ⊕ Site
- * Tracer Release Sites



Figure 3-3. Network of 6-hour gas and aerosol sampling locations.

Table 3-5. Aerosol and tracer monitoring site abbreviations, names, latitude, longitude, elevation, and purposes.

	<u>Name</u>	<u>Latitude</u>	<u>Longitude</u>	<u>Elevation</u> <u>(m)</u>	<u>Purpose</u>
AMST	Amistad	29.47	-101.02	351	Downwind of <i>Carbón</i> /Eagle Pass
ARAN	Aransas	28.32	-96.83	0	Coastal
BIBE	Big Bend (K-Bar)	29.30	-103.18	1,052	Receptor/Big Bend area gradient
BGTH	Big Thicket	30.48	-94.35	38	Texas/Louisiana border/gradient
BRAC	Brackettville	29.32	-100.42	335	Downwind of <i>Carbón</i> /Eagle Pass
CACR	Caney Creek	34.42	-94.15	646	Class I area
CNTR	Center	31.83	-94.17	24	Texas/Louisiana border/gradient
EPS	Eagle Pass	28.87	-100.52	274	Mexico border/near <i>Carbón</i>
ESPR	Esperanza	31.17	-105.72	1,067	Mexico border gradient
EVRA	Everton Ranch	29.63	-97.65	244	Gradient
FALC	Falcon Dam	26.55	-99.17	61	Border gradient
FTLA	Fort Lancaster	30.67	-101.70	762	Gradient
FTMK	Fort McKavett	30.83	-100.10	671	Gradient
FTST	Ft Stockton	30.92	-102.90	983	Big Bend area gradient
GUMO	Guadalupe Mtns	31.83	-104.82	1,659	Class I area
HGRM	Hagerman	33.73	-96.75	244	Texas/Oklahoma border
ATAS	Laguna Atascosa	26.22	-97.35	4	Coastal and Mexico border gradient
LCCI	Lake Colorado City	32.32	-100.90	640	Gradient
LCCH	Lake Corpus Christi	28.07	-97.90	91	Inland ion balance
LANG	Langtry	29.80	-101.55	396	Mexico border/downwind of <i>Carbón</i>
LRDO	Laredo	27.80	-99.45	148	Mexico border gradient
LBJN	LBJ	30.25	-98.63	518	Gradient/downwind of San Antonio
MARA	Marathon	30.20	-103.23	1,280	Big Bend area gradient
MDOB	McDonald Observatory	30.67	-104.02	2,043	Gradient
MONA	Monahans Sandhills	31.48	-102.80	831	Big Bend area gradient
PADR	North Padre Island	27.45	-97.30	0	Coastal/ion balance
PRSG	Persimmon Gap	29.67	-102.18	915	Big Bend area gradient
PLSN	Pleasanton	28.78	-98.57	122	Gradient
PRES	Presidio	29.57	-104.35	838	Mexico border gradient
PURT	Purtis Creek	32.35	-98.00	187	Gradient/downwind of Big Brown
SNBD	San Bernard	29.90	-95.58	0	Coastal gradient
SNVI	San Vicente	29.12	-103.03	549	Big Bend area gradient
SAND	Sanderson	30.18	-103.22	610	Gradient/downwind of <i>Carbón</i>
SMRV	Somerville Lake	30.33	-96.52	84	Gradient
STPH	Stephenville	32.27	-98.17	274	Gradient
STLL	Stillhouse Lake	31.02	-97.53	213	Gradient
WIMO	Wichita Mtns	34.70	-98.58	488	Class I area
WPLA	Wright Patman Lake	33.30	-94.15	9	Texas/Arkansas/Louisiana border

Table 3-6. Specialized aerosol and gaseous measurements at Big Bend.

<u>Measurement</u>	<u>Averaging period</u>
High time resolution, high sensitivity SO ₂	1 hour
High time resolution particulate sulfate	12 minutes
Hourly tracer sampling	1 hour
PM _{2.5} carbonaceous aerosol	24 hours
Carbon speciation by GC/MS for selected periods	24 hours
Gaseous nitric acid	24 hours
Gaseous ammonia	24 hours
MOUDI size resolved aerosol	24 hours
Various particle size measurements- differential mobility analyzer, optical particle counters, aerodynamic particle sizers	seconds
Gaseous hydroperoxides	1 hour
Scanning electron microscopy (SEM) analysis	24 hours

3.4 Optical Measurements

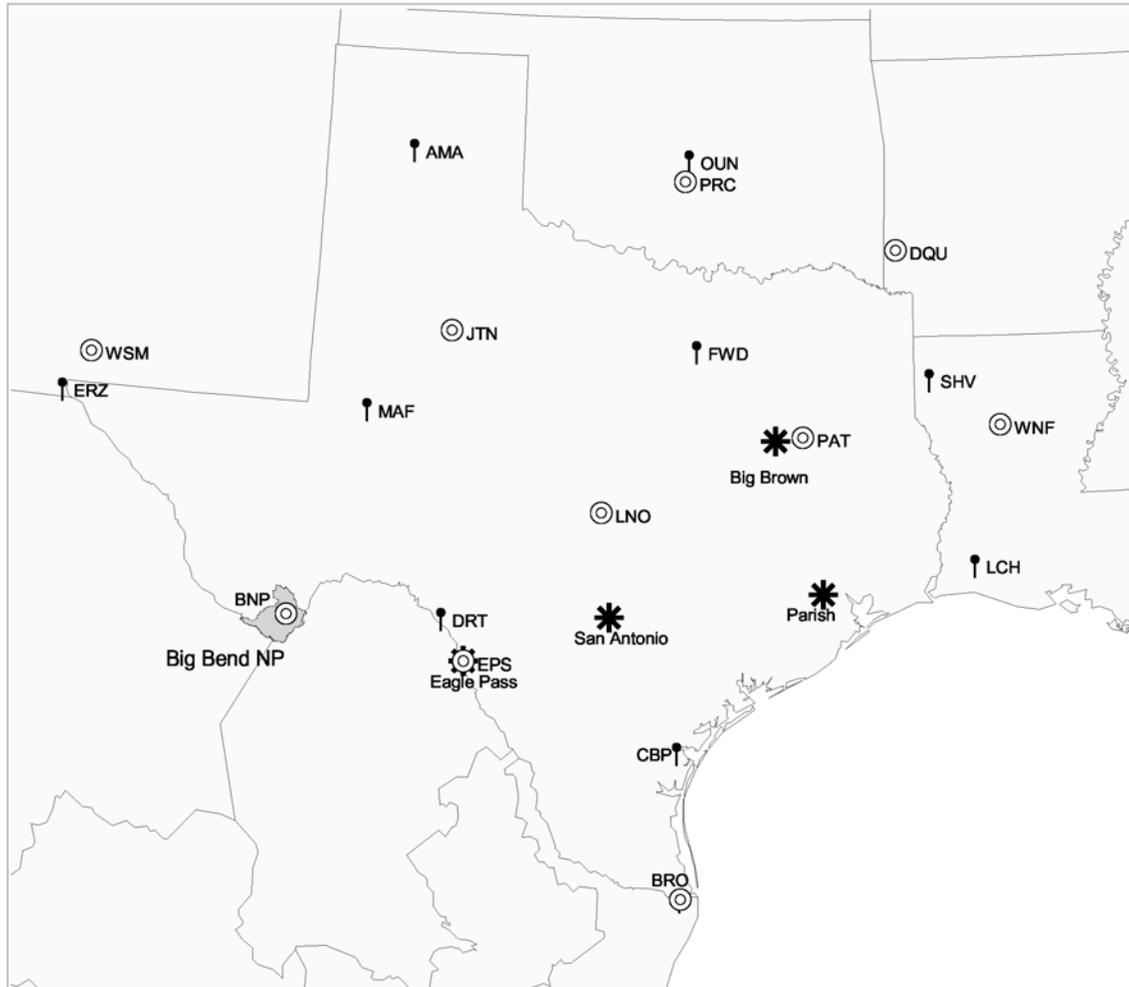
Optical measurements are made routinely at BBNP using an Optec transmissometer and an Optec ambient integrating nephelometer at a site about 5 km north of the main BRAVO monitoring location at K-Bar Ranch. For the BRAVO study, additional optical measurements were made by two additional transmissometers, two open-air Optec nephelometers, two ambient PM_{2.5} Optec nephelometers, and one ambient PM₁₀ Optec nephelometer. The additional transmissometers were located about 0.5 km southwest of the K-Bar Ranch site. The additional nephelometers were all located at the K-Bar Ranch site. There were also five 35mm cameras and two 8mm time-lapse cameras at the south end of the new transmissometer path. The cameras gave views from the Rio Grande River Basin to the existing transmissometer site path.

Additional optical instruments at the K-Bar Ranch site included two PM_{2.5} Radiance Research nephelometers for which relative humidity is controlled, an aethalometer (operated with no particle cut, 2.5 µm cut and 1 µm cut inlets), and a photoacoustic light absorption instrument. The additional nephelometers were used to investigate the effects of relative humidity changes upon particle size and to quantify the light scattering by fine and coarse particles.

3.5 Meteorological Measurements

Upper-air meteorological measurement sites are shown in Figure 3-4 and listed in Table 3-7. Radiosonde sites measured pressure, wind speed, wind direction, temperature, and dew point temperature, as a function of height usually twice per day at 0 and 1200 Greenwich Mean Time (7 am and 7 pm CDT). Radar wind profilers measured wind speed and direction as a function of height; data was generally reported hourly. Radar wind

profilers equipped with a radio acoustic sounding system (RASS) also obtained vertical profiles of virtual temperature, although usually only to 500-1,500 meters. Data from the radar wind profilers were employed in a four-dimensional data assimilation nudging of the MM5 generated wind-fields as described in Appendix 9.



BRAVO Upper Air Network Configuration



Figure 3-4. Upper-air meteorological sites.

Table 3-7. Upper-air meteorological monitoring site locations and types.

<u>Station</u>	<u>Location</u>	<u>Latitude</u>	<u>Longitude</u>	<u>Type</u>
AMA	Amarillo, TX	35.23	-101.70	Rawinsonde
BBNP	Big Bend, TX	29.30	-103.25	BRAVO Profiler
BRO	Brownsville, TX	25.90	-97.43	Rawinsonde and NOAA Wind Profiler
CBP	Corpus Christi, TX	27.77	-97.50	Rawinsonde
DQU	Dequeen, AR	34.11	-94.29	NOAA Wind Profiler
DRT	Del Rio, TX	29.37	-100.92	Rawinsonde
EPS	Eagle Pass	28.87	-100.57	BRAVO Profiler
ERZ	Santa Teresa, NM	31.87	-106.7	Rawinsonde
FWD	Fort Worth, TX	32.83	-97.30	Rawinsonde
JTN	Jayton, TX	33.01	-100.98	NOAA Wind Profiler
LCH	Lake Charles, LA	30.12	-93.22	Rawinsonde
LNO	Llano, TX	30.79	-98.66	BRAVO Profiler
MAF	Midland, TX	31.95	-102.18	Rawinsonde
MONT	Monterrey, MX	25.70	-100.25	Rawinsonde
OUN	Norman/Westheimer, OK	35.22	-97.45	Rawinsonde
PAT	Palestine, TX	31.77	-95.71	NOAA Wind Profiler
PRC	Purcell, OK	34.97	-97.51	NOAA Wind Profiler
SHV	Shreveport, LA	32.47	-93.82	Rawinsonde
SNAN	San Antonio, TX	29.47	-98.50	BRAVO Profiler
WNF	Winfield, LA	31.89	-92.78	NOAA Wind Profiler
WSM	White Sands, NM	32.40	-106.34	NOAA Wind Profiler
MCV	Chihuahua	28.70	-106.07	Rawinsonde

3.6 Source Characterization

Source profiles are the fractional particle composition of chemical species relative to the primary $PM_{2.5}$ mass measured at specific emission sources. Certain receptor analysis methods like Chemical Mass Balance (CMB) use source profiles to attribute ambient PM measurements to various source types (e.g., coal fired power plants, oil refining, cement kilns, gasoline and diesel vehicles). Most archived source profiles available for such use were derived from source characterization measurements made years ago and far from the BRAVO Study area. Texas area source samples were collected and subsequently analyzed for composition to produce more applicable source profiles for use in the BRAVO Study and to evaluate their similarity to source profiles derived from other times and places.

Chemical source profiles for elements, ions, and carbon fractions were developed for BRAVO Study area paved and unpaved roads, natural soil dust, motor vehicle exhaust, vegetative burning, four coal-fired power plants, and oil refinery catalytic cracker, two cement kilns, and residential meat cooking. Though part of the original data analysis plan, CMB analysis using the source profiles was not thought to be productive because the ambient trace particulate compositional data were not sufficiently sensitive to support the receptor modeling at Big Bend. For more information on the source profiles as well as the process used to develop them, see Chow et al. (2003).

3.7 Aircraft Measurements

Aircraft measurements were made by Baylor University in coordination with TCEQ. The flight paths of interest for BRAVO documented transport of continental haze over Texas toward Big Bend National Park (over Texas Gulf coast and east Texas interior areas), and transport along and across the U.S./Mexico border towards Big Bend. Flights were scheduled when forecast back-trajectories showed the conditions of interest were likely to occur. The Baylor aircraft measurements included the following variables: light scattering (5-second data); SO₂, sulfates, NO, NO₂, and NO_Y (1-second data); and temperature, relative humidity, barometric pressure, altitude, location (1/5-second data). The aircraft measurement data were not used in the quantitative source attribution assessments, principally because of the difficulty of integrating them with surface air quality observations. A description of the measurements is contained in a report by Baylor University (2000) (in the Appendix).