Exhibit 40

STATE OF WYOMING

Technical Support Document I
For Recommended 8-Hour Ozone Designation
For the Upper Green River Basin, WY

March 26, 2009

The Wyoming Department of Environmental Quality
Air Quality Division
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EXECUTIVE SUMMARY

In March 2008 the US EPA promulgated a new National Ambient Air Quality Standard (NAAQS) for ozone. The new standard was lowered from 0.08 ppm to 0.075 ppm based on the fourth highest 8-hour average value per year at a site, averaged over three years. Based on monitoring results from 2006 through 2008, the entire state of Wyoming is in compliance with this standard except for at a single monitor, the Boulder monitor, in Sublette County.

The Wyoming Department of Environmental Quality, Air Quality Division (AQD) evaluated whether a nonattainment area should be designated due to the monitored results at the Boulder monitor. Using EPA's guidance in the Robert J. Meyers December 4, 2008 memo, the AQD performed a nine-factor analysis, which is the basis of this document. This analysis supports AQD's recommendation that the Upper Green River Basin (UGRB), as defined in the introduction to this document, be designated as nonattainment for the 2008 ozone NAAQS.

The AQD bases this recommendation on a careful review of the circumstances surrounding the incidence of elevated ozone events. Elevated ozone in the UGRB is associated with distinct meteorological conditions. These conditions have occurred in February and March in some (but not all) of the years since monitoring stations began operation in the UGRB in 2005. Our determination of an appropriate nonattainment area boundary is focused on an evaluation of EPA's nine factors, applied to the first quarter of the year. It is important to evaluate conditions during the first quarter of the year in order to focus on the very specific set of circumstances that lead to high ozone.

The most compelling reasons for the boundary recommendation are based on the meteorological conditions in place during and just prior to elevated ozone events. Elevated ozone episodes occurred in 2005, 2006 and 2008; they were associated with very light low-level winds, sunshine, and snow cover, in conjunction with a strong low-level surface-based temperature or "capping" inversion. The longest such event (February 19-23, 2008), which also resulted in the highest measured ozone of 122 ppb as an 8-hour average at the Boulder station, has been reviewed in detail and summarized in Section 7 of this document. Section 7 demonstrates that sources outside the recommended nonattainment area would not have a significant impact on the Boulder monitor due to the presence of an inversion and very low wind speeds, which significantly limit precursor and ozone transport from sources located outside of the UGRB.

The AQD carefully examined sources of ozone and ozone precursors within Sublette and surrounding counties. When evaluating sources, AQD considered these five of EPA's factors: population density, traffic and commuting patterns, growth rates and patterns, emission data, and level of control of air emissions. Sublette County is a rural county with a population density of two people per square mile; the most densely populated nearby county (Uinta) is also largely rural with a population density of ten people per square mile. As would be expected, the number of commuters into or out of the UGRB is small and does not represent a significant source of precursor emissions. While there is an interstate highway 80 miles south of the Boulder monitor, the attached analysis demonstrates that I-80 traffic is not considered to be a significant contributor of emissions that impact the Boulder monitor during ozone events.

Although population and population growth was not a significant factor, growth in the oil and gas (O&G) industry in Sublette County was considered pertinent. The volume of natural gas produced doubled between 2000 and 2008 in the county; the number of wells completed doubled between 2004 and 2008. Approximately 1,500 well completions were recorded in Sublette County in the last four years. Growth in the oil and gas industry in nearby areas is much slower.

AQD prepared an estimated inventory of emissions for the recommended nonattainment area and the surrounding counties. The inventory showed that approximately 94% of VOC emissions in the UGRB and 60% of NOx emissions are attributable to oil and gas production and development. Of the eleven major sources in the UGRB, all are O&G related. To the north, east and west there are few major sources in counties adjacent to the UGRB. In addition to the major sources, there are numerous minor sources in the UGRB including several concentrated areas of O&G development. Just to the south of the UGRB, there are a few major sources, several minor sources and again, a concentrated area of O&G wells. AQD then used other factors, meteorology, topography, and level of control of emissions, to determine which of the sources to the south of Sublette County should be included in the proposed nonattainment boundary.

The level of control of emissions in the Jonah and Pinedale Anticline Development is very stringent and new oil and gas production units in Sublette County and surrounding counties require permits including Best Available Control Technology (BACT). An interim policy for Sublette County which took effect in 2008 results in a net decrease in emissions of ozone precursors with every permit that is issued. Since stricter controls for O&G are already in place in Sublette County, if O&G sources outside of Sublette County might contribute ozone or ozone precursors to the Boulder monitor, including these O&G sources in the proposed nonattainment area would provide motivation to control these sources.

In evaluating topography, the east, north and west county boundaries are natural boundaries of high mountains. These geographical and jurisdictional boundaries also coincide with population boundaries and emission source boundaries. To the south, the topographical boundaries are less dramatic, but there are rivers, valleys, and buttes that form geographic boundaries near the southern border of Sublette County. Therefore, the AQD considered the county boundary to the north, east and west to be a reasonable boundary based on geography, jurisdictions, emission sources, population and growth.

However, meteorology provided the strongest basis for setting the southern boundary of the proposed nonattainment area. Elevated ozone in the UGRB is associated with distinct meteorological conditions. These conditions have occurred in February and March in some (but not all) of the years since monitoring stations began operation in the UGRB in 2005.

Meteorological conditions in place during and just prior to elevated ozone events provide the most specific data for setting the south boundary. Elevated ozone episodes are associated with very light low-level winds, cold temperatures, sunshine, and snow cover, in conjunction with strong low-level surface-based temperature inversions. Sources outside the recommended nonattainment area would not have a significant impact on the Boulder monitor due to the presence of an inversion and the very low wind speeds, which influence the transport of

emissions. Detailed meteorological data collected during intensive field studies shows that emissions from sources south of the recommended nonattainment area are generally carried toward the east and not into the UGRB during or just prior to an ozone episode. Speciated VOC data collected in the UGRB during elevated ozone episodes also has a dominant oil and gas signature, indicating the VOC concentrations are largely due to O&G development activities.

Meteorology and topography indicate that sources outside a southern boundary defined by the Little Sand Creek and Pacific Creek to the east and the Green River and Fontenelle Creek to the west do not contribute to ozone and ozone precursors which could affect the Boulder monitor.

The analysis conclusively shows that elevated ozone at the Boulder monitor is primarily due to local emissions from oil and gas (O&G) development activities: drilling, production, storage, transport, and treating. The ozone exceedances only occur when winds are low indicating that there is no transport of ozone or precursors from distances outside the proposed nonattainment area. The ozone exceedances only occur in the winter when the following conditions are present: strong temperature inversions, low winds, cold temperatures, clear skies and snow cover. If transport from outside the proposed nonattainment area was contributing to the exceedances, then elevated ozone would be expected at other times of the year. Mountain ranges with peaks over 10,000 feet border the area to the west, north and east influence the local wind patterns. Emission sources in nearby counties are not upwind of the Boulder monitor during episodes which exceed the 8-hour ozone standard in Sublette County.

The proposed nonattainment area boundary includes the violating monitor and the sources which are most likely to contribute ozone and ozone precursors to the monitored area. Using this as a boundary will allow the State to focus its resources on the emission sources that contribute to the ozone issue and will allow the State to control the ozone problem in a timely manner.

INTRODUCTION

BACKGROUND AND REGULATORY HISTORY

The U.S. Environmental Protection Agency (EPA) is charged with developing air quality standards for the protection of human health and welfare. EPA is also required to periodically evaluate those standards and revise them if scientific analyses indicate different standards would be more protective of public health and welfare. In March of 2008, EPA promulgated a new National Ambient Air Quality Standard (NAAQS) for ozone. This new standard lowered the 8-hour level of ozone from 0.08 parts per million (ppm) to 0.075 ppm, based on the fourth maximum 8-hour value at a site averaged over three years. Each state must recommend ozone designations no later than March 12, 2009 and final designations must be complete by March 12, 2010.

BASIS FOR TECHNICAL SUPPORT

This technical support document considers nine criteria, or "factors" to make a recommendation for the appropriate location and boundary of a nonattainment area. Those factors are derived from EPA's memorandum issued December 4, 2008, "Area Designations for the 2008 Revised Ozone National Ambient Air Quality Standards." States must submit an analysis of these nine factors, along with a proposed nonattainment boundary, for any areas that are not meeting the federal standard. The nine factors that must be addressed are:

- Air quality data
- Emissions data (location of sources and contribution to ozone concentrations)
- Population density and degree of urbanization (including commercial development)
- Traffic and commuting patterns
- Growth rates and patterns
- Meteorology (weather/transport patterns)
- Geography/topography (mountain ranges or other air basin boundaries)
- Jurisdictional boundaries (e.g., counties, air districts, existing nonattainment areas, Reservations, metropolitan planning organizations (MPOs))
- Level of control of air emissions

RECOMMENDED NONATTAINMENT AREA BOUNDARY

The State of Wyoming recommends that the UGRB, with boundaries described as follows, be designated as a nonattainment area for the 2008 8-hour ozone standard:

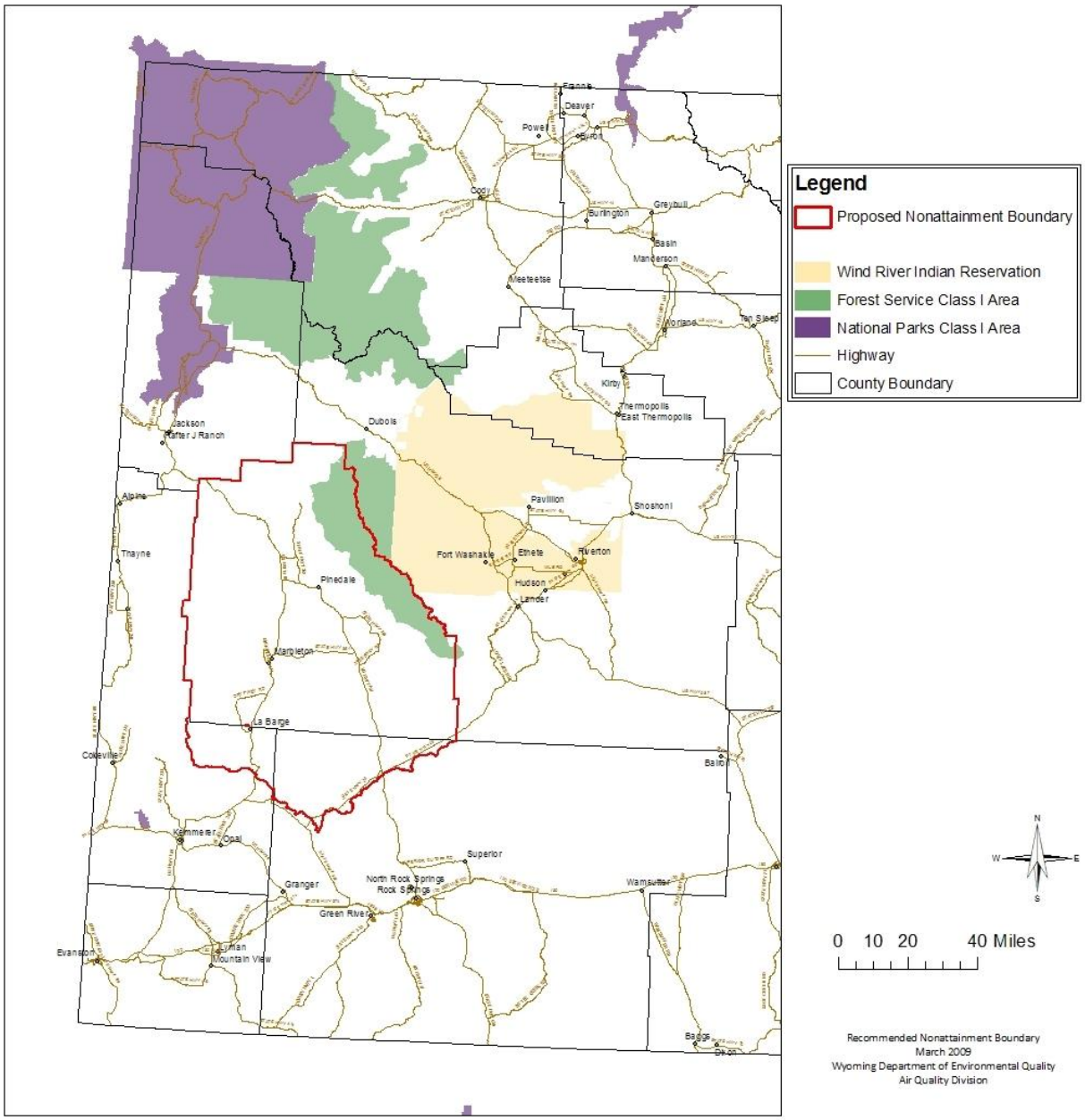
Sublette County: (all)

Lincoln County: (part) The area of the county north and east of the boundary defined by a line starting at the point defined by the intersection of the southwest corner Section 30 Range

(R) 115 West Township (T) 27N and the northwest corner of Section 31 R 115 West T 27N of Sublette County at Sublette County's border with Lincoln County. From this point the boundary moves to the west 500 feet to Aspen Creek. The boundary follows the centerline of Aspen Creek downstream to the confluence of Aspen Creek and Fontenelle Creek (in R 116 W T26N, Section 1). From this point the boundary moves generally to the south along the centerline of Fontenelle Creek to the confluence of Fontenelle Creek and Roney Creek (in R115W T24N Section 6). From the confluence, the boundary moves generally to the east along the centerline of Fontenelle Creek and into the Fontenelle Reservoir (in R112W T24N Section 6). The boundary moves east southeast along the centerline of the Fontenelle Reservoir and then toward the south along the centerline of the Green River to where the Green River in R111W T24 N Section 31 crosses into Sweetwater County.

Sweetwater County: (part) The area of the county west and north of the boundary which begins at the midpoint of the Green River, where the Green River enters Sweetwater County from Lincoln County in R111W T24N Section 31. From this point, the boundary follows the center of the channel of the Green River generally to the south and east to the confluence of the Green River and the Big Sandy River (in R109W R22 N Section 28). From this point, the boundary moves generally north and east along the centerline of the Big Sandy River to the confluence of the Big Sandy River with Little Sandy Creek (in R106W T25N Section 33). The boundary continues generally toward the northeast along the centerline of Little Sandy Creek to the confluence of Little Sandy Creek and Pacific Creek (in R106W T25N Section 24). From this point, the boundary moves generally to the east and north along the centerline of Pacific Creek to the confluence of Pacific Creek and Whitehorse Creek (in R103W T26N Section 10). From this point the boundary follows the centerline of Whitehorse Creek generally to the northeast until it reaches the eastern boundary of Section 1 R103W T 26North. From the point where Whitehorse Creek crosses the eastern section line of Section 1 R103W T 26North, the boundary moves straight north along the section line to the southeast corner of Section 36 R103W T27N in Sublette County where the boundary ends.

A picture of this area follows.



KEY ISSUES

Elevated ozone concentrations in most areas occur during the warm summer months, when there is abundant solar radiation and high temperatures. The elevated ozone concentrations at the Boulder monitor in Sublette County occur in late winter and early spring when sun angles are low so there is less solar radiation and temperatures are below freezing. Ozone formation at the Boulder monitor in Sublette County does not follow the pattern of ozone formation found in urban areas in the summer.

Moderately elevated ozone was first detected in Sublette County in February of 2005 and 2006. The Wyoming Air Quality Division (AQD) conducted intensive meteorological and ambient data collection and analyses in 2007 and 2008 in order to understand this phenomenon. AQD is continuing this effort in 2009. Although analysis of all the data is not complete, AQD has already determined that:

- Local meteorological conditions are the single most important factor contributing to the formation of ozone and the definition of the nonattainment boundary.
- Meteorological models that utilize only regional data will not correctly attribute ozone and ozone precursors to the sources which affect the UGRB.
- Trajectory analyses using detailed observation-based wind field data show that local scale transport of ozone and ozone precursors is dominant during periods of elevated ozone.
- Trajectory analyses using the wind field data show that regional transport of ozone and ozone precursors appears to be insignificant during periods of elevated ozone.

SECTION 1
AIR QUALITY DATA

SYNOPSIS

Ozone at levels exceeding the standard has been monitored at one of three stations in the UGRB – specifically, the Boulder monitor.

Measured ozone levels have not exceeded the standard in the counties adjacent to the UGRB.

Elevated ozone within the UGRB typically only occurs in January, February, or March.

VOCs detected in ambient air in the UGRB have a strong oil and gas signature.

ANALYSIS

The Wyoming Air Quality Division (AQD) operated three monitoring stations in the proposed nonattainment area in 2005-2008. Monitor locations are shown on the map in Figure S.1-1. This map also shows the location of monitors in adjacent counties.

FIGURE S.1-1: Map Showing Monitoring Stations In and Near the Upper Green River Basin

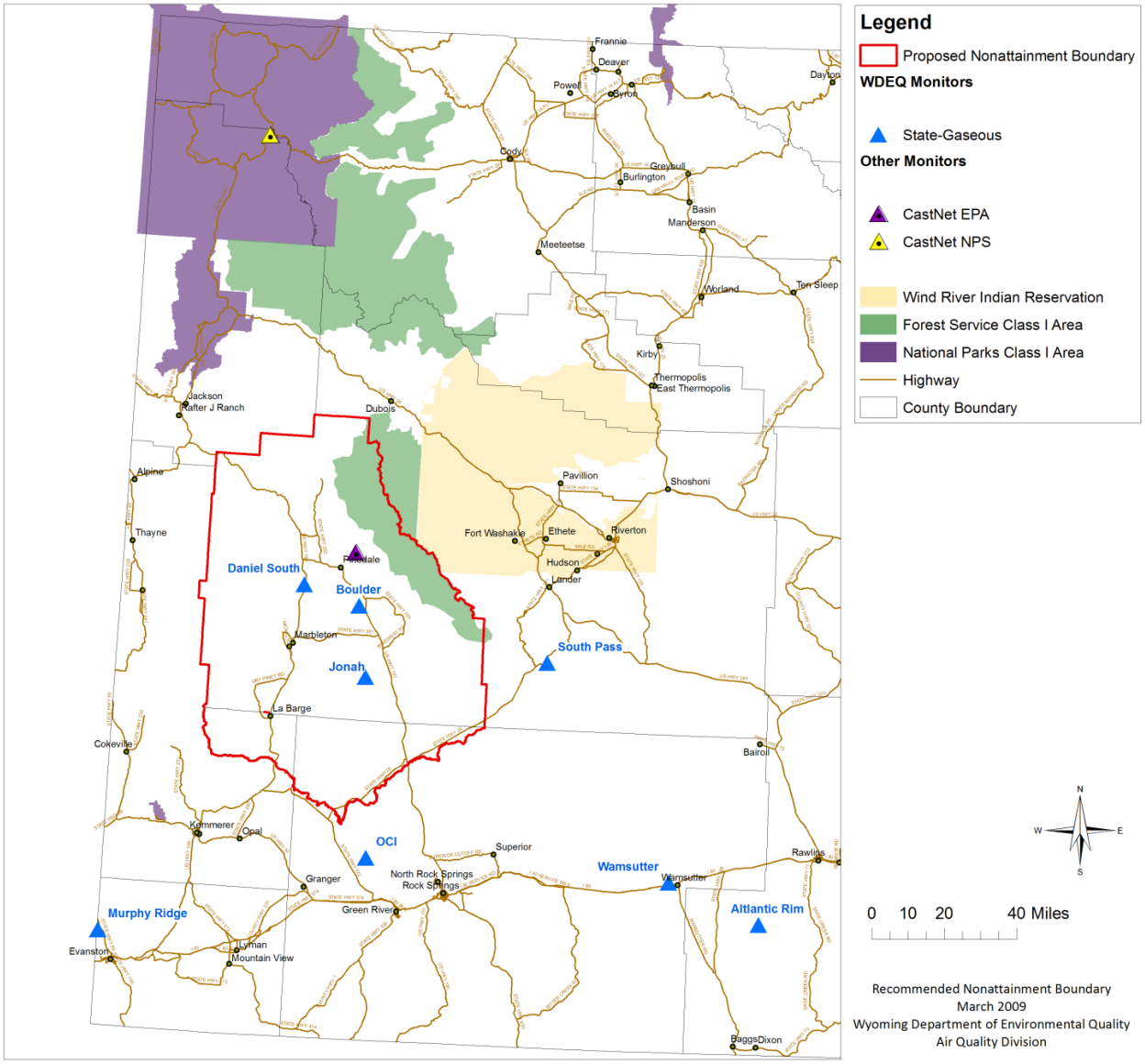


Table S.1-1 shows the ozone design values for the 8-hour standard for the Reference or Equivalent Method monitoring stations shown in Figure S.1-1. All data are collected by Reference or Equivalent Method monitors and meet EPA's criteria for quality and completeness unless otherwise noted. Please note, Pinedale CASTNet data are not included in the design values because this station was not operated in accordance with Part 58 QA requirements until 2007. The design value is the three-year average of the annual fourth highest daily maximum 8-hour ozone concentration (a calculated value less than or equal to 0.075 ppm indicates attainment of the standard; a calculated value of greater than 0.075 ppm is a violation of the standard). Table S.1-2 shows monitored data from other Federal Reference Method (FRM) or Federal Equivalent Method (FEM) ozone monitors in the counties surrounding the UGRB. These monitors have been running for less than 3 years and therefore do not have a design value calculated.

Table S.1-1: Design Values for Monitors In or Near the Upper Green River Basin

Site Name	AQS ID	Year				3-Year Average 2005-2007 (ppm)	3-Year Average 2006-2008[1] (ppm)
		2005 (ppm)	2006 (ppm)	2007 (ppm)	2008 Q1 – Q3 (ppm)		
Daniel South	56-035-0100	0.067[2]	0.075	0.067	0.074	N/A	0.072[1]
Boulder	56-035-0099	0.080[3]	0.073	0.067	0.101	0.073[3]	0.080[1]
Jonah	56-035-0098	0.076	0.070	0.069	0.082	0.072	0.074[1]
Yellowstone (NPS)	56-039-1011	0.060	0.069	0.064	0.065	0.064	0.066

[1] Data collected and validated through 3rd quarter 2008
[2] Incomplete year; began operation in July 2005
[3] Incomplete year; began operation in February 2005

Table S.1-2: 4th Maximum 8-Hour Ozone Values for Monitoring in Surrounding Counties					
Site Name	AQS ID	Year			
		2005 (ppm)	2006 (ppm)	2007 (ppm)	2008 Q1 – Q3 (ppm)
Murphy Ridge	56-041-0101	---	---	0.070	0.061[1]
South Pass	56-013-0099	---	---	0.071[2]	0.065[1]
OCI[3]	56-037-0898	---	0.071[3]	0.066	0.072[1]
Wamsutter	56-005-0123	---	0.067[4]	0.064	0.064[1]
Atlantic Rim	56-007-0099	---	---	0.047[5]	0.064[1]

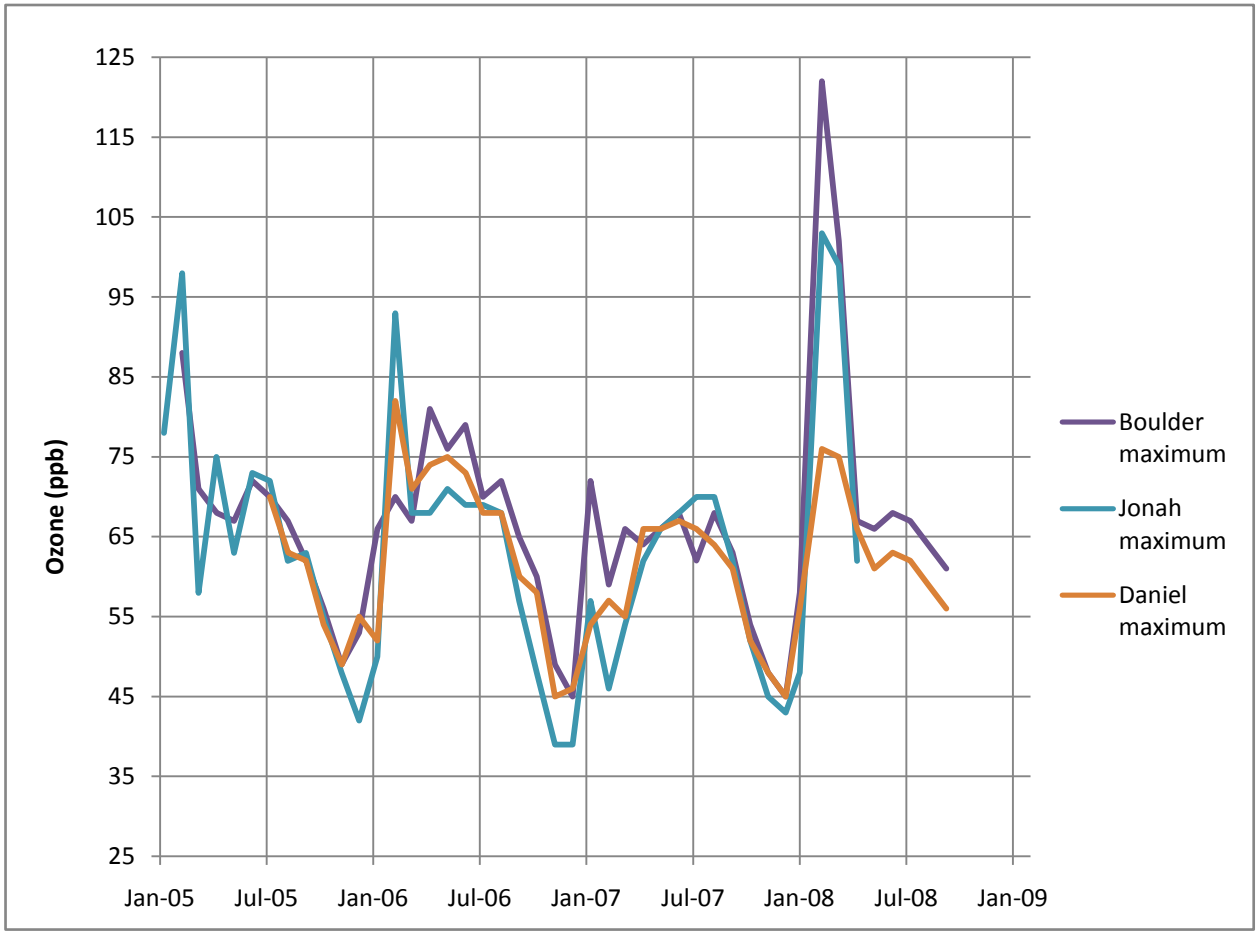
[1] Data collected and validated through 3rd quarter 2008
[2] Incomplete year; began operation in March 2007
[3] Site operated by industry. Incomplete year; began operation in May 2006
[4] Incomplete year; began operation in March 2006
[5] Incomplete year; began operation in October 2007

Using only data from 2005 through 2007, the monitors for which a design value can be calculated indicate compliance with the ozone NAAQS. Year-to-date data from 2008, however, bring the 2006 - 2008 design value for the Boulder monitor to 0.080 ppm (compared to the standard of 0.075).

While monitors in counties adjacent to the UGRB have not been in operation for a full three-year period (with the exception of the Yellowstone NPS monitor), none of them have 4th-high maximum 8-hour ozone values above 0.075 ppm for any year. This would indicate that, based on ambient monitoring data, ozone levels have not been measured that exceed the standard outside of the UGRB (within Wyoming).

When the data from the Boulder monitoring station, the only monitor showing ozone levels in excess of the standard, is reviewed closely, it shows that elevated ozone typically occurs in the winter. This trend is also evident at the two stations nearby (South Daniel and Jonah). Figure S.1-2 shows the daily 8-hour maximum for these stations on a monthly basis over the last four years. This is an unprecedented phenomenon, as ozone was thought to be a summertime problem. The Wyoming DEQ, with the help of industry, has dedicated significant resources to better understand this situation. The studies indicate that elevated ozone occurs in the UGRB under very specific meteorological conditions, described in greater detail in Section 7 of this document. Briefly, these conditions are the presence of a strong temperature inversion in conjunction with low wind speeds, snow cover and clear skies. These conditions have occurred in January, February, and March.

Figure S.1-2: Monthly 8-Hour Maximum Ozone Within the UGRB



AQD performed Winter Ozone Studies in 2007, 2008 and 2009 in the UGRB. The purpose of these studies is to investigate and monitor the mechanisms of ozone formation during the winter months. These data will in turn be used to develop a conceptual model of ozone formation in the UGRB. As the study has progressed, the scope of the study has been refined as AQD has learned about the unique issue of winter ozone formation. In general terms, the scope of the winter ozone studies include:

1. Placing additional FEM and non-FEM (2B ozone analyzers) monitors throughout the UGRB to characterize spatial and temporal distribution of ground-level ozone.
2. Placing additional three-meter meteorological towers (mesonet) throughout the UGRB to characterize local micro-scale meteorology.
3. Placing additional precursor monitoring (e.g., VOC, NOx and CO) in a few sites around the UGRB to characterize precursor concentrations.
4. Flying a plane equipped with continuous ozone and $PM_{2.5}$ around the UGRB to characterize spatial distribution of ozone (above, in, and below the boundary layer).
5. Launching ozone and rawinsondes to characterize vertical meteorology and ozone distribution.

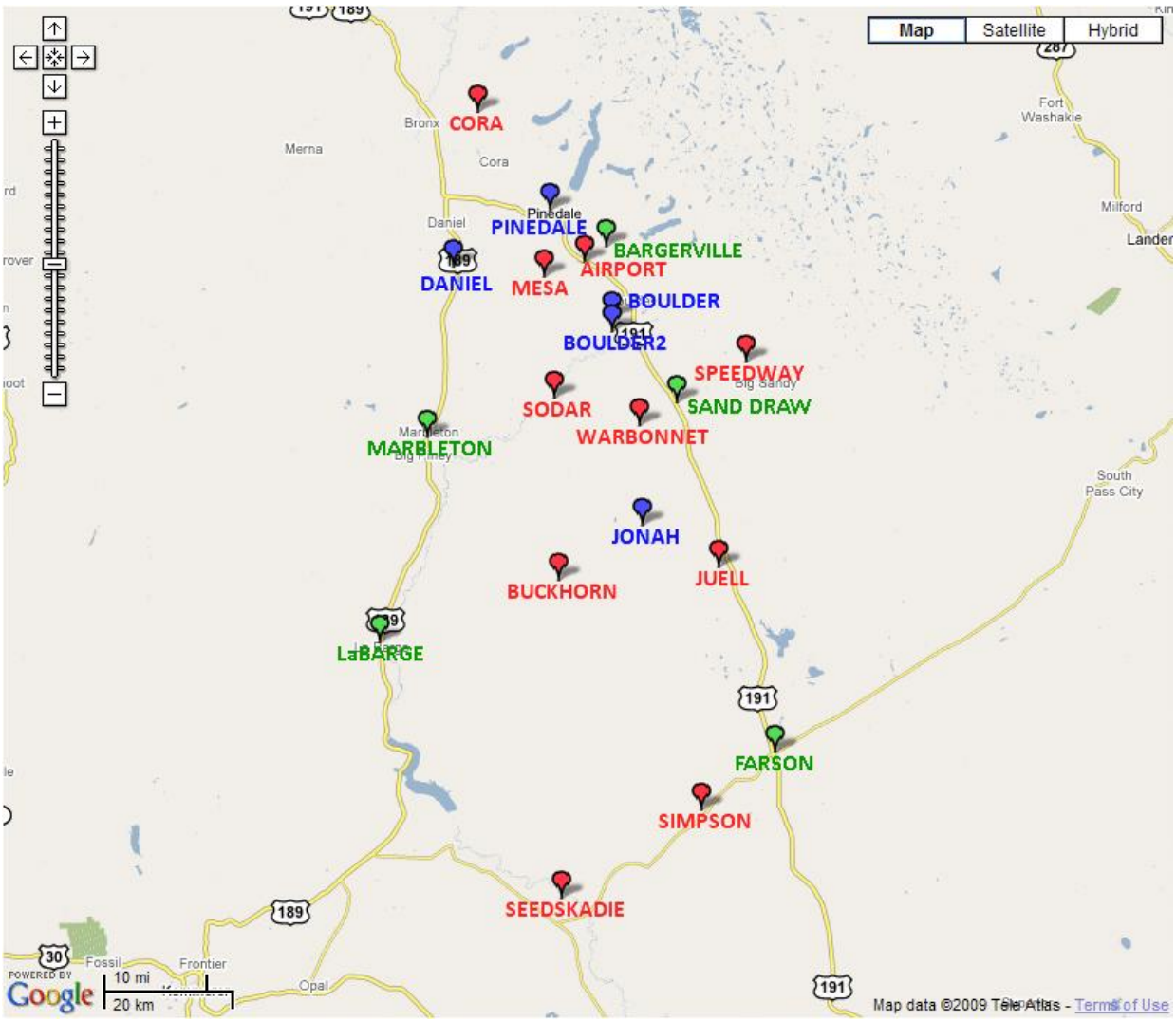
6. Operating ground based upper-air meteorological instruments (e.g., Mini-SODAR, RASS, Wind Profiler) to characterize mixing levels and inversion heights.

In 2007, meteorological conditions did not set up as they had in 2005 and 2006 and elevated ozone did not form in February and March. However, AQD collected data that helped to draw some conclusions about winter ozone formation. The speciated VOC samples collected had a strong oil and gas signature. AQD was able to investigate which detected VOC species were having a greater effect on ozone formation. UV radiation measurements showed that when fresh snow is available, greater than 80% of the ultra-violet light can be reflected.

During the 2008 winter study, several multi-day episodes of elevated ozone were studied. Six additional ozone monitoring locations were added and the plane was flown to provide more information on the spatial and temporal variability around the UGRB. AQD continued to collect speciated VOC samples which confirmed the strong oil and gas signature. These data also allowed us to identify species of interest with respect to elevated ozone formation. AQD also used a mini-SODAR and rawinsondes to characterize the mixing heights and inversion strength on elevated ozone days. It was found that on days with elevated ozone, mixing heights could be as shallow as 50-200 meters above ground level.

For the 2009 winter study, AQD has placed eleven FEM and non-FEM continuous ozone monitors around the UGRB. Additionally, AQD has placed five FEM ozone monitors in communities around the UGRB as part of an Air Toxics study. These monitors compliment the three long-term FEM ozone monitors currently operating. AQD has also added precursor monitoring at the Boulder, Jonah and SODAR stations. Figure S.1-3 shows the current configuration of ozone monitoring in the UGRB.

Figure S.1-3: Winter 2009 Ozone Monitoring in the Upper Green River Basin



While ozone data from these studies cannot be used directly for designation, AQD has used these data to support our recommendation on a nonattainment area boundary for the UGRB. Specifically, VOC data are referenced in Section 2 and mesonet data are used to develop a localized wind field referenced in Section 7. Final reports, quality assurance project plans, and databases from the 2007 and 2008 studies are available on the WDEQ/AQD website: (http://deq.state.wy.us/aqd/Monitoring%20Data.asp). Data from the 2009 study will be posted to the AQD Monitoring page after it has been fully quality assured.

SECTION 2
EMISSIONS DATA

SYNOPSIS

The primary sources of ozone-forming precursors in the recommended nonattainment area are associated with the oil and gas development and production industry in the UGRB.

ANALYSIS

Ground-level ozone is primarily formed from reactions of volatile organic compounds (VOCs) and oxides of nitrogen (NOx) in the presence of sunlight. VOCs and NOx are considered "ozone precursors." As part of the nine-factor analysis, the Air Quality Division compiled emission estimates for VOCs and NOx for ten source categories in the proposed nonattainment area as well as counties or portions of counties surrounding the area. This information is summarized in Table S.2-1 and represents preliminary estimated first quarter 2007 emission inventory data for all potential sources. Emissions information for 2007 is used because it is the most recently available data for all source sectors. Only the first quarter is shown because elevated ozone in the UGRB occurs during limited episodes in the first three months of the calendar year. In general, quarterly emissions for the second through fourth quarters of the year are the same as for the first quarter, with the exception that biogenic VOC emissions are expected to be greater in the spring and summer months.

When comparing the raw precursor emission totals in Table S.2-1, AQD is aware that the total for the area defined as "Sweetwater Outside of Upper Green River Basin" is the largest for both VOCs and NOx. However, after carefully reviewing the other eight factors to determine an appropriate boundary, AQD has concluded that there are no violations occurring in Sweetwater County, nor are the emissions sources in most of Sweetwater County contributing meaningfully to the observed violations in Sublette County. AQD will demonstrate in this document that the emissions identified in the UGRB, along with other key factors such as site-specific air quality data (Section 1), unique meteorological and geographical conditions (Sections 6 and 7), as well as extraordinary industrial growth rates (Section 5), will explain the exceedances of the ozone standard at the Boulder monitor in Sublette County.

AQD has taken the next step to focus in on the particular emission sources believed to be contributing to high ozone levels. Figure S.2-1 shows emission inventory data for the UGRB. These emission estimates indicate that the most significant sources of ozone precursors in the UGRB are biogenics and the oil and gas industry.

<u>Biogenics</u>

During the first quarter of the year, biogenic emissions are lower than emissions from the other months of the year. The 2007 and 2008 Upper Green Winter Ozone Study (described in Section 1) analyzed canister samples for four biogenic species: isoprene, a-pinene, b-pinene, and d-limonene. Of particular interest is that isoprene, which is a common and highly reactive species of overwhelmingly biogenic origin, was not detected in any of the samples collected at the Jonah

monitor and found only at levels just above the method detection limit in one sample at the Daniel monitor and two samples at the Boulder monitor. A-pinene, b-pinene and a-limonene were detected in 3% or less of the samples at each site. These results are consistent with the expected absence of biogenic VOCs in the study area during the winter months.

Biogenic emissions may be overestimated in the standard models used to prepare Table S.2-1, as typical biogenic species have not been detected in significant quantities in canister samples. Alternatively, they may be attributed to forested areas on the east and west flanks of the recommended nonattainment area, which may not influence air composition at Boulder, Daniel, and Jonah during the episodic ozone conditions when canister samples have been taken.

Oil and Gas Production and Development

Oil and gas production and development is the only significant industry emission source within the UGRB. We have divided the emissions from this industry further into those associated with construction, drilling, and completion of wells; well site production; and major sources. Oil and gas production is the largest source of VOCs, with the second largest being biogenic sources. The largest NOx emission sources are from rigs drilling the natural gas wells, natural gas compressor stations (O&G Major Sources) and gas-fired production equipment.

Figure S.2-2 shows the nonattainment boundary and the location of emission sources within and around the boundary. There are 11 major sources within the proposed boundary. Ten of these are compressor stations and one is a liquids gathering system. The figure also shows the distribution of oil and gas wells in the nonattainment and surrounding area.

The boundary encompasses areas of oil and gas development and their respective emissions sources, defined by topography (Section 6) and meteorology (Section 7), which are the most likely sources of ozone-forming precursors influencing the Boulder monitor during elevated ozone episodes.

While the Air Quality Division has been studying the emissions from oil and gas production and development for a number of years, it is an extremely complex industry to understand from an air quality perspective. AQD has made a concerted effort to estimate the emissions impacting the monitors during very unusual circumstances. These efforts will continue and AQD has plans to refine these estimates over time.

Table S.2-1: 1st Quarter, 2007 Estimated Emissions Summary (tons)

	Upper Green River Basin		Lincoln Outside of Upper Green River Basin		Sweetwater Outside of Upper Green River Basin		Uinta		Fremont		Teton	
Emissions Sources	NOx	VOCs	NOx	VOCs	NOx	VOCs	NOx	VOCs	NOx	VOCs	NOx	VOCs
On-Road Mobile Emissions	136	79	155	89	1,727	308	655	122	242	138	157	90
Non-Road Mobile Emissions	36	473	593	208	2,000	174	604	157	101	104	34	256
O&G Well Construction, Drilling & Completion	915	166	243	227	747	870	12	13	102	254	0	0
O&G Production Emissions	327	20,550	148	7,074	460	21,232	133	4,095	281	10,005	0	0
O&G Major Sources	481	198	488	63	9,631	2,200	174	196	111	20	0	0
EGUs Major Sources	0	0	3,151	24	6,335	75	0	0	0	0	0	0
Other Major Sources	0	0	0	0	2,445	1,929	0	0	0	0	0	0
Non-O&G Minor Sources	17	86	346	31	171	56	22	60	10	33	3	0
Biogenic Emissions	0	2,957	0	2,376	0	2,184	0	816	0	5,354	0	3,268
Fire Emissions	5	4	0	0	0	0	0	0	317	232	0	0
Total Emissions	**1,917**	**24,514**	**5,124**	**10,092**	**23,516**	**29,027**	**1,600**	**5,458**	**1,163**	**16,142**	**194**	**3,614**

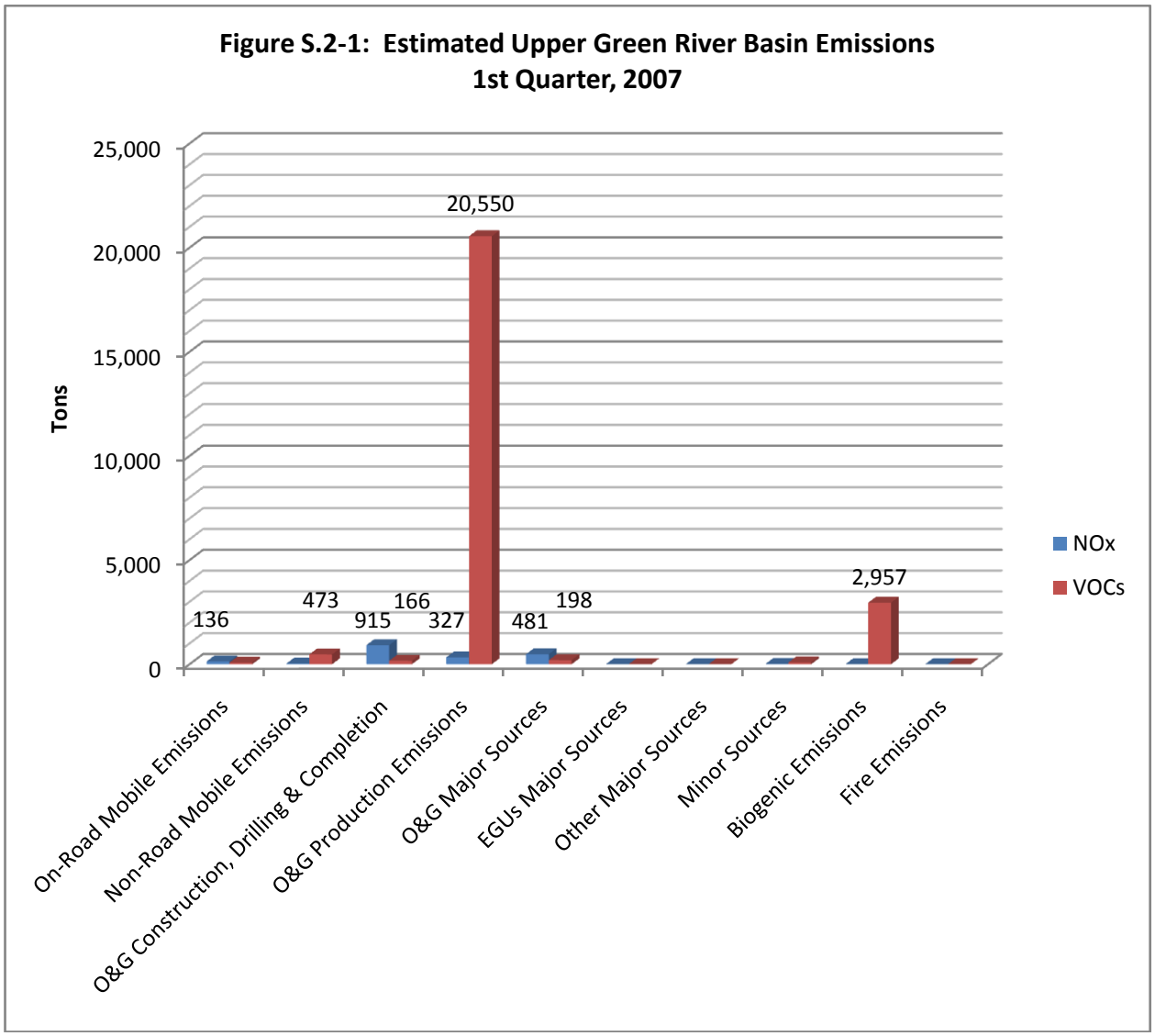


Figure S.2-1: Estimated Upper Green River Basin Emissions
1st Quarter, 2007
Tons
25,000
20,000
15,000
10,000
5,000
0
136
473
915
166
327
20,550
481
198
2,957
On-Road Mobile Emissions
Non-Road Mobile Emissions
O&G Construction, Drilling & Completion
O&G Production Emissions
O&G Major Sources
EGUs Major Sources
Other Major Sources
Minor Sources
Biogenic Emissions
Fire Emissions
NOx
VOCs

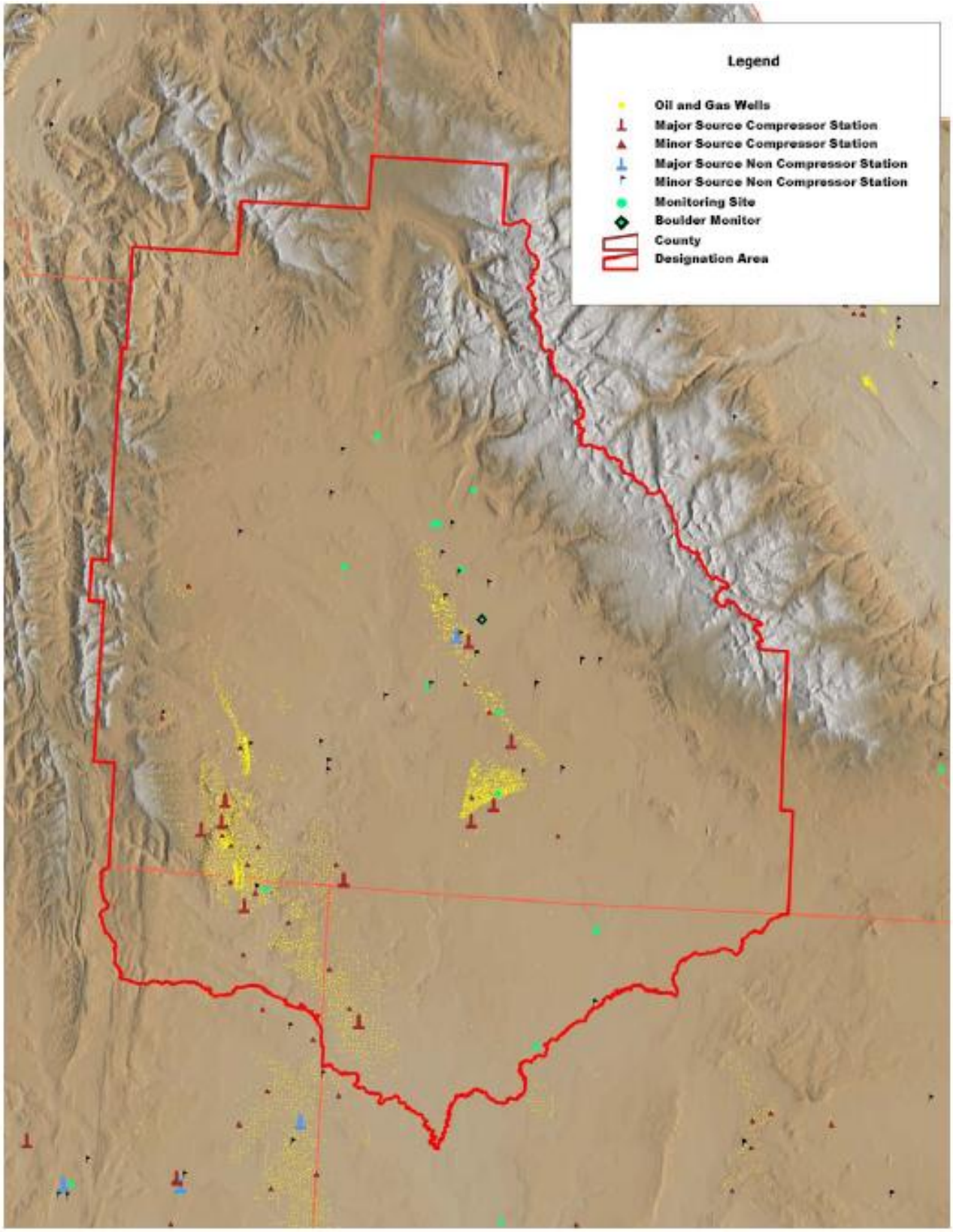


Figure 2.2-2: Designation Area Boundary

SECTION 3
POPULATION DENSITY AND DEGREE OF URBANIZATION

SYNOPSIS

Urbanized areas in surrounding counties do not affect ozone formation or precursors in the proposed nonattainment area just prior to and during elevated ozone episodes, because the urbanized areas are distant and in some cases separated by geographical features such as mountains.

The past and anticipated future rapid population growth is expected to be limited to the proposed nonattainment area, which would suggest that neighboring counties should not be included in the proposed nonattainment area.

Factors which are associated with ozone formation in urban areas have a lower significance for selecting the boundary for this nonattainment area since Southwest Wyoming is mostly rural with a low population density.

ANALYSIS

Sublette County and the surrounding counties (Table S.3-1) are rural with a low overall population density. There are no metropolitan areas with a population of 50,000 or more in this six-county area.

Table S.3-1: Population Density

	Sublette	Sweetwater	Lincoln	Uinta	Fremont	Teton
Estimated 2007 Population	7,925	39,305	16,171	20,195	37,479	20,002
Area (square mile)	4,882	10,426	4,069	2,082	9,183	4,008
Population/square mile	2	4	4	10	4	5
Percent in Urbanized Area*	0	89	20	59	48	56
Percent in Rural Area*	100	11	80	41	52	44

* Based on 2000 Census

The largest community in Sublette County is Pinedale. The estimated population in 2007 was 2,043. The largest communities in the counties surrounding Sublette are Rock Springs (population 19,659), Green River (population 12,072) and Evanston (population 11,483). Rock Springs, Evanston, Riverton and Jackson are classified by the U.S. Census Bureau as Micropolitan Statistical Areas. Table S.3-2 shows population estimates and projections from the Wyoming State Department of Administration and Information.

Table S.3-2: Population Estimates and Projections

County and Cities	2007 Estimate	2008 Forecast	2010 Forecast	2015 Forecast	2020 Forecast	2025 Forecast	2030 Forecast
Sublette	**7,925**	**8,340**	**9,170**	**11,200**	**13,370**	**15,010**	**16,930**
Big Piney	476	501	551	673	803	902	1,017
Marbleton	919	967	1,063	1,299	1,550	1,741	1,963
Pinedale	2,043	2,150	2,364	2,887	3,447	3,869	4,364
Fremont	**37,479**	**37,870**	**38,390**	**39,320**	**40,110**	**41,130**	**42,370**
Dubois	1,033	1,044	1,058	1,084	1,106	1,134	1,168
Lander	7,131	7,205	7,304	7,481	7,632	7,826	8,062
Riverton	9,833	9,936	10,072	10,316	10,523	10,791	11,116
Lincoln	**16,171**	**16,560**	**17,240**	**18,710**	**20,100**	**21,190**	**22,430**
Afton	1,782	1,825	1,900	2,062	2,215	2,335	2,472
Alpine	764	782	815	884	950	1,001	1,060
Kemmerer	2,427	2,485	2,587	2,808	3,017	3,180	3,366
Star Valley Ranch	1,567	1,605	1,671	1,813	1,948	2,053	2,174
Sweetwater	**39,305**	**40,180**	**41,700**	**44,430**	**46,530**	**47,220**	**48,130**
Green River	12,072	12,341	12,808	13,646	14,291	14,503	14,782
Rock Springs	19,659	20,097	20,857	22,222	23,273	23,618	24,073
Teton	**20,002**	**20,240**	**20,570**	**21,340**	**22,140**	**23,470**	**24,990**
Jackson	9,631	9,746	9,904	10,275	10,660	11,301	12,033
Uinta	**20,195**	**20,420**	**20,730**	**21,210**	**21,550**	**21,950**	**22,440**
Evanston	11,483	11,611	11,787	12,060	12,253	12,481	12,760
Lyman	1,990	2,012	2,043	2,090	2,124	2,163	2,211
Mountain View	1,176	1,189	1,207	1,235	1,255	1,278	1,307

Population in Sublette County and Sublette County communities is expected to increase at a rate of approximately 5% over the next 23 years. Population in surrounding counties is expected to increase more slowly at rates of 2% or less.

The population in Sublette County has increased at a greater pace than surrounding counties (Table S.3-3). In the period 2006 to 2007, Sublette County continued to see faster growth than surrounding counties.

Table S.3-3: Population Growth

Population	Sublette	Sweetwater	Lincoln	Uinta	Fremont	Teton
Estimated 2007	7,925	39,305	16,171	20,195	37,479	20,002
Estimated 2006	7,359	38,763	16,383	20,213	37,163	19,288
Estimated 2004	6,879	38,380	15,780	20,056	36,710	18,942
2000	5,920	37,613	14,573	19,742	35,804	18,251
Percent Population Increase						
2000 to 2007	34%	4%	11%	2%	5%	10%
2004 to 2007	15%	2%	2%	1%	2%	6%
2006 to 2007	8%	1%	-1%	0%	1%	4%

Sublette County does not have any urbanized areas. Urbanized areas in surrounding counties are geographically distant from the monitor with the ozone exceedance in Sublette County (the Boulder monitor). As is described in Section 7 of this document, meteorological conditions associated with elevated ozone episodes greatly limit the possibility of emissions transport. Table S.3-4 shows the approximate distance to the Boulder monitor from communities with a population greater than 9,000 in 2007. Additionally, Riverton is separated from the UGRB by the Wind River Range. (Appendix S3 - **Figure -** Wyoming Population Density by Census Tract)

Table S.3-4: Distance to Boulder Monitor
(Miles, approximate)

Riverton	Green River	Rock Springs	Jackson	Evanston
73	82	80	75	118

The analysis in Section 7 of this document will demonstrate that emissions from sources outside of the UGRB do not significantly influence ozone levels at the Boulder monitor during elevated ozone episodes.

References:

1. http://www.census.gov/main/www/cen2000.html, U.S. Census Data.
2. http://eadiv.state.wy.us/pop/CO-07EST.htm, State of Wyoming populations statistics and projections by county and city.
3. Appendix S.3., Population Density by Census Tract

SECTION 4
TRAFFIC AND COMMUTING PATTERNS

SYNOPSIS

The number of commuters into or out of Sublette County (and the UGRB) is small and does not support adding other counties or parts of counties into the nonattainment area based on contribution of emissions from commuters from other counties.

The percent of emissions from on-road mobile sources is small within the proposed nonattainment area: 7% of NOx and 0.3% of VOCs. Even if this source increases, it will remain a small percentage of total emissions.

Interstate 80, the interstate highway that is nearest to the Boulder monitor, is approximately 80 miles south of the Boulder monitor. Ozone monitors in closer vicinity to the interstate have not shown ozone exceedances. I-80 traffic is not considered to be a significant contributor of emissions that impact the Boulder monitor during ozone events.

ANALYSIS

Consistent with the rural character of the counties in southwest Wyoming including Sublette County, traffic volumes are low. The Wyoming Department of Transportation's (WYDOT)[1] inventory shows traffic volume at 447,953 daily vehicle miles traveled (DVMT) for Sublette County in 2007. WYDOT inventories are based on travel on paved roads. Table S.4-1 shows traffic volumes for Sublette County and surrounding counties for 1994, 2004 and 2007.

Emissions from mobile sources within the UGRB are very low, as would be expected from such low DVMTs. As shown in Table S.2-1, NOx emissions for the first quarter of 2007 are approximately 136 tons (7% of total NOx) and VOC emissions are 79 tons (0.3%). This makes emissions from this sector of much lower significance than is typically seen in urban nonattainment areas.

Approximately 90% of the traffic volume in Sweetwater and Uinta Counties is interstate traffic. Interstate 80 is located approximately 80 miles south of the Boulder monitor, the ozone monitor that showed the exceedance. There are five ozone monitors located closer to the Interstate: Wamsutter (~1 mile), OCI (~12 miles), South Pass (~45 miles), Murphy Ridge (~5 miles), and Jonah (~60 miles) (See Figure S.1-1). None of the monitors located closer to the Interstate have shown an ozone exceedance.

Table S.4-1: WYDOT - 2007 Traffic Surveys

	Sublette	Sweetwater	Lincoln	Uinta	Fremont	Teton
DVMT-2007	447,953	2,667,117	615,113	1,013,595	979,546	622,356
DVMT - interstate-2007		2,421,684		911,916		
DVMT-2004	342,034	2,473,882	564,771	944,416	892,814	600,836
DVMT-1994	229,553	1,917,738	466,753	761,626	737,863	504,904
Increase 1994 to 2007	95%	39%	32%	33%	33%	23%
Miles of roads	229.2	568.7	337.2	218.4	507.2	144.2
DVMT/mile of road	1954	4689	1824	4641	1931	4315

The Wyoming Department of Employment (DOE)[2] surveys commuting trends between counties. Table S.4-2 summarizes the average number of commuters for the years 2000 through 2005 that commute between Sublette County (the county with the Boulder monitor) and surrounding counties. Although commuting has increased for some neighboring counties, such as Sweetwater County, the volume of commuters is low.

Table S.4-2: Wyoming DOE Commuter Surveys 2000 Through 2005

Commuters driving to Sublette from:	2000	2001	2002	2003	2004	2005
Fremont	20	29	17	26	41	47
Lincoln	112	117	106	84	100	128
Sweetwater	62	86	79	77	111	185
Teton	49	52	45	35	38	49
Uinta	14	12	22	31	38	53
Total						462
Commuters driving from Sublette to:						
Fremont	81	67	70	37	48	44
Lincoln	77	59	76	114	97	93
Sweetwater	126	129	109	121	152	209
Teton	171	148	150	135	142	130
Uinta	33	66	55	31	20	26
Total						502

North Carolina's Economic Development Intelligence System (EDIS)[3] compiled 2000 Census data to determine the number of commuters in Wyoming counties. Extrapolating this data to 2008, to account for only population growth, the estimated number of commuters in Sublette County and surrounding counties is shown in Table S.4-3. Since rapid population growth in Sublette County is biased toward the working age population, the straight extrapolation from 2000 data is likely to underestimate the number of commuters. The EDIS data indicate the majority of commuters commute within their county of residence. The number of commuters leaving Sublette County calculated by the Wyoming DOE correlates well with the EDIS generated estimates of commuters leaving Sublette County.

Table S.4-3: Number of Commuters in Sublette and Surrounding Counties

	Sublette	Sweetwater	Lincoln	Uinta	Fremont	Teton
Estimated number of commuters in 2000*	2767	18,012	6069	8921	15,074	10,527
Estimated number of commuters in 2008	3357	18,726	7084	9114	15,761	11,811
Estimated number of 2008 commuters that stay in their county	2921	17,977	5596	7565	14,973	11,338

* 2000 Census data

Commuting patterns in Sublette County and in surrounding counties show that commuting to or from the adjacent counties is not a major source of VMT in Sublette County. Therefore, commuters from adjacent counties are not a significant factor in ozone generation in the proposed nonattainment area.

Reference:

1. Appendix S.4.A, 2007 Vehicle Miles on State Highways By County
2. Appendix S.4.B, Commuting Patterns in Sublette County
3. North Carolina Department of Commerce web site. https://edis.commerce.state.nc.us/docs/countyProfile/WY/

SECTION 5
GROWTH RATES AND PATTERNS

SYNOPSIS

The pace of growth in the oil and gas industry in Sublette County is significantly greater than in surrounding counties. While population is growing in Sublette County, the county and surrounding area is rural with a low population density. Population growth does not influence determination of a designation area boundary in this case.

ANALYSIS

Statistical data available is broken down on a county basis. The following analysis compares Sublette County to surrounding counties. While the recommended nonattainment area includes a portion of Sweetwater and Lincoln counties in addition to Sublette, the trends described for Sublette County also hold true, in general, to the recommended nonattainment area.

Population growth is described in Section 3. Sublette County population has grown at an annual rate of approximately five percent over the last seven to ten years. Sublette County is forecast to continue to grow at this rate for the foreseeable future. Counties surrounding Sublette have grown at rates of less than two percent during this time period and are forecast to continue to grow at this slower pace.

Industrial growth in Sublette County is driven by the oil and gas (O&G) industry. Table S.5-1 shows the increase in O&G production for Sublette County as shown by the number of well completions for years 2000 through 2008. Table S.5-2 shows total well completions for 2005 through 2008 for Sublette, Sweetwater, Uinta and Lincoln counties. Sweetwater and Lincoln counties also show an increasing trend in well completions, though to a lesser extent than in Sublette. Teton County is not listed because it has no oil and gas production. Fremont County is not shown because O&G production areas in Fremont County are separated from the other counties by the Wind River Mountain Range.

Table S.5-1: Completion Report Sublette County*

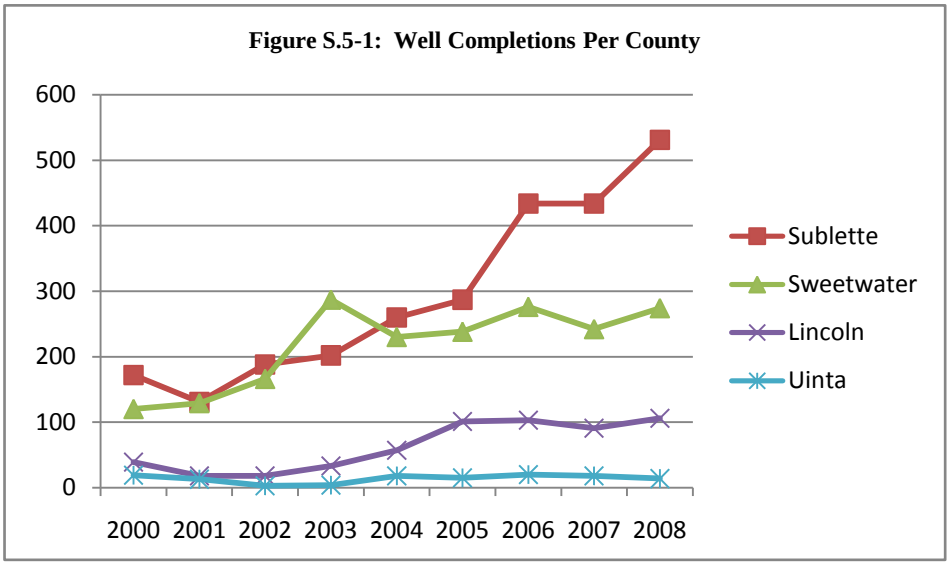
(Confidential Records Are Not Listed)

	2000	2001	2002	2003	2004	2005	2006	2007	2008
Distinct Gas Well Completion Count	126	110	150	185	252	281	428	420	517
Distinct Oil Well Completion Count	45	20	32	15	5	0	3	5	4
Total Distinct Well Completion Count	172	131	188	202	260	287	434	434	531

*Wyoming Oil and Gas Conservation Commission (WOGCC)

Table S.5-2: Total Well Completions/Oil, Gas, and CBM* (Confidential Records Are Not Listed)									
	2000	2001	2002	2003	2004	2005	2006	2007	2008
Sublette	172	131	188	202	260	287	434	434	531
Sweetwater	120	129	166	287	230	238	276	242	274
Lincoln	39	18	18	33	57	101	103	91	106
Uinta	19	13	3	4	18	15	20	18	14

*Wyoming Oil and Gas Conservation Commission (WOGCC)



As Figure S.5-1 shows, there have been more O&G well completions in Sublette than for the surrounding counties. Table S.5-3 and Figure S.5-2 show the steady growth in Sublette County O&G production since 2000.

Table: S.5-3 Sublette County Production Levels			
	Oil Bbls	**Gas Mcf**	**Water Bbls**
2008	7,666,396	1,143,614,170	22,921,983
2007	7,096,499	1,008,001,400	18,251,807
2006	5,769,581	880,855,575	13,203,000
2005	5,102,164	814,748,425	11,641,926
2004	4,705,836	731,276,509	11,812,077
2003	4,539,385	655,573,062	10,526,328
2002	4,380,011	571,000,866	13,950,895
2001	3,840,436	493,577,283	7,785,291
2000	3,345,063	448,281,668	7,364,792

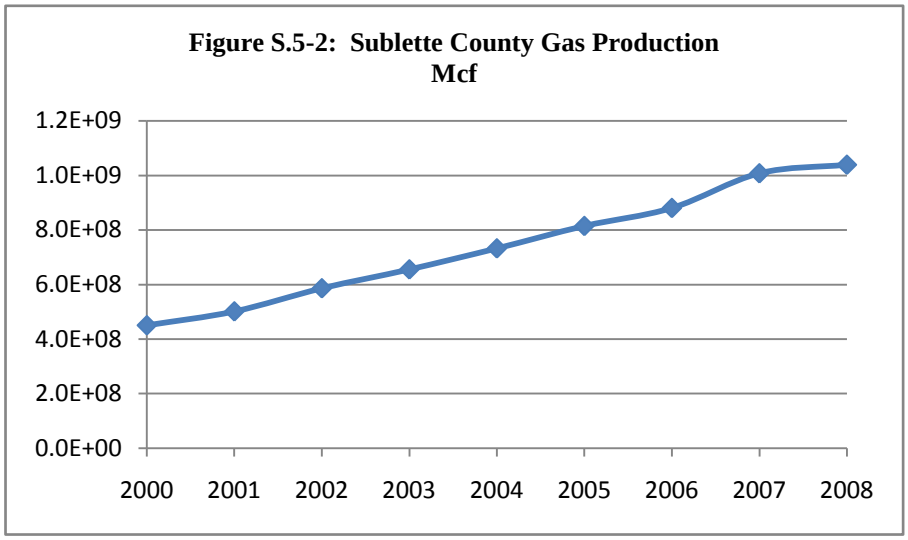


Table S.5-4 shows growth in the oil and gas industry by county through the following three measures: oil production (in barrels), gas production (in thousand cubic feet), and produced water generation (in barrels). Growth in production of gas and water is increasing in Sublette County and is either static or decreasing in the surrounding counties.

Table S.5-4: Four County Production				
	Oil Bbls			
	Sublette	Lincoln	Sweetwater	Uinta
2008	7,666,396	819,751	5,392,316	1,341,993
2007	7,096,499	801,807	5,738,262	1,506,562
2006	5,769,581	782,165	5,295,610	1,914,262
2005	5,102,164	762,801	4,872,531	2,246,896
	Gas Mcf			
2008	1,143,614,170	89,516,900	240,214,449	130,282,928
2007	1,008,001,400	89,189,164	235,687,851	128,068,870
2006	880,855,575	85,753,007	238,339,251	139,700,716
2005	814,748,425	83,579,467	222,772,057	141,490,407
	Water Bbls			
2008	22,921,983	1,228,058	42,026,953	3,011,981
2007	18,251,807	1,300,854	47,522,714	2,843,082
2006	13,203,000	1,375,969	49,928,115	2,641,554
2005	11,641,926	1,065,943	45,110,120	2,950,473

References:

Wyoming Oil and Gas Conservation Commission (http://wogccms.state.wy.us/)

SECTION 6
GEOGRAPHY/TOPOGRAPHY

SYNOPSIS

The Wind River Range, with peaks up to 13,800 feet, bounds the UGRB to the east and north; the Wyoming Range, with peaks up to 11,300 feet, bounds the UGRB to the west.

Significant terrain influences the weather patterns throughout Southwest Wyoming. Other terrain features such as river and stream valleys also influence local wind patterns.

Mountain-valley weather patterns in the UGRB tend to produce limited atmospheric mixing during periods when a high pressure system is in place, setting up conditions for temperature inversions, which are enhanced by the effect of snow cover.

ANALYSIS

Southwest Wyoming and the UGRB are within the Wyoming Basin Physiographic Province. Topography in the UGRB is characterized by low, gently rolling hills interspersed with buttes. Elevations range from approximately 7,000 to 7,400 feet above mean sea level (AMSL) in the lowest portions of the UGRB. The Wind River Range, with peaks up to 13,800 feet, bounds the UGRB to the east and north and the Wyoming Range, with peaks up to 11,300 feet, bounds the UGRB to the west. There are also important low terrain features such as the Green River Basin and the Great Divide Basin.

Mountain elevations decrease moving south along both the Wyoming and Wind River ranges. Along the western boundary of the Green River Basin, in the southern part of the Wyoming Range, the elevation decreases to about 6,900 feet above mean sea level (AMSL) with some peaks in the 7,500 to 8,000-foot range. Moving south along the Wind River Range, the elevation decreases to 7,800 feet at South Pass.

Figure S.6-1: Nonattainment area shown (blue outline) against an aerial view of the topography in the Upper Green River Basin and adjacent areas.

The surrounding significant terrain features effectively create a bowl-like basin in the northern portion of the Green River Basin, which greatly influences localized meteorological and climatological patterns relative to geographical areas located outside of the UGRB. Although difficult to quantify over the entire UGRB valley, the UGRB is roughly 900 to 1,300 meters (3,000 to 4,300 feet) lower than the terrain features bounding the UGRB to the east and west. Typical elevation profiles within the UGRB are illustrated in two different cut-planes (transects) across the UGRB, as shown in Figure S.6-2.

The southern boundary of the area is defined by river and stream channels. To the east the Big Sandy, Little Sandy and Pacific Creek drainages define the boundary and to the west the Green River and Fontenelle Creek drainages define the boundary.

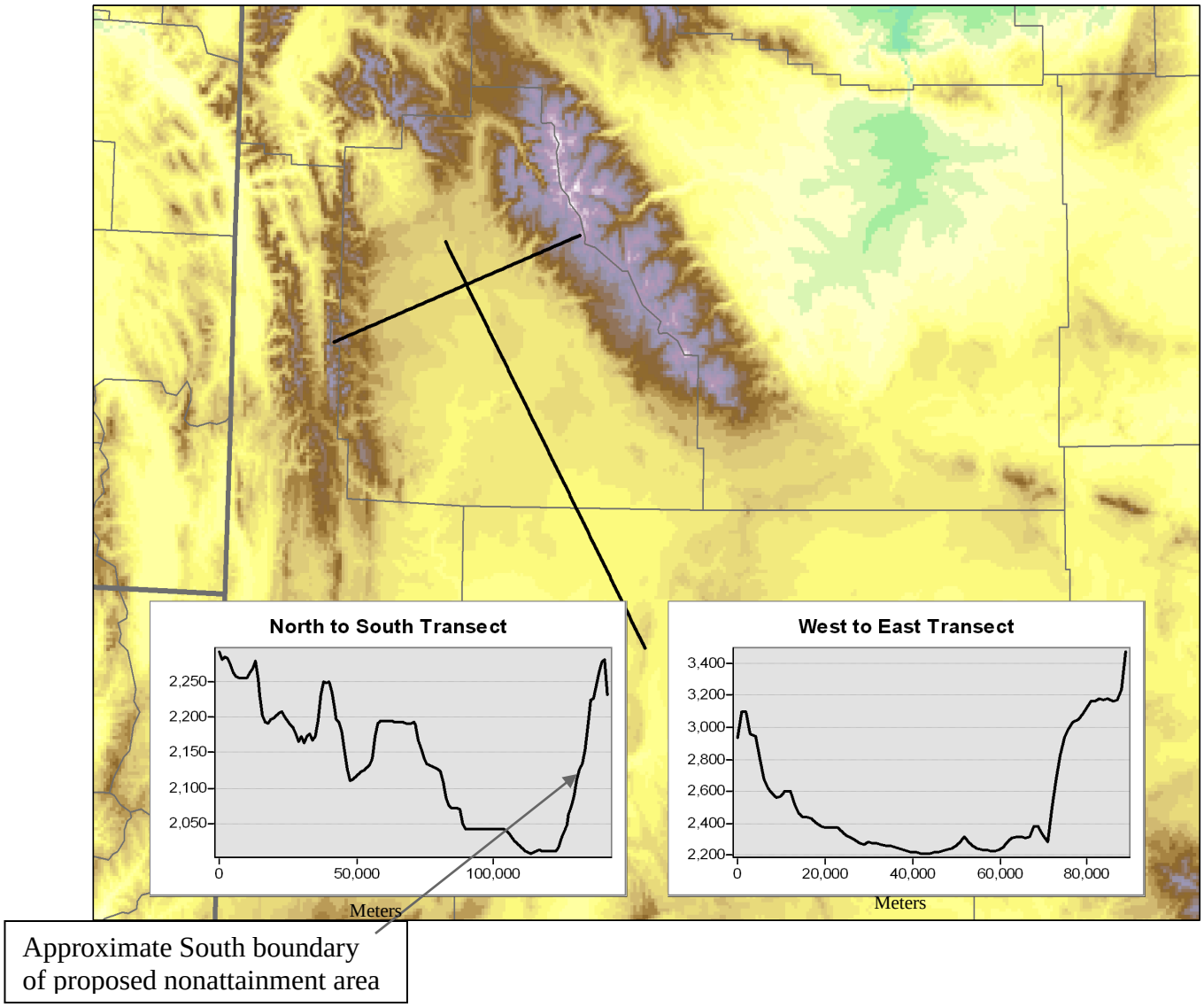


Figure S.6-2: Transects across the Upper Green River Basin (running north-south and west-east) showing cross sections of the terrain; terrain elevations and distance units shown in the transects are in meters.

Significant terrain in the UGRB has an impact on the local meteorology (wind speed, wind direction, and atmospheric stability). In mountain-valley areas – such as the UGRB – during the night cold air will accelerate down the valley sides (downslope winds), while during the day warmer air will flow up the valley sides (upslope winds). At night, this can create a cold pool of air within the UGRB that stratifies the atmosphere (inhibits mixing) since colder, denser air exists at the surface with warmer air above. Further, at the valley floor, the wind speed is likely to be lower than in an open plain as the roughness of the surrounding terrain tends to decrease wind speeds at the surface. The terrain obstacles surrounding the UGRB also tend to cut-off, block, or redirect air that might normally flow through the valley. This effect is exacerbated

during times of calm weather, such as the passage of a high pressure system that tends to set up conditions for strong surface-based temperature inversions.

The Wind River Range on the east and the Wyoming Range on the west provide significant barriers to movement of ozone and ozone precursors into the area proposed for a nonattainment area designation. Although the recommended southern boundary is not bordered by a mountain range, the southern boundary lies along two significant drainage divides: the Fontenelle/Green River and the Pacific/Big Sandy River. These geographic features influence air flow, although they do not provide an absolute barrier to migration. The influence of these geographic features on wind flows, especially during periods of low winds which are needed for ozone formation is illustrated in Figure S.7-17. This figure shows winds generally conforming to the drainages which establish the southern boundary of the proposed nonattainment area. The conclusions about the southern boundary are further supported by the meteorological analyses presented in Section 7.

SECTION 7
METEOROLOGY

SYNOPSIS

The unique meteorology in the UGRB of Wyoming creates conditions favorable to wintertime ozone formation.

The meteorology within the UGRB during winter ozone episodes is much different than on non-high ozone days in the winter, and is also much different than the regional meteorology that exists outside of the UGRB during these wintertime high ozone episodes.

The 2008 field study data reveal that, for the days leading up to the February 19-23, 2008 ozone episode, sustained low wind speeds measured throughout the monitoring network were dominated by local terrain and strong surface-based inversions, which significantly limited the opportunity for long-range transport of precursor emissions and ozone to reach the Boulder monitor.

Minimal emissions transport and dispersion, due to the influence of localized winds (light winds) in the UGRB characterize the February 19-23, 2008 ozone episode.

An ozone-event specific wind field was developed to more accurately simulate meteorological conditions in the UGRB and surrounding areas, and was used to drive a trajectory model for air parcel movement into and out of the UGRB.

Trajectory analyses were used to develop a reasonable southern boundary for the nonattainment area.

The unique meteorological conditions in the UGRB are one of the most significant factors for assigning this nonattainment boundary.

ANALYSIS

General

There is significant topographic relief in Wyoming which affects climate and daily temperature variations. This is a semiarid, dry, cold, mid-continental climate regime. The area is typified by dry windy conditions, with limited rainfall and long, cold winters. July and August are generally the hottest months of the year, while December and January are the coldest. Pinedale's mean temperature in January is 12.5°F with a mean of 60°F in July (Western Regional Climate Center, 2009). The high elevation and dry air contribute to a wide variation between daily minimum and maximum temperatures. At Pinedale, the total annual average precipitation is about 10.9 inches, and an average of 61 inches of snow falls during the year.

Strong winds are common in Wyoming, especially in the south. Wind velocity can be attributable, in part, to the prevailing westerly winds being funneled through the Rock Mountains at a low point in the Continental Divide.

The meteorological conditions conducive to the formation of high ozone levels in the UGRB during the winter and early spring are characterized by:

- A stable atmosphere, characterized by light low-level winds

- Clear or mostly sunny skies
- Low mixing heights or capping inversions
- Extensive snow cover
- Low temperatures

The above conditions take some time to develop (at least 48 hours after a storm frontal passage), and occur during periods when the synoptic weather is dominated by high pressure over the western Rockies.

Looking at the meteorological conditions in the UGRB, elevated ozone episodes in 2005, 2006 and 2008 were associated with strong temperature inversions and light low-level winds. This was the case during the February 19-23, 2008 ozone episode, in which the highest ozone concentrations monitored to date in the UGRB were recorded at the Boulder monitor. Because these meteorological conditions are common to all of the high ozone episodes in the UGRB observed to date, the ozone episode of February 19-23, 2008, a 5-day period marking the longest consecutive ozone episode observed, is considered to be representative of other ozone episodes. This particular 5-day ozone episode is the primary focus of this section on meteorological influences and wintertime high ozone.

Winter Ozone Field Studies

After elevated ozone levels were monitored in the winter of 2005 and 2006; the AQD initiated intensive field studies to collect meteorological and ambient data in the first quarter of 2007, 2008, and 2009 throughout the Green River Basin to better understand the relationships between winter meteorological conditions and high ozone levels versus low ozone levels. In spite of careful planning to record data, the winter of 2007 did not produce conditions conducive to the formation of ozone. In contrast, the winter of 2008 provided a significant amount of data on ozone formation since there were several high ozone episodes. A map showing the monitoring sites employed in the 2008 field study and regional terrain features in the 2008 study area is shown in Figure S.7-1. The entire data set and reports on the winter studies completed to date are available on the WDEQ/AQD website (http://deq.state.wy.us/aqd/Monitoring%20Data.asp). AQD has continued field studies into 2009, but those results will not be available until later in 2009.

During January and the beginning of February 2008, the study area was under the influence of a series of weak to moderately strong synoptic disturbances that migrated from the Gulf of Alaska, across the Pacific Northwest and southern British Columbia and the northern Great Basin and into the Northern Rockies. These weather features generally moved rapidly through southwest Wyoming as they migrated along a belt of strong westerly to northwesterly winds aloft that were associated with a persistent high pressure ridge located over the eastern Pacific, off California. In addition, a number of deep Pacific troughs moved across the area earlier in the winter and into the first half of January. The end result of all this activity was the deposit of substantial snow cover in southwestern Wyoming, including the UGRB, which was to remain in place through the rest of the winter. After mid-February, the eastern Pacific ridge exhibited a tendency to extend or migrate into the interior west until it finally moved directly over southwest Wyoming by February 20, 2008.

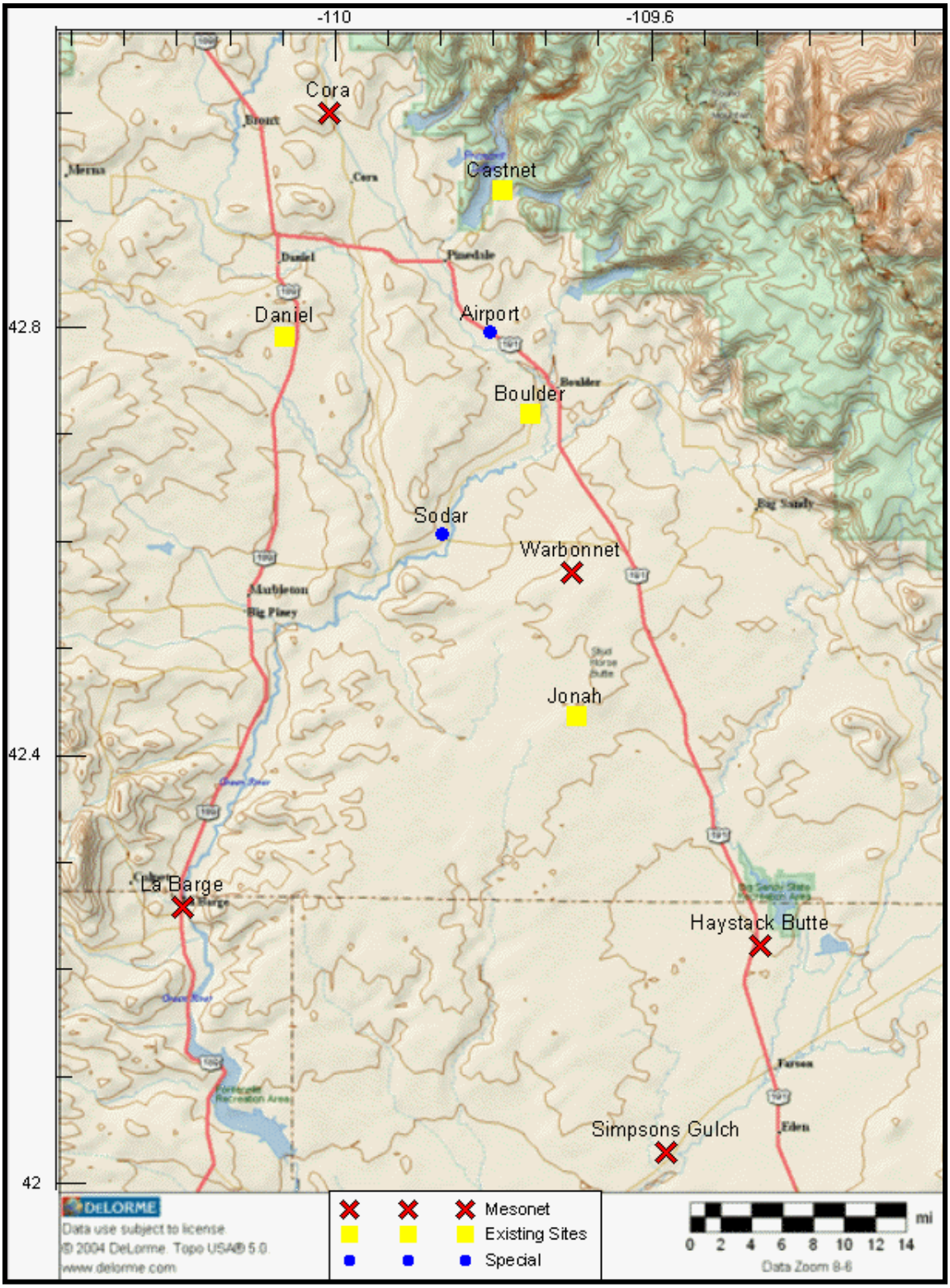


Figure S.7-1. Surface and upper air monitoring sites employed in the 2008 field study.

Comparison of 2007 and 2008 Field Study Observations

Snow Cover and Sunlight

Comparison of meteorological conditions in 2008 with those prevailing during the 2007 field study revealed that one of the key differences was the extensive snow cover in 2008 which was not present during 2007. Snow cover appears to be a key ingredient in winter ozone development, specifically, fresh snow, which results in higher surface albedo, perhaps as great as 0.9. The increased surface albedo results in greater actinic flux and therefore elevated NO_2 photolysis rates. The elevated photolysis rate due to the high (snow cover driven) albedo is likely greater than the photolysis rate in the UGRB in the summer months.

During the 2007 field study, although there were extended periods when synoptic-scale meteorological conditions were conducive to poor horizontal dispersion, the lack of snow cover and subsequent lower UV albedo reduced the amount of UV radiation available for photolysis and associated ozone production. In addition, the 2007 and 2008 field studies suggest that the sensible and radiative heat flux impacts of the snow cover enhance low-level atmospheric stability, substantially reducing vertical mixing during most or all of the daylight hours.

Low Wind Speeds

Stable, stagnant weather conditions occurred in southwest Wyoming during the period from February 18 through 22, 2008. The main synoptic feature responsible for this was a strong Pacific high pressure ridge that slowly migrated across the western United States. This period was dominated by low wind speeds in the boundary layer, which reduced pollutant transport and dispersion. This effect is shown in Figure S.7-2 where ozone concentrations and wind speeds are plotted for the Boulder monitor for February and March of 2008.

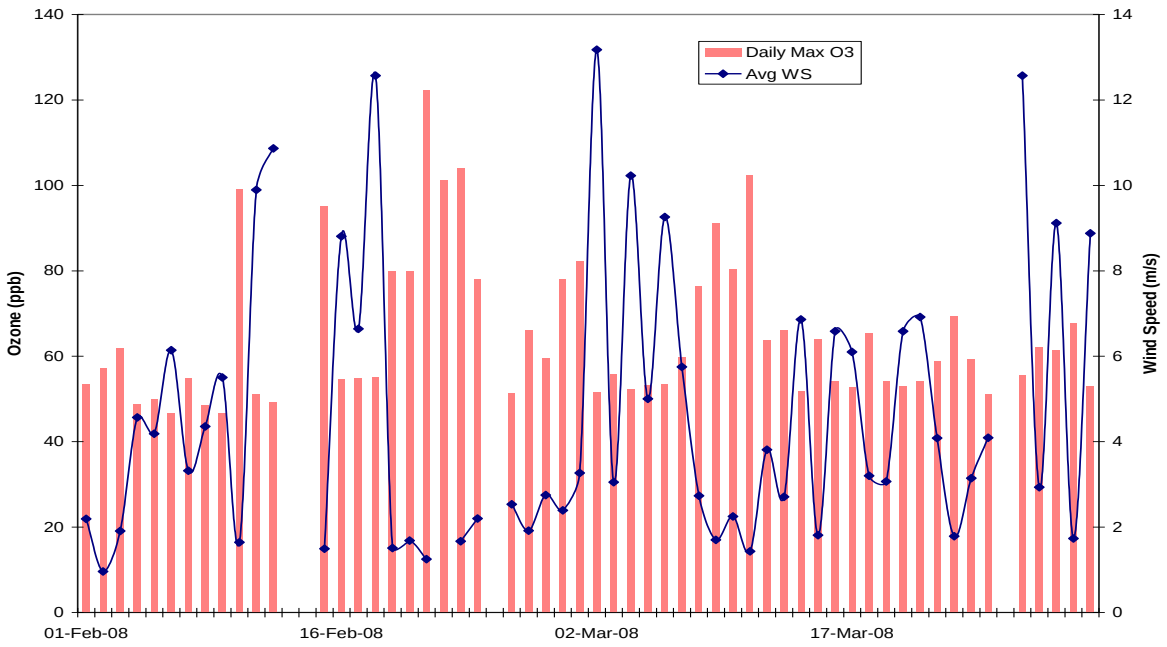


Figure S.7-2. Wind speed and ozone concentrations plotted for the Boulder monitor in February and March 2008.

The 2008 field study data reveal that the sustained low wind speeds measured throughout the monitoring network were dominated by local terrain and strong surface-based inversions, which significantly limited the opportunity for long-range transport of precursor emissions and ozone on the days leading up to the February 19-23, 2008 ozone episode.

Ozone Carryover

When the favorable synoptic conditions described above develop late in the day or during the night hours, the first high ozone concentrations typically develop the following day between approximately 11:00 and 13:00 so long as favorable conditions for high ozone formation persist. During a day of elevated ozone, such as February 20, 2008, the high readings at the monitors in the UGRB peak in the afternoon. As the day progresses, lower but still elevated concentrations continue, in some cases lasting well into the evening hours and, in a few cases, past midnight before lowering. When the following day continues to have these favorable weather conditions, the ozone levels begin to rise earlier than the previous day and frequently to much higher levels, indicative of some carryover of ozone and precursors from one day to the next. Once high ozone concentrations have formed, ozone levels were observed to remain elevated even with increasing cloud cover ahead of an approaching storm system. Additionally, wind reversals, which were most apparent at the Jonah and Boulder monitors, were observed at many of the monitoring sites during the field study; which further assisted in the carryover and build-up of ozone and ozone precursors from emission sources in close proximity to the monitors. Ozone concentrations do not return to near background conditions until brisk (usually west or northwesterly) winds have arrived and scoured out the surface inversion.

Atmospheric Mixing

The observed weather patterns in the 2007 field study showed that the winter storm systems generally did not provide a strong push of cold air and did not produce much precipitation in the project area, but did allow strong wind speeds aloft with considerable mixing of the atmosphere. Specifically, the weather conditions over the study area during February and March of 2007 were characterized by less precipitation (including less snow depth), stronger winds aloft and much warmer surface temperatures compared to the previous two winters. High pressure systems in 2007 tended to keep the air mass over the study area relatively well mixed and mild, which in turn did not allow for snow accumulation and strong inversion development.

Feb. 19 – 23, 2008 Case Study Illustrating the Specific Weather Conditions Which Produce Elevated Ozone in the Upper Green River Basin

This ozone episode is of particular interest for study, as it: 1) occurred over five days, marking the highest 1-hour and 8-hour ozone concentrations recorded at the Boulder monitor to date, 2) occurred during a field study Intensive Operating Period (IOP) that was in place to measure detailed actual ambient and meteorological conditions leading up to and during this multi-day winter ozone episode, 3) provides a high quality database of observations for several meteorological parameters, both during IOPs and regular hourly observations during this ozone episode, and 4) provides information which clearly shows how the topography in the Upper Green River Basin creates different meteorological conditions within the UGRB. A summary of the daily maximum 8-hour averaged ozone concentrations monitored at the Jonah, Boulder, and Daniel FRM monitors during this ozone episode, as well as the day immediately preceding it, are provided in Table S.7-1.

Date	Jonah (ppb)	Boulder (ppb)	Daniel (ppb)
2/18/09	45	55	54
2/19/08	80	79	74
2/20/08	75	79	76
2/21/08	84	122	62
2/22/08	102	101	76
2/23/08	76	104	74

Table S.7-1. Summary of daily maximum 8-hour averaged ozone concentrations monitored at the Jonah, Boulder, and Daniel monitors during February 18-23.

A synopsis of the particular meteorological conditions associated with the February 19-23, 2008 winter high ozone episode is provided below, describing the evolution of the meteorological conditions that were in place during the February 19-23, 2008 ozone episode.

Synopsis of 19 – 23 February 2008 Ozone Episode

Figure S.7-3 shows the 700 millibar (mb) chart for the morning of February 19, 2008, which shows the axis of the Pacific ridge extending north and south from the Four Corners area, through northwestern Idaho and up into eastern British Columbia. At that time, the ridge axis was still west of Wyoming, resulting in fairly strong northwesterly gradient flow (winds blowing from the northwest along the isobars) just above ground level in southwest Wyoming. With clear skies accompanying the approaching ridge, and a good snow cover at the surface, a capping inversion formed overnight and persisted throughout the next day in the UGRB. However, the strong winds above the stable layer, along with mixing heights on the order of several hundred meters, transferred sufficient momentum downward, allowing these northwest winds to mix down to the surface during the day resulting in predominant northwesterly wind patterns within the UGRB.

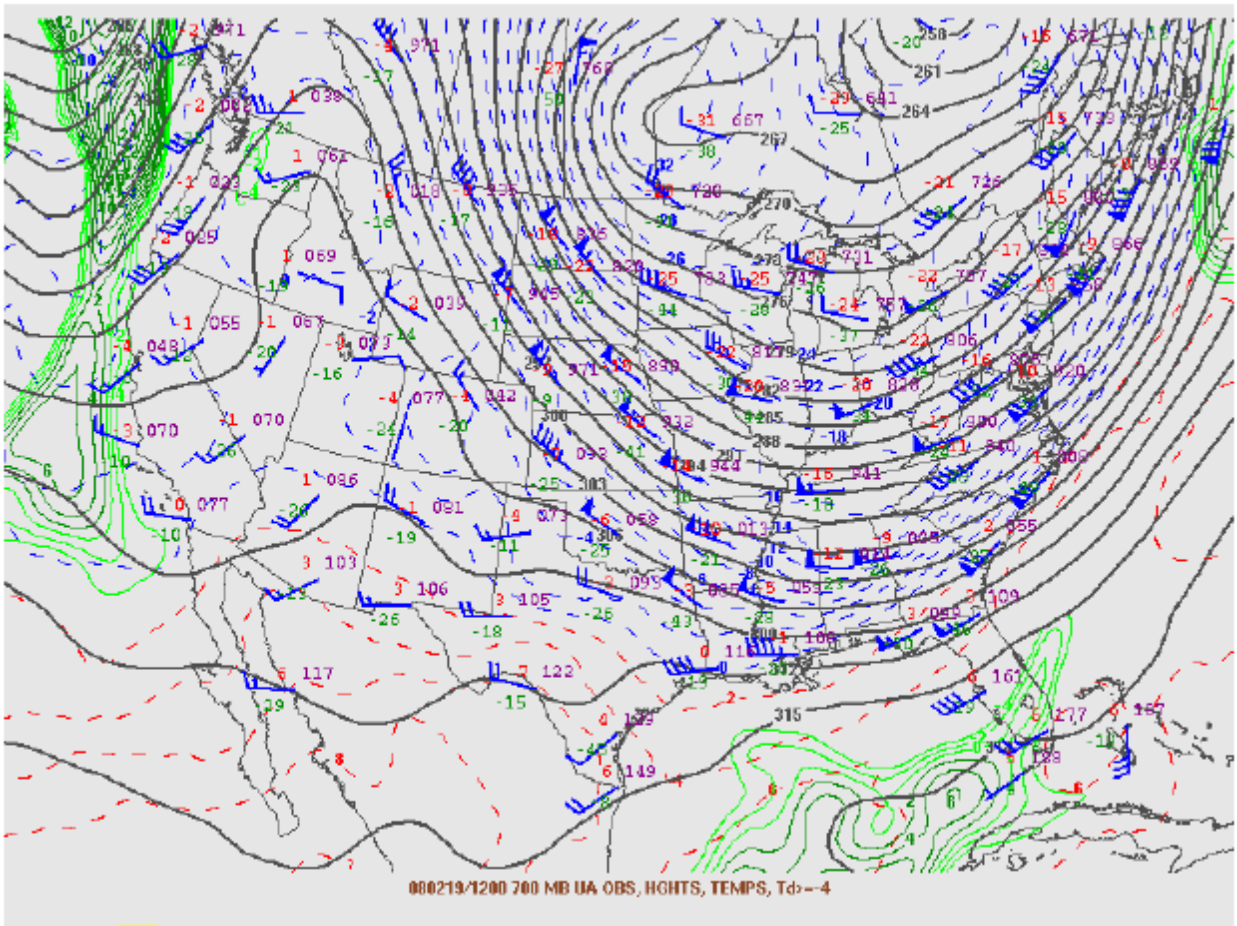


Figure S.7-3. Constant pressure map for 700 mb, 02/19/08 (1200 UTC) [(5 am LST)].

The high pressure ridge continued to progress slowly eastward during February 20th resulting in the central axis pushing into southwestern Wyoming by the middle of the day. As a result, a capping low-level inversion was observed throughout the day, and a weakened northwest gradient wind flow allowed the establishment of local valley flow patterns in the area. Local valley flow patterns are characterized by light variable winds with pronounced down slope winds at night. A weak storm system that moved out of California and across the southern Great Basin during February 20th forced some broken high cloudiness over southwestern Wyoming during the afternoon, but the clouds failed to curtail ozone production in the area, based on monitored data.

Figure S.7-4 shows the 700 mb chart for the evening of February 21, 2008. Although the high pressure ridge had weakened by the afternoon of February 21st, it had also flattened and the central ridge axis was over southwestern Wyoming through the entire day. The resulting light wind situation, characterized by low wind speeds and significantly reduced air flow movement within the UGRB, enabled the strongest ozone production seen to date in Sublette County.

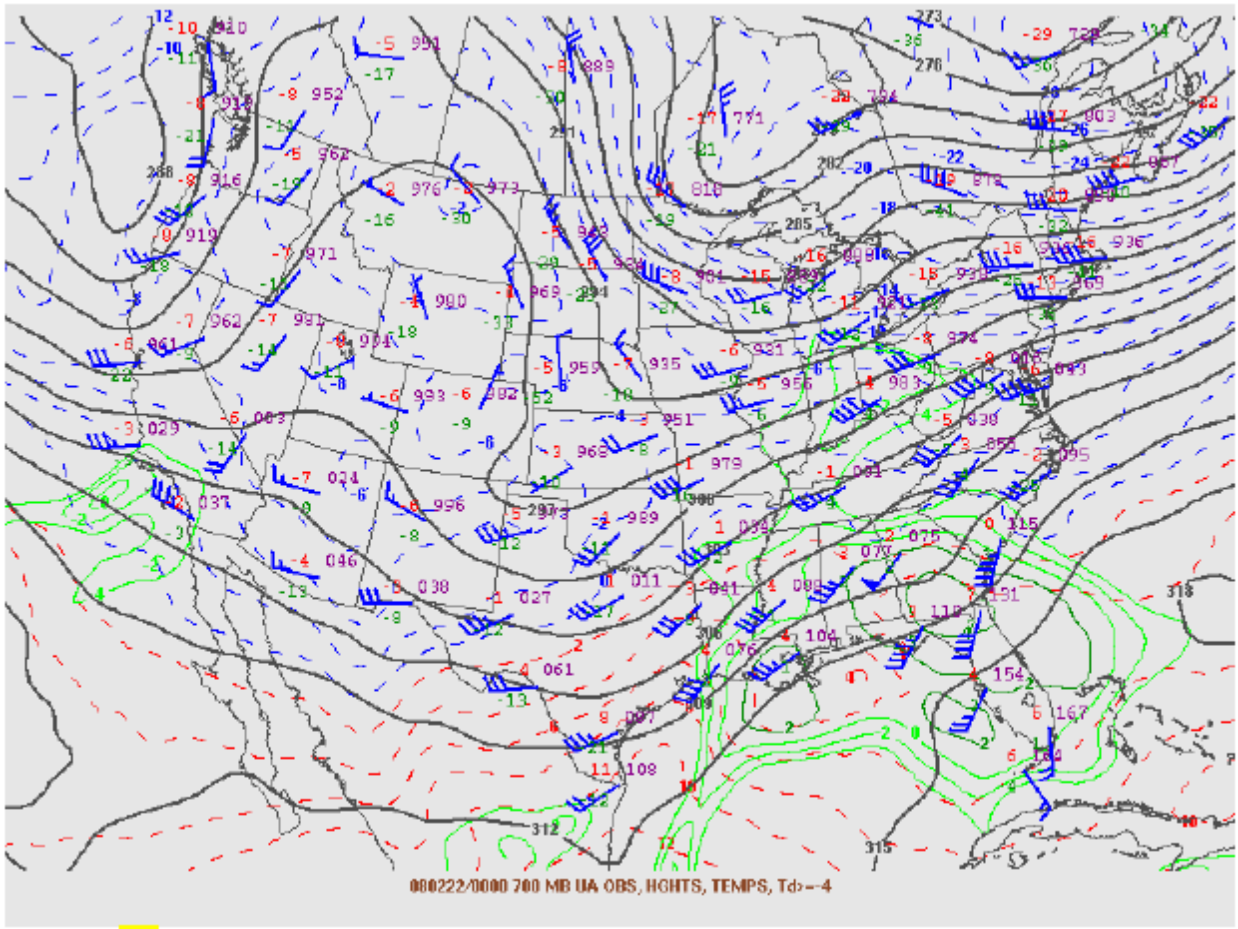


Figure S.7-4. Constant pressure map - 700 mb, 02/22/08 (0000 UTC) [02/21/08 (5 pmLST)].

On February 21, 2008, the low level inversion stayed intact through the entire daylight period, keeping ground level emissions trapped near the surface. With the very light and variable winds above the inversion (see Figure S.7-10) localized wind flow patterns near the ground level developed during the day allowing emissions to transport along those pathways (see Figure S.7-6 and Figure S.7-7). The height of the 700 mb pressure surface during the day was around 3,020 meters (MSL), the temperature averaged about -6° C, and the wind speeds were less than 5 knots. The height of the 500 mb pressure surface averaged around 5,550 meters (MSL) and the wind speeds at that height were around 15 knots.

The high pressure ridge continued to weaken during February 22, 2008, while a shortwave low pressure trough approached southwestern Wyoming from the northwest. Skies became mostly cloudy during the morning hours and light precipitation spread over the area later in the afternoon; the low level inversion stayed intact well into the afternoon, and ozone concentrations remained high during most of the day. It was anticipated that the stable layer would be mixed-out by the trough by early morning the next day and trapped emissions would be dispersed. Instead, the late arrival of the trough allowed one more day of high ozone concentrations.

Description of Surface Wind Data

With the addition of the temporary mesonet monitoring sites to the existing permanent meteorological monitoring stations in the 2007 and 2008 field studies, a fairly detailed picture of wind flow patterns within the UGRB was obtained, revealing that the wind flow patterns were distinctly different throughout the northern and southern portions of southwest Wyoming. A composite map of wind rose plots generated from meteorological data collected throughout southwest Wyoming during the time period 18 – 22, February 2008 is provided in Figure S.7-5.

As can be seen in Figure S.7-5, the wind patterns in the northern portion of Sublette County reflect the prevailing northwest winds typical of this area during most of the year. However, this moderately strong, organized northwest flow does not extend to the southern monitoring sites (Haystack Butte and Simpsons Gulch). Monitoring sites located in Sweetwater, Lincoln and Uinta Counties experienced a generally westerly wind flow, which was also a characteristic of the prevailing flows noted during the 2007 field study at those monitoring sites. Additionally, during the afternoon, winds reversed at some monitoring sites in the UGRB, shifting from the northwest to the southeast; this mid-day flow reversal is typical of high ozone days in the UGRB, and is thought to be causing recirculation of pollutants within the UGRB.

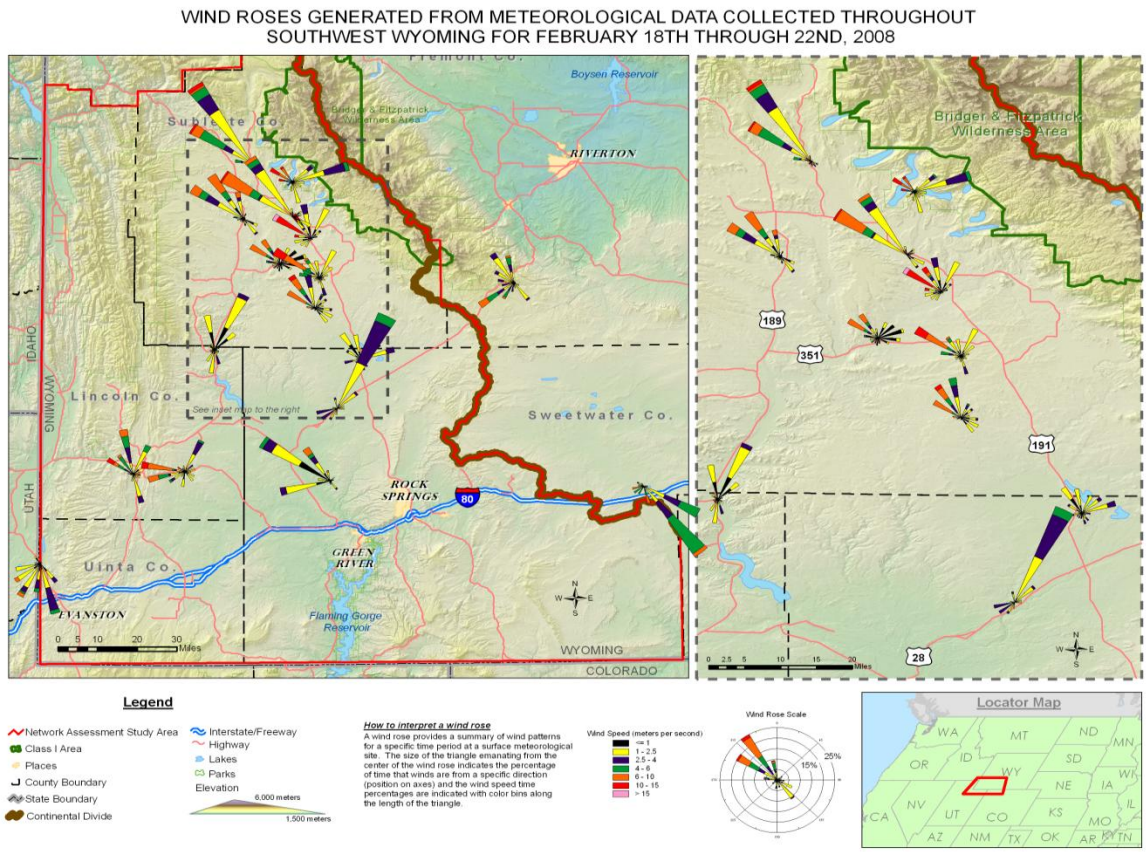


Figure S.7-5. Composite wind rose map for February 18 – 22, 2008 at monitoring sites located throughout Southwest Wyoming.

Wind vector fields were also examined spatially to gain an understanding of flow patterns in the field study area. Winds on a typical ozone episode day (February 20th), and on the day with the highest 8-hour ozone concentration recorded at the Boulder monitoring site (February 21st) are shown in Figure S.7-6 and Figure S.7-7.

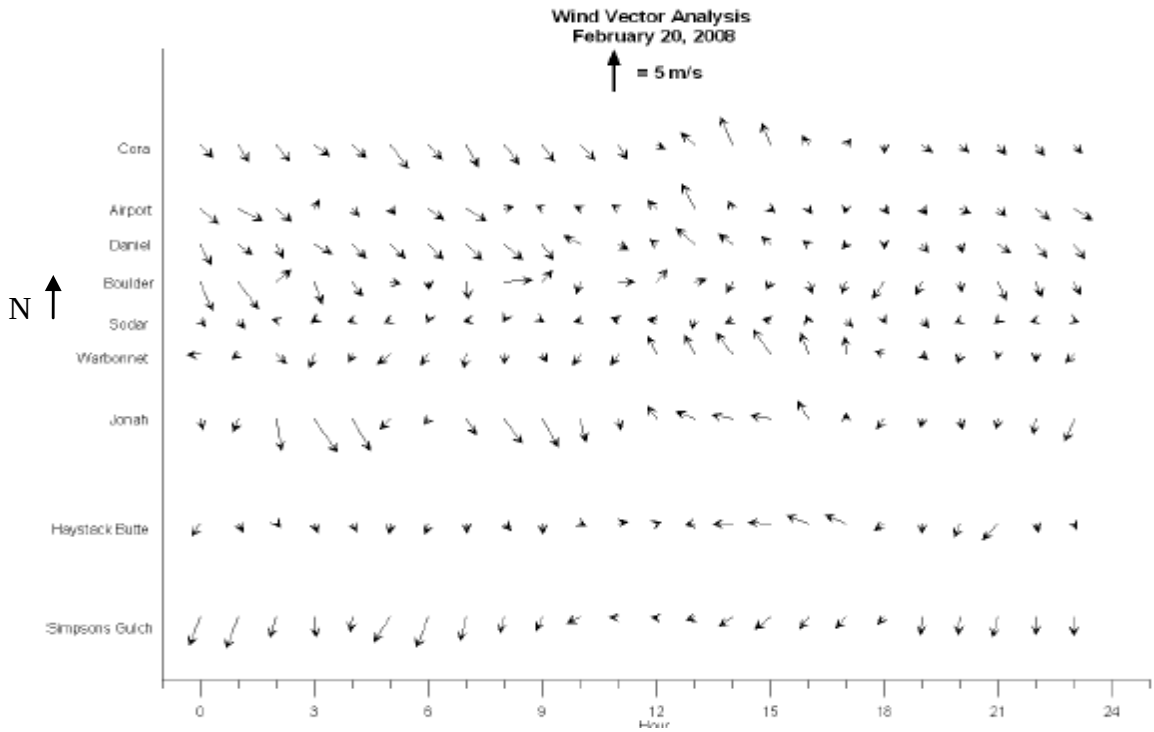


Figure S.7-6. Time-series showing February 20, 2008 hourly wind vectors for monitors used in 2008 field study monitoring network.

As shown in Figure S.7-6, winds in the UGRB are generally out of the northwest in the morning until about mid-day, at which point the flow has reversed with southeasterly winds, or at least southerly component winds are observed at most sites. This continues through the afternoon until 18:00 MST at which time the flow begins to switch back to the northwest, and by 6:00 MST the following morning, winds are northwest or northeast at nearly all of the monitoring sites. The switch from an overnight flow consisting of generally northwesterly or down slope winds, which last until approximately mid-day before reversing to a generally southeasterly wind flow pattern during the afternoon, was repeated on many of the 2008 ozone episode days.

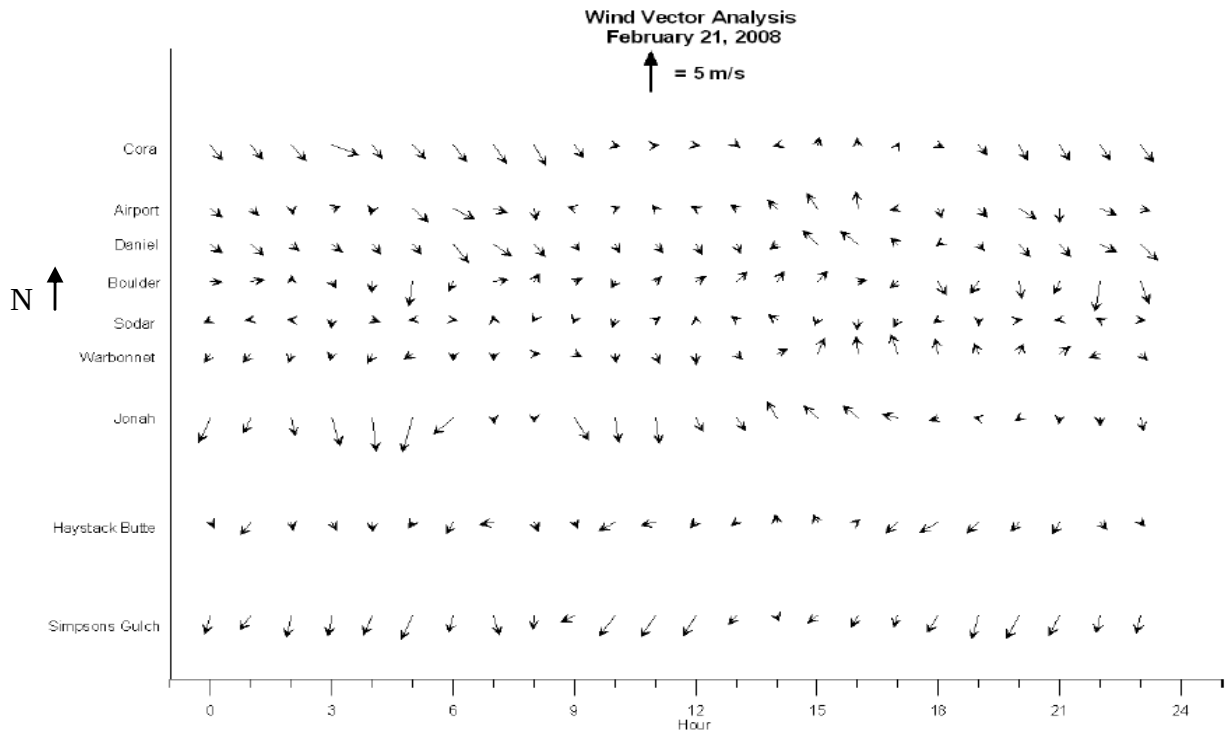


Figure S.7-7. Time-series showing February 21, 2008 hourly wind vectors for monitors used in 2008 field study monitoring network.

As shown in Figure S.7-7, winds on February 20th and 21st were generally light with variable directions throughout the monitoring network. There were two notable exceptions. After midnight, there was a general light northwest flow suggestive of a regional drainage pattern as colder, heavier air from the higher elevations flows downhill.

Generally stronger winds were measured at Jonah in the forenoon hours relative to the other sites in the network; this effect is also sometimes seen at Daniel and is likely due at least in part to the fact that winds at these two sites are measured on a standard 10 meter tower whereas the other sites made use of 3 meter high tripod mounted anemometers. During the afternoon, winds reversed at some sites, shifting to the southeast. This mid-day flow reversal is typical of high ozone days in the UGRB. On February 20, 2008, peak 8-hr ozone concentrations in the 70-85 ppb range were measured at sites throughout the study area; on February 21, 2008, the Boulder monitor recorded a 122 ppb 8-hr average ozone concentration. High ozone continued on February 22, 2008 with the Jonah monitor recording a daily maximum 8-hour average ozone concentration of 102 ppb. Minimal emissions transport and dispersion, due to the light winds in the UGRB, were characteristic throughout the February 19-23, 2008 ozone episode.

The South Daniel FRM monitor which is in the northwest portion of the recommended nonattainment area is typically upwind of local precursor sources and the Boulder monitor. On February 20 ambient nitrogen dioxide (NO_2) concentrations at the Daniel monitor were essentially equal to zero (0) ppb for all 24 hours; very low concentrations of VOCs were also measured in the VOC canister samples collected at Daniel on this day. Nearly identical values

were observed at the Daniel monitor and in the Daniel VOC canister samples obtained throughout the ozone episode (February 19-23, 2008); this was also the case during all three IOPs. The canister samples collected at the Daniel monitor in the 2007 field study also showed consistently low VOC concentrations. Additionally, monitored NOx concentrations recorded at Daniel have been very low since this site began operation nearly four years ago; the VOC canister data and the NOx monitoring conducted at Daniel clearly indicate the air coming into this area has low ozone precursor concentrations. Additionally, based on the 2008 field study data at the Daniel monitor, background ozone concentrations during the winter are typically in the 50 - 60 ppb range. Daily maximum 8-hour ozone concentrations at the Daniel monitoring site during the February 19-23, 2008 ozone episode ranged between 62-76 ppb.

One view of the surface wind direction-ozone relationship is shown on Figure S.7-8, which presents a wind rose using measurements from the Boulder monitoring site. This diagram is constructed using the daily peak 8-hr ozone level and 15:00 MST hourly averaged winds. These results show that high ozone levels were associated with afternoon winds from a variety of directions, reflecting the "light and variable" nature of the surface layer winds when the monitored 8-hour ozone levels were above 75 ppb, as opposed to 8-hour ozone concentrations that were less than 75 ppb, which tend to be associated with persistent higher wind speeds and the predominant northwest flow direction along the valley axis.

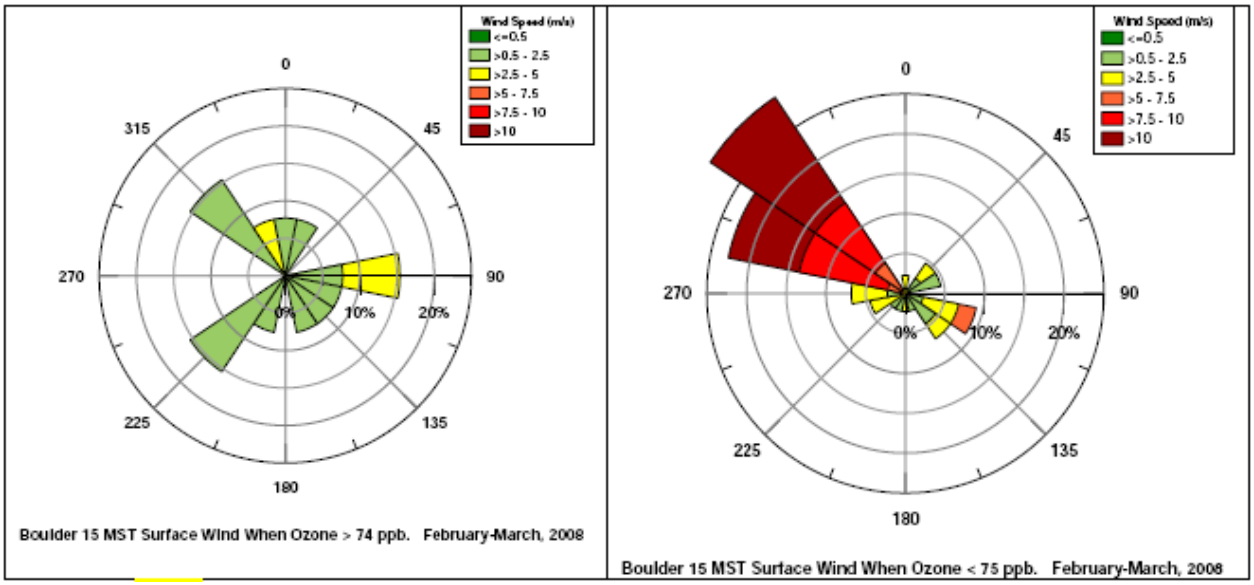


Figure S.7-8. Wind roses based on 15:00 (MST) data from the Boulder site for days with maximum 8-hour average ozone a) greater than 74 ppb (left) and b) less than 75 ppb (right).

Description of Conditions Aloft

A multi-level SODAR was operated continuously at a location approximately 3 miles southwest of the Boulder monitoring site during the 2008 field study. The SODAR provided two types of data: 1) vertical profiles of wind speed and wind direction at 10-meter increments up to 250 meters above ground level, and 2) information which allows an estimation of mixing height (mixed layer depth). The regular hourly observations during the 2008 field study were supplemented with high resolution measurements of vertical wind speed, wind direction, and temperatures during the IOPs. The hourly meteorological data capture rate was excellent. Comparing the measured wind data with peak 8-hour ozone concentrations at Boulder, a strong correlation between ozone concentrations and low mixed layer average wind speeds is evident. Looking at SODAR data on the afternoon of February 21, 2008, a day when 8-hour ozone concentrations above 75 ppb were noted throughout the field study area, reveals a top to the mixing layer at about 100 meters above ground level (AGL) representing a very shallow layer trapping ozone precursors and other pollutants in high concentrations near the surface.

Similar vertical profiles (soundings) and boundary layer development were measured by balloon-borne observations (ozone measurements, temperature, relative humidity and winds) on each of the high ozone days. Stable atmospheric conditions prevailed, and were characterized by strong low-level temperature inversions with very shallow mixing heights and light boundary-layer winds**.** Peak ozone concentrations were often observed somewhat above the surface but still within the stable inversion layer. As shown in Figure S.7-9, at low mixing heights (below 100 meters), the highest values of ozone were observed. Table S.7-2 provides a summary of the days with low-level capping inversions, and the measurements obtained, including the date and time of each balloon launch, the ground temperature and maximum inversion temperature (temperature at top of inversion layer), the difference between the maximum inversion temperature and the ground temperature (inversion layer Delta T), which reflects the strength of the temperature inversion. Note the highest inversion layer temperature measured is 14.5 (^{o}C) and occurs on February 19th.

Launch Date	Launch Time (MST)	Ground Temp (^oC)	Max Inversion Temp (^oC)	Inversion Layer ΔT (^oC)	Inversion Height (meters AGL)
2/18/08	11:00	-3.8	-3.2	0.6	150
2/18/08	16:00	-1.8	-1.7	0.1	47
2/19/08	7:00	-14.8	-0.3	14.5	489
2/19/08	1100	-8.1	1.3	9.4	442
2/19/08	13:00	-5.3	2.2	7.5	403
2/19/08	16:00	-4.5	1.8	6.3	445
2/20/08	7:00	-13.6	-2.4	11.2	398
2/20/08	1100	-13.9	-2.0	11.9	342
2/20/08	13:00	-7.7	-3.2	4.5	449
2/20/08	16:00	-5.4	-2.3	3.1	543
2/21/08	7:00	-17.4	-4.0	13.4	500
2/21/08	1100	-7.9	-3.0	4.9	405
2/21/08	13:00	-3.4	-2.6	0.8	373
2/21/08	16:00	-5.7	-2.9	2.8	494
2/27/08	8:00	-9.7	-1.4	8.3	670
2/27/08	1100	-5.4	0.1	5.5	711
2/27/08	13:00	-2.3	1.0	3.3	608
2/27/08	16:00	-1.2	0.7	1.9	527
2/28/08	8:00	-8.6	-2.3	6.3	149
2/28/08	1100	-1.4	-2.4	-1.0	265
2/28/08	13:00	1.8	0.0	-1.8	91
2/28/08	17:00	0.5	1.0	0.5	190
2/29/08	8:47	-6.2	-2.5	3.7	460
2/29/08	1100	-8.9	-0.3	8.6	396
2/29/08	13:00	-1.4	0.3	1.7	314
2/29/08	16:00	-0.3	1.5	1.8	470
3/10/08	8:00	-12.2	-5.8	6.4	470
3/10/08	1100	-7.6	-5.0	2.6	480
3/10/08	14:00	-1.6	-2.1	-0.5	312
3/10/08	17:00	-1.3	-2.0	-0.7	705
3/11/08	8:00	-13.1	1.3	14.4	373
3/11/08	1100	-2.4	1.5	3.9	312
3/11/08	13:00	2.1	2.0	-0.1	252
3/11/08	17:00	0.5	1.2	0.7	236
3/12/08	8:00	-9.3	-2.1	7.2	142
3/12/08	1100	2.3	2.5	0.2	90
3/12/08	15:00	3.5	-0.3	-3.8	261

Table S.7-2. Summary of low-level temperature measurements, and related data on inversion strength.

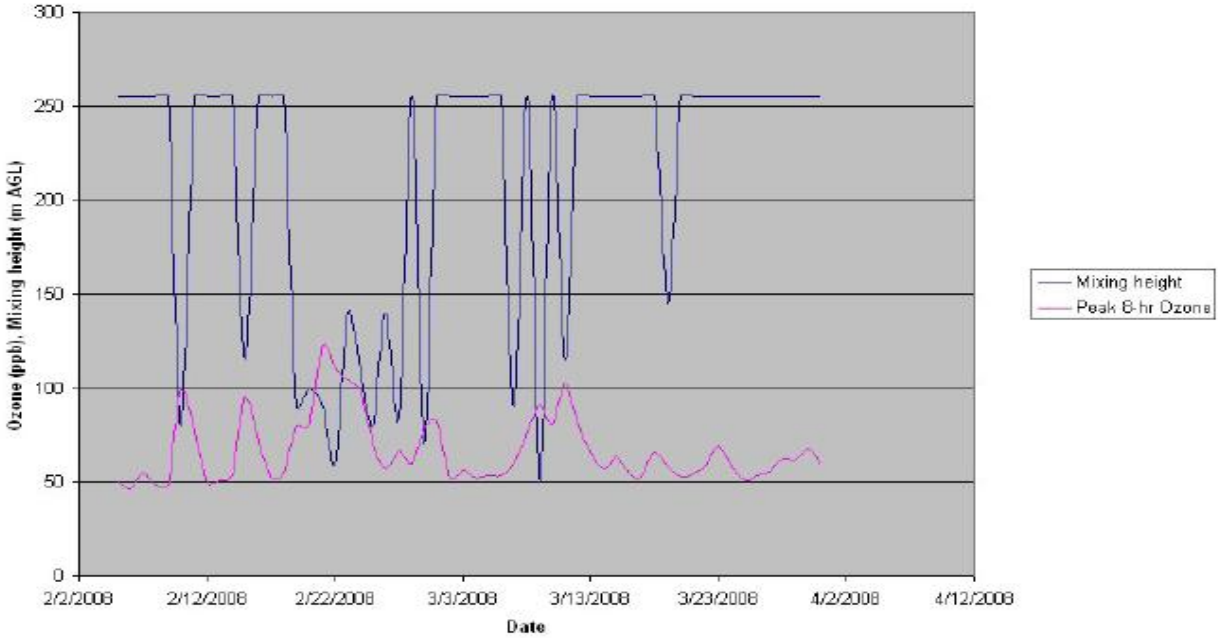


Figure S.7-9. SODAR-reported mixing height versus peak daily 8-hour ozone concentrations at Boulder. Measurements limited to below approximately 250 meters above ground level (AGL).

Soundings taken in the forenoon and afternoon of February 21, 2008 are shown in Figure S.7-10. Profiles for ozone (black line), temperature (red line), dew point temperature (dashed blue line) and winds (vectors) are plotted as functions of height above the ground elevation of the balloon launch site. A strong low-level inversion was present up to 2,500 meters-msl (~ 400 meters-agl) with a maximum temperature at the top of the inversion of -2.9 ^{o}C, several degrees warmer than the temperature at the surface. Boundary-layer winds in the forenoon were light from the west when ozone levels were ~50 ppb, before becoming southeast in the afternoon.

Figure S.7-10 shows the inversion is setting up in the morning of February 21, 2008, and that the inversion persisted through daylight hours, resulting in high ozone concentrations beneath the inversion. Figure S.7-10 also shows that at 11:00 (MST) ozone concentrations were ~ 50 ppb below the inversion height of 2,500 meters (MSL) which is shown by the green circle (left pane) towards the bottom of Figure S.7-10; measured ozone levels above the inversion layer were also generally ~ 50 ppb.

Normally, some vertical mixing of the air would exist, as the temperature aloft begins to fall off with increasing height above ground; however, the strong surface-based inversion persists to 4:00 pm, effectively inhibiting vertical mixing. A shallow layer of high ozone (> 110 ppb) was present in the afternoon (16:00 MST) sounding, which is shown by the green oval (right pane) towards the bottom of Figure S.7-10. Ozone concentrations decrease rapidly with height below the inversion; ozone levels above the inversion are about 50 ppb. Note that the vertical wind shear measured at the top of the inversion layer height above ground (wind arrows on the right side of graphs) attest to the complete decoupling of the boundary layer air from layers aloft.

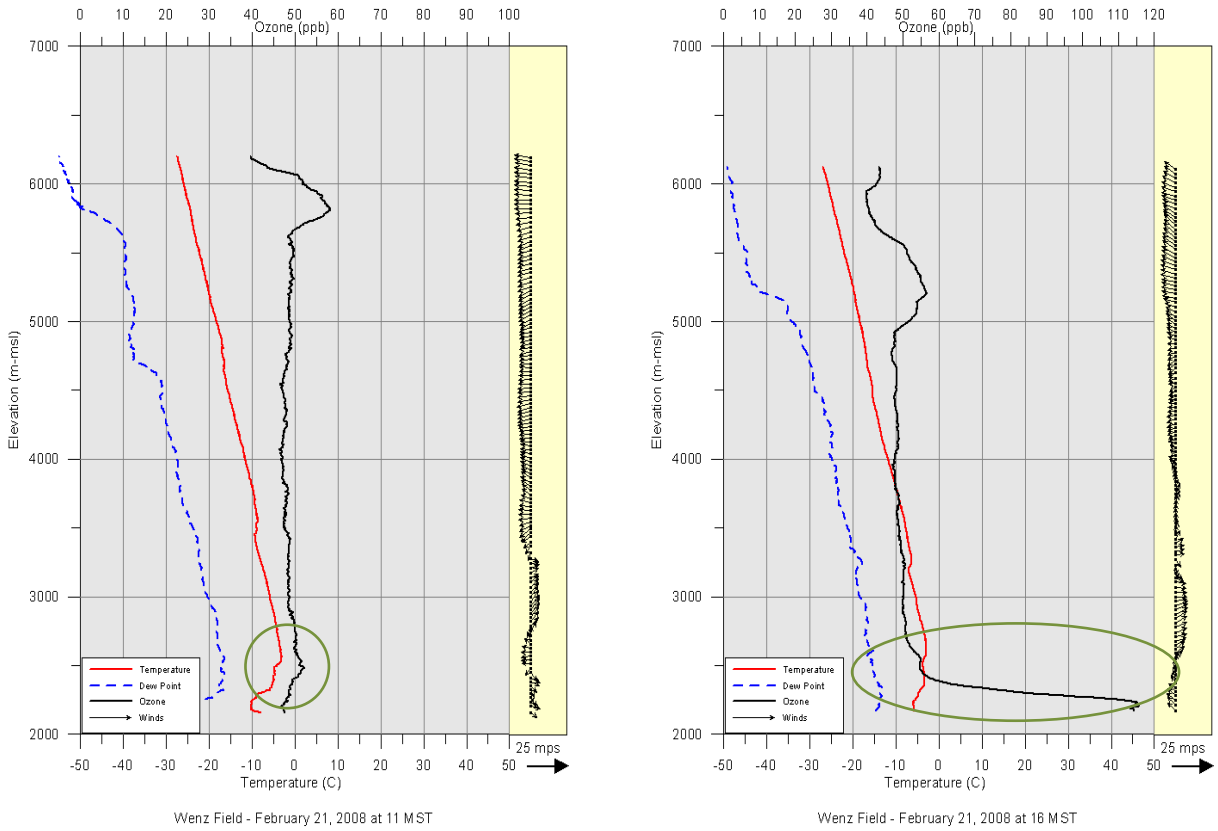


Figure S.7-10. February 21, 2008 balloon-borne soundings; Sounding at 11:00 (MST) (left); Sounding at 16:00 (MST) (right).

Tools to Evaluate Air Parcel Transport: HYSPLIT vs. AQplot Back Trajectory Analyses

Trajectory analyses were used to determine possible air parcel transport into the UGRB during February 20, 2008, as a means of evaluating possible precursor emissions and ozone transport in the UGRB and at the Boulder and Jonah monitors.

The HYSPLIT (HYbrid Single-Particle LaGrangian Integrated Trajectory) model is a trajectory model that is used for computing simple air parcel trajectories. HYSPLIT can use meteorological data from several archived meteorological modeling databases, including the NCEP Eta Data Assimilation System (EDAS), which is based on a 40 kilometer resolution data (2004-present). However, 40 kilometer (km) data may not provide sufficient resolution to resolve the significant terrain features that influence the wind flow patterns in the UGRB. The result of using such low resolution data to represent the terrain features in and surrounding the UGRB will be that the modeled terrain will be much smoother, and will not match the actual terrain (see Figure S.7-11). This will affect the wind trajectory analysis because the roughness of the terrain as well as terrain blocking and channeling effects may not be well represented, which would otherwise influence the wind speeds and the trajectory path lengths. In very complex terrain, such as in the UGRB, the HYSPLIT model trajectories may not be very accurate unless the local wind flow patterns are being driven by the large-scale synoptic conditions (e.g., strong winds).

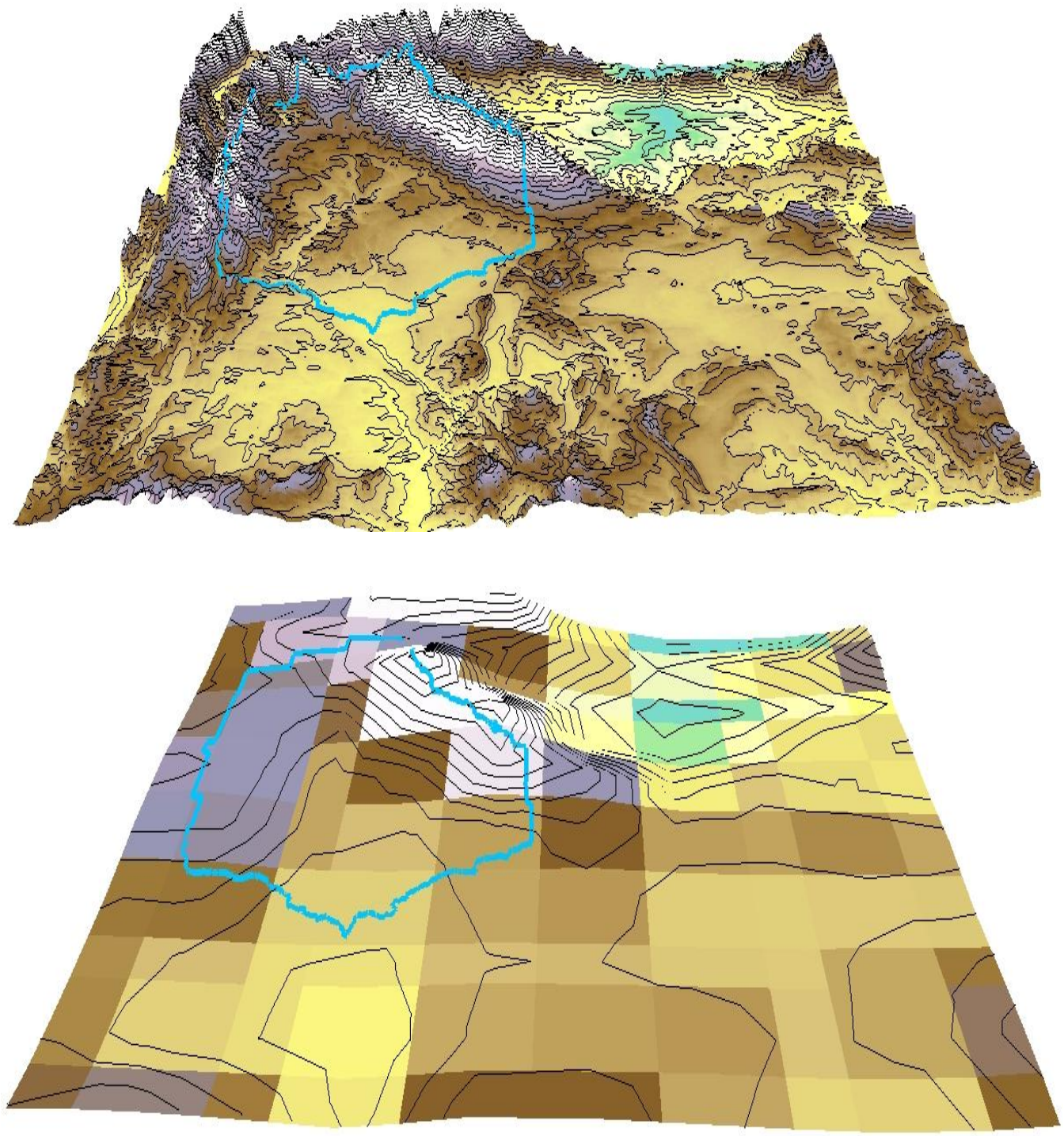


Figure S.7-11. A comparison of the local terrain features at 1 km and 40 km resolution, respectively, and the resulting "smoothed" terrain as shown in the 40 km 3-D topographic plot.

Figure S.7-12 shows a similar comparison of the local terrain features at 1 km and 40 km resolution as depicted in the 2-dimensional contour plots. Note the terrain features in the bottom pane are much less resolved (less terrain detail and decreased roughness) than those terrain features as shown in the top pane.

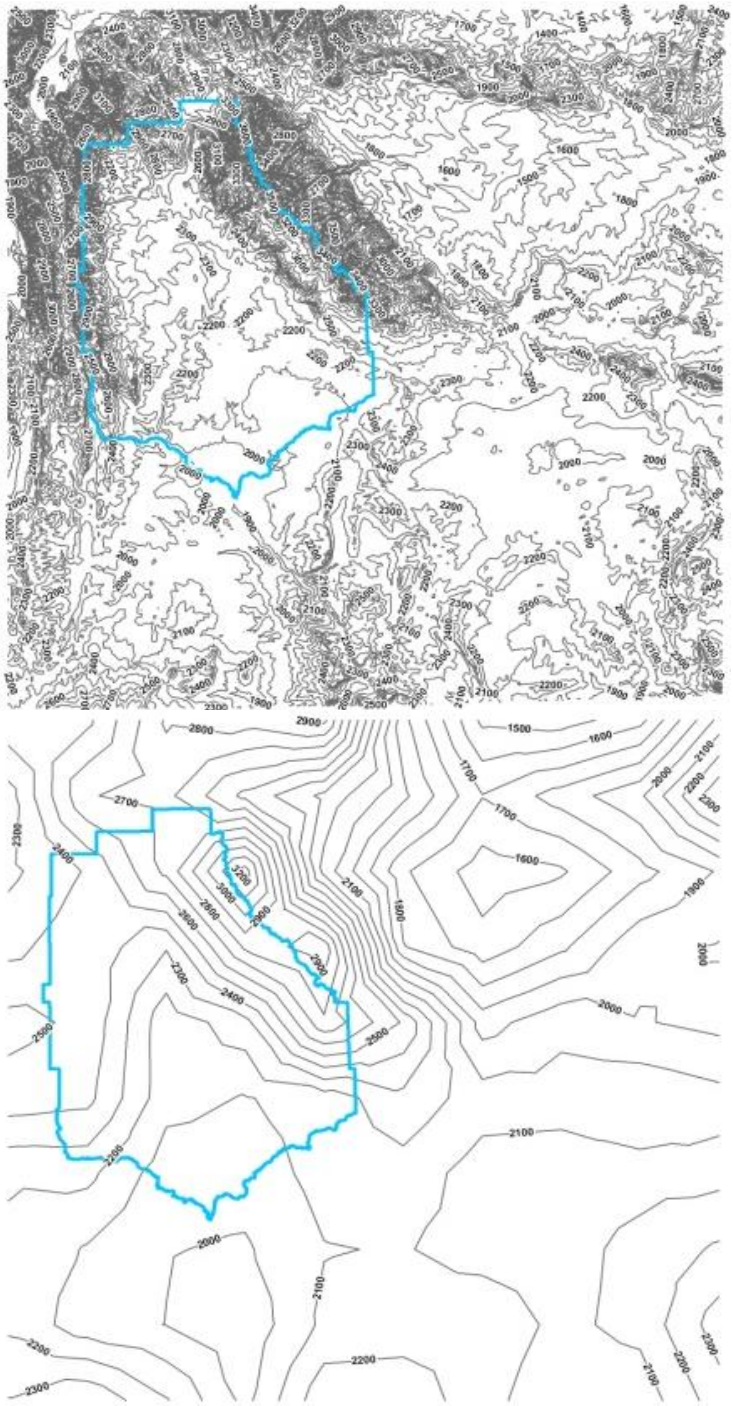


Figure S.7-12. A comparison of the local terrain features at 1 km and 40 km resolution, respectively, as depicted in the 2-D contour plots.

While the trajectory model is a useful tool in assessing approximate air parcel movement, and can be used to better understand potential pathways for pollutants moving within and into and out of the UGRB, trajectories are a highly simplified representation of the complex, two- and three-dimensional transport and turbulent diffusion processes that move pollutants from place to place. Thus, a particular trajectory path is subject to uncertainty and should not be interpreted as an exact representation of actual pollutant transport. Generally, the longer an air mass is tracked forward or backward in time, the more uncertain is its position (Kuo et al., 1985; Rolph and Draxler, 1990; Kahl and Samson, 1986).

Additionally, the trajectory model error is a function of the complexity of the meteorological scenario under study. In this analysis, the strong surface-based inversion layer in place on February 19-22, 2008 results in a decoupling of the upper air layers (above the inversion layer) and the lower air layers (below the inversion) and winds in the upper and lower layers will at times blow in different directions at different speeds. Winds are light and variable in the lower layer, adding to the complexity of the situation. This very complex meteorological scenario is difficult to represent accurately in a trajectory model.

AQD ran a comparison of 12-hour back trajectories from the Jonah and Boulder monitoring sites, using the HYSPLIT model with the EDAS 40 kilometer meteorological data, and AQplot, (a 2-dimensional trajectory model) using actual meteorological data from the Jonah and Boulder monitoring sites, respectively. This comparison shows that much different back trajectories are produced by these two models, as shown in Figures S.7-13 and S.7-14. The 2-dimensional trajectory model (AQplot), used in these analyses, was developed by the Texas Commission on Environmental Quality.

Additional trajectory analyses using a 3-D trajectory model are discussed in the next section. However, for this particular comparison, a 2-D trajectory model is an acceptable model to assess trajectories near the monitoring sites because the surface winds in the UGRB under these episodic winter conditions have been effectively decoupled from the upper air layers. The amount of vertical air movement is limited due to the capping inversion in place – in other words, the movement of air parcels below the inversion is not influenced by winds above the inversion, and there is little vertical mixing of air near the ground. Monitoring data of the localized meteorological patterns in the proposed nonattainment area boundary show that under these episodic conditions, the wind patterns are 2-dimensional, and the use of the 2-D AQplot trajectory model for this particular application is reasonable under these winter meteorological conditions (inversion, low mixing height, and stable atmosphere) as the air parcel trajectories start off and tend to stay close to the ground.

As shown in Figures S.7-13 and S.7-14, the resulting short trajectories never get very far away from the monitor site; considering the short duration of the trajectory analysis, less interpolation error would be expected. The HYSPLIT model does not consider the wind influences as measured in the 2008 field study surface monitoring network; the AQplot local-scale back trajectories are a more accurate depiction of what is going on because of the input of local data.

- **Trajectories ending 14:00 MST at Boulder on 20 February 2008**
- **Markers at 1-hour intervals; 12 hours total**
- **Very light, meandering surface winds at Boulder not reproduced by EDAS 40 km data set**

Figure S.7-13. Comparison of HYSPLIT (red) and AQplot (pink) 12-hour back trajectories from the Boulder monitoring site on February 20, 2008.

- **Regional-scale model: HY-SPLIT back trajectories using 40 km resolution EDAS**
- **Local scale: UGWOS '08 surface wind data (markers at 1-hour intervals)**

- **20 February 2008: 14:00 MST surface back trajectory from Jonah**
- **Markers at 1-hour intervals; 12 hours total**

Figure S.7-14. Comparison of HYSPLIT (red) and AQplot (green) 12-hour back trajectories from the Jonah monitoring site on February 20, 2008.

This comparison demonstrates that the HYSPLIT model overestimates the back trajectory path length because the localized low wind speed conditions and the wind flow reversal are not reproduced in 40 kilometer EDAS meteorological analysis fields. Additionally, the HYSPLIT model trajectory shows a less dramatic shift in wind direction and much higher wind speeds leading to a completely different result. A trajectory model that accurately reflects the terrain influence, sustained low wind speeds, and local-scale observed wind flow patterns was needed to effectively evaluate air parcel transport throughout the UGRB under these episodic conditions.

AQplot Back Trajectory Analysis

Back trajectories using the AQplot model and the meteorological data collected during the field study on February 20, 2008 are shown in Figure S.7-15; the trajectories were used to evaluate air parcel movement near the monitors during the 12 hours leading up to the February 20, 2008 monitored high ozone concentrations. These back trajectories start at 2:00 pm (MST), and show that the wind patterns leading up to the afternoon high monitored ozone concentrations at the Boulder monitoring site (and other monitors in close proximity to the Boulder monitor) produce short trajectories, with the air parcels remaining in close proximity to these monitors during this 12-hour period, due to the observed low wind speeds and recirculation patterns (wind reversals).

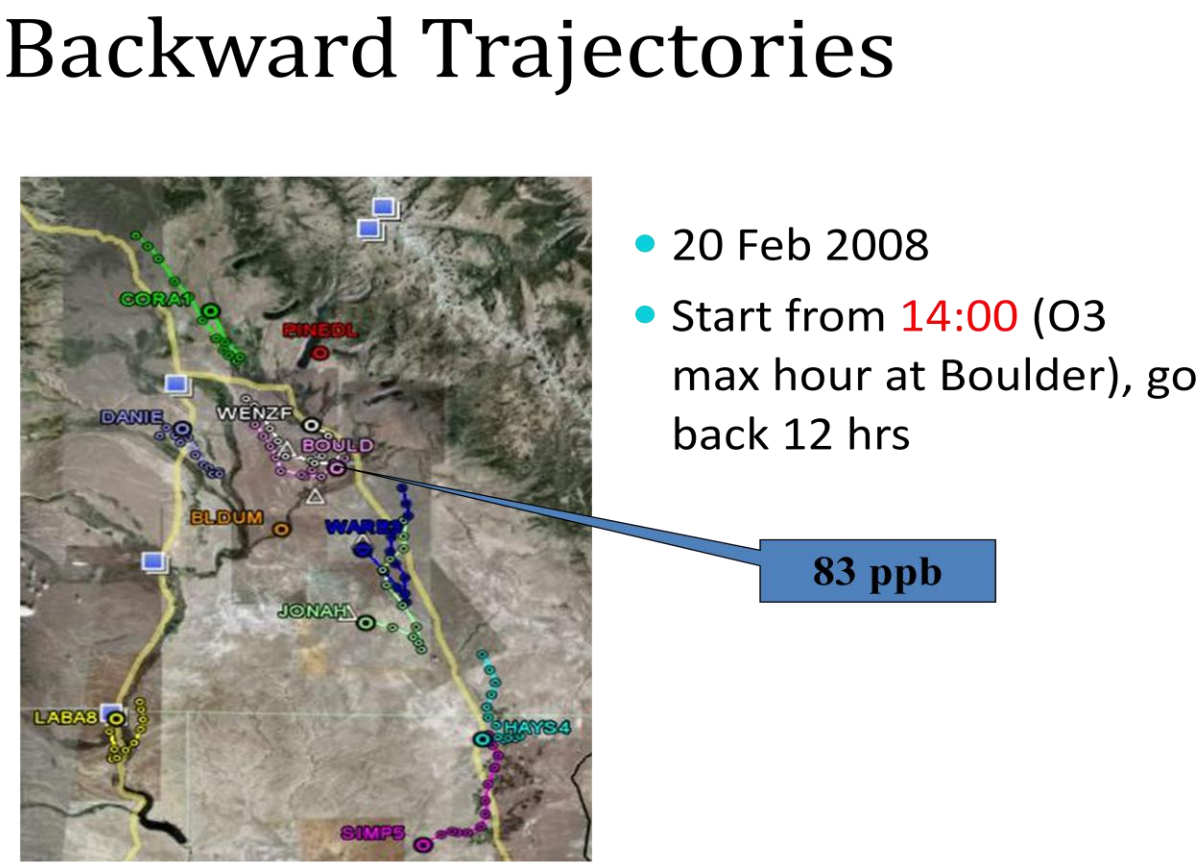


Figure S.7-15. 12-hour back trajectories near field study monitors on February 20, 2008.

Due to the complexity of the winds in the UGRB during February 19-23, 2008, including the significant terrain-dominated effects on localized winds, stable conditions, and wind flow reversals, as discussed, and the terrain-dominated regional meteorology outside of the UGRB, a high resolution 3-dimensional (3-D) wind field was needed that could correctly reproduce:

1) Shallow inversions and near-field wind flow patterns as measured at the SODAR, which is near the Boulder monitor; and
2) Regional-scale wind flow patterns.

This particular wind field would be utilized in conjunction with a full 3-D trajectory model to evaluate:

1) Air parcel movement in the study area;
2) Influences from the surrounding regional terrain on air parcel movement;
3) Air parcel inflow (ozone or precursor emissions transport) into Sublette County on the days leading up to and during the February 19-23, 2008 ozone episode.

AQD contracted out the development of a 3-D CALMET wind field to evaluate the above, which is discussed in the following section.

CalDESK Trajectory Analysis

AQD developed a high resolution (spatial and temporal) 3-dimensional wind field that uses the National Center for Environmental Prediction (NCEP) Rapid Update Cycle (RUC) model at 20 kilometer resolution, coupled with the high resolution observational database of surface and upper air meteorological data measurements obtained during the 2008 field study. It should be noted that the terrain elevation data used in this wind field is based on much higher terrain resolution than is currently used in the HYSPLIT model. The RUC and field meteorological data were processed through the CALMET diagnostic wind model to generate a 1 kilometer gridded wind field, using high resolution terrain and land use/land cover data, and actual observations of daily snow cover to account for actual snow cover (and albedo effects) within the CALMET domain. The complexity of the terrain, as represented in this 3-dimensional (3-D) CALMET wind field in shown in Figure S.7-16.

This CALMET wind field was developed to evaluate the ozone episode-specific meteorology associated with the February 18-23, 2008 ozone episode. The CALMET domain was set up using the same meteorological modeling domain (464 km x 400 km) developed for the Southwest Wyoming Technical Air Forum (SWWYTAF) modeling analyses (1999), with increased vertical resolution to total 14 vertical layers; the lower layers having small vertical depths in order to better resolve complex flow patterns and temperature inversions near the surface.

Figure S.7-17 provides a snapshot of the wind field based on the winds at 4:00 am (MST) on February 20, 2008, and shows the complexity of the terrain surrounding the UGRB is very well represented in the CALMET wind field. The wind field captures the strong terrain-dominated down slope winds during the early morning hours, and the strong channeling and drainage effects which are exhibited throughout the UGRB – CALMET “sees” the influence of the terrain.

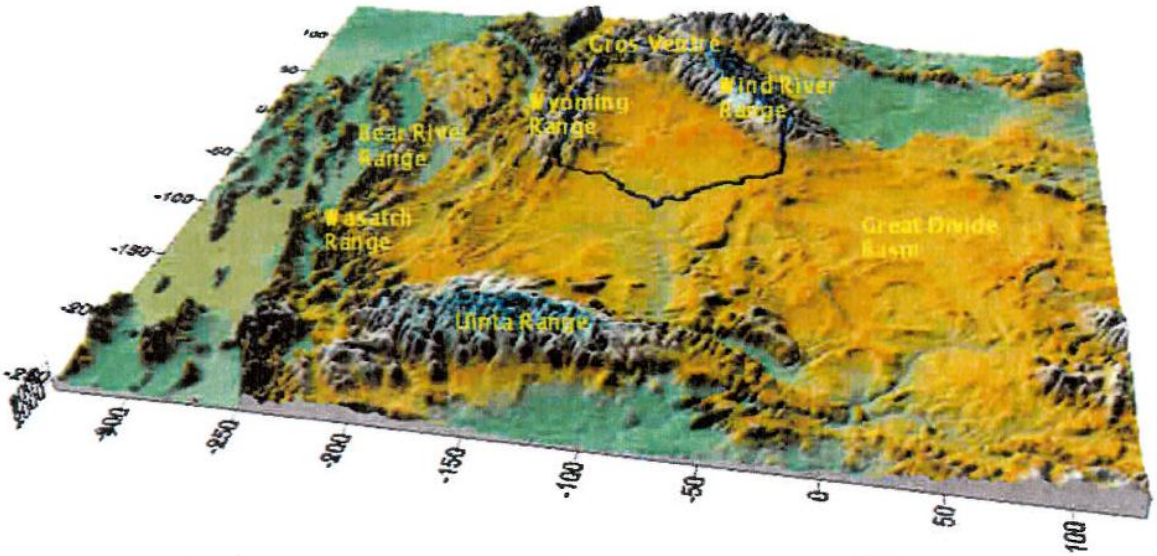


Figure S.7-16. Terrain features in CALMET modeling domain (464 km x 400 km).

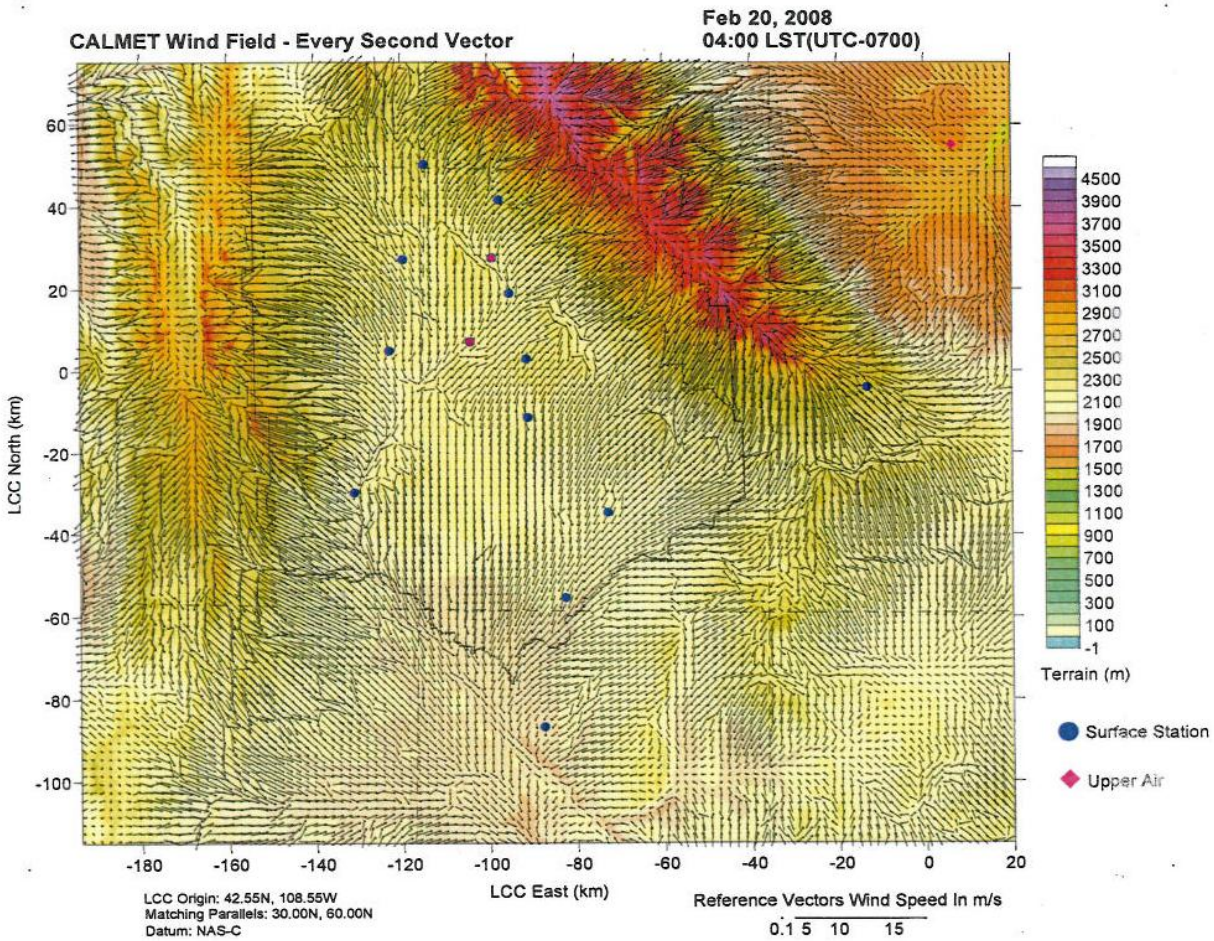


Figure S.7-17. CALMET wind field at 4:00 am (MST) on February 20, 2008. The 2008 field study meteorological monitoring sites are shown for reference.

The 3-D CALMET wind field accurately depicts meteorological conditions in the UGRB and surrounding area. A detailed report discussing the development of the CALMET wind field and the validation of the wind field compared to observations, entitled, "Upper Green River Winter Ozone Study: CALMET Database Development Phase I" will be posted on the DEQ web site and will be sent under separate cover to EPA shortly. Validation of this wind field has shown that the local-scale observed meteorological conditions are being reproduced:

- Temperature lapse rates associated with inversion conditions and low mixing heights
- Wind speeds and wind reversals
- Duration of down slope winds, which last until approximately mid-day before reversing to a generally southeasterly wind flow pattern

The trajectory analyses using this wind field lead to the conclusion that regional transport is insignificant, and local-scale precursor emissions transport is the dominant means of precursor transport during the high ozone periods. The trajectory analyses that follow were a key factor in selection of an appropriate southern boundary of the nonattainment area. The trajectory analyses demonstrate that the proposed southern boundary of the nonattainment area is reasonable, and that there is no significant contribution of ozone or ozone precursors from areas or sources outside the proposed nonattainment area during elevated ozone events.

Specific Examples of Trajectory Analyses Using CalDESK

Based on this wind field, AQD used the CalDESK visualization software to run forward trajectory analyses to evaluate air parcel transport into and out of the UGRB, specifically with respect to air parcels from large stationary sources (power plants and Trona plants) located to the south of the UGRB, and to evaluate the southern extent of air parcel inflow into the UGRB. A series of CalDESK forward trajectory analyses follow, along with a brief discussion of the resulting trajectories generated by CalDESK during February 18-23, 2008. CalDESK Forward Trajectory Analyses (FTA) for February 18, 2008 are shown in Figures S.7-18 through S.7-22.

NOTE: Trajectory figures (Figures S.7-18 through S.7- 49) are being updated to show the proposed nonattainment area boundary. Those figures will be available shortly. AQD will send those figure to EPA as replacement pages.

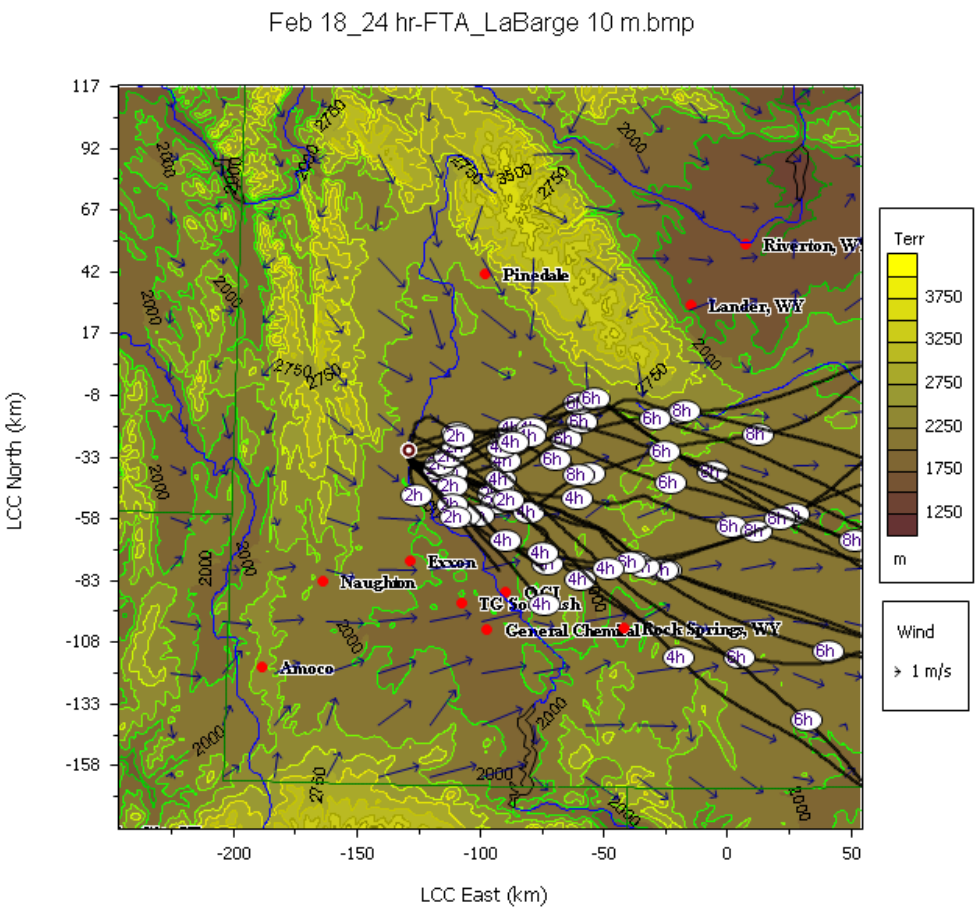


Figure S.7-18. 24-hour forward trajectory analysis at LaBarge, Wyoming on February 18, 2008.

As shown in Figures S.7-18 through S.7-22, the prevailing northwest winds within the UGRB on this day limit air parcel transport into the UGRB from sources located south of Sublette County, which is reflected in the trajectory analysis for the LaBarge and Moxa Arch areas, the Naughton power plant, the OCI Trona processing facility, and the Bridger power plant. Additionally, the wind speeds at the monitoring sites on the Pinedale Anticline were also generally high and reflect the prevailing northwest winds typical of the study area during most of the year. This moderately strong, organized northwest flow does not extend to the field study southern monitoring sites (Haystack Butte and Simpsons Gulch); these southern monitoring sites experienced a generally westerly wind. The 2008 field study monitoring sites are shown in Figure S.7-1.

Wind speeds were generally high throughout the monitoring network on February 18th. These conditions continued throughout the night until the early morning of February 19th. Winds decreased significantly thereafter becoming light and variable for the remainder of the day, setting the stage for the next several days. Ozone levels were relatively low, in the 50 ppb range on February 18th; increasing on February 19th, with both the Boulder and Jonah monitoring sites experiencing 8-hr peaks of 80 ppb.

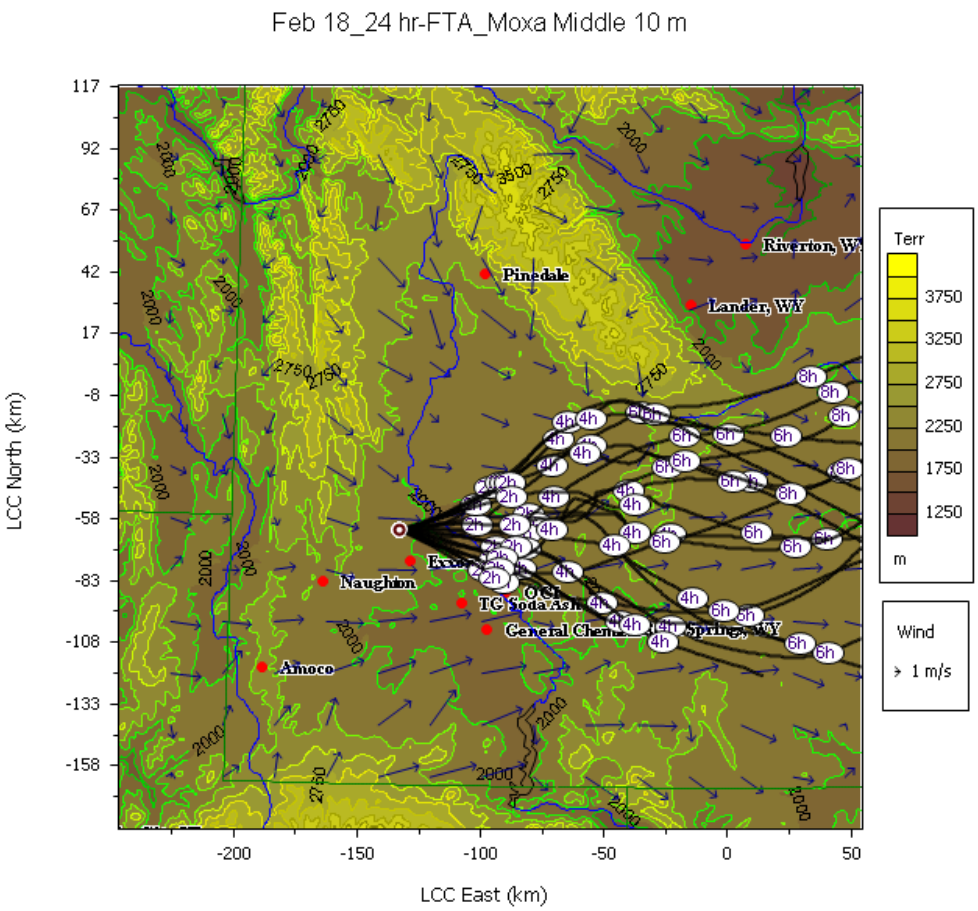


Figure S.7-19. 24-hour forward trajectory analysis in the Moxa Arch area on February 18, 2008.

The trajectory analysis shown in Figure S.7-19 places the initial air parcel release point in the northern part of the Moxa Arch field. The predominant paths shown trend to the east, and there is a slight northerly component to several of the modeled trajectories. These trajectories generally parallel the southern boundary of the proposed nonattainment area along Pacific Creek. While some of the trajectory paths lie within the proposed nonattainment area, none of the paths indicate that sources within the Moxa Arch cause or contribute to elevated ozone levels within the proposed nonattainment area.

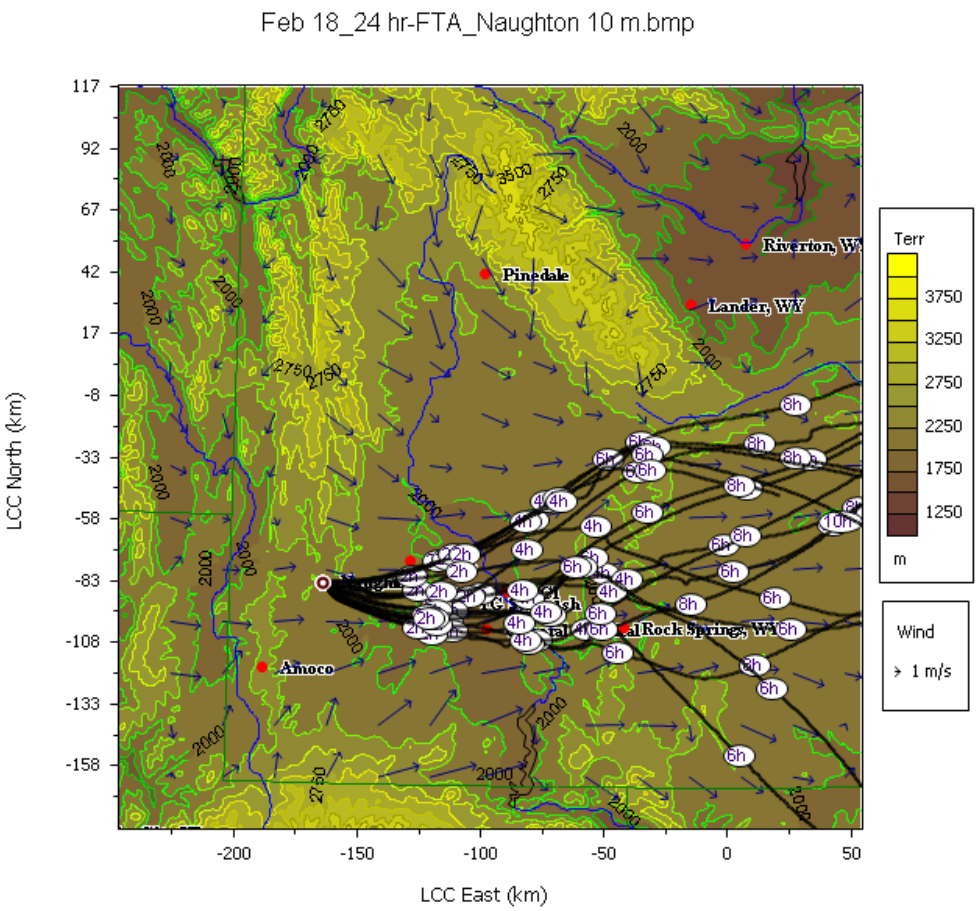


Figure S.7-20. 24-hour forward trajectory analysis at Naughton power plant on February 18, 2008.

The trajectory analysis in Figure S.7-20 shows all modeled trajectories from Naughton not entering the proposed nonattainment area.

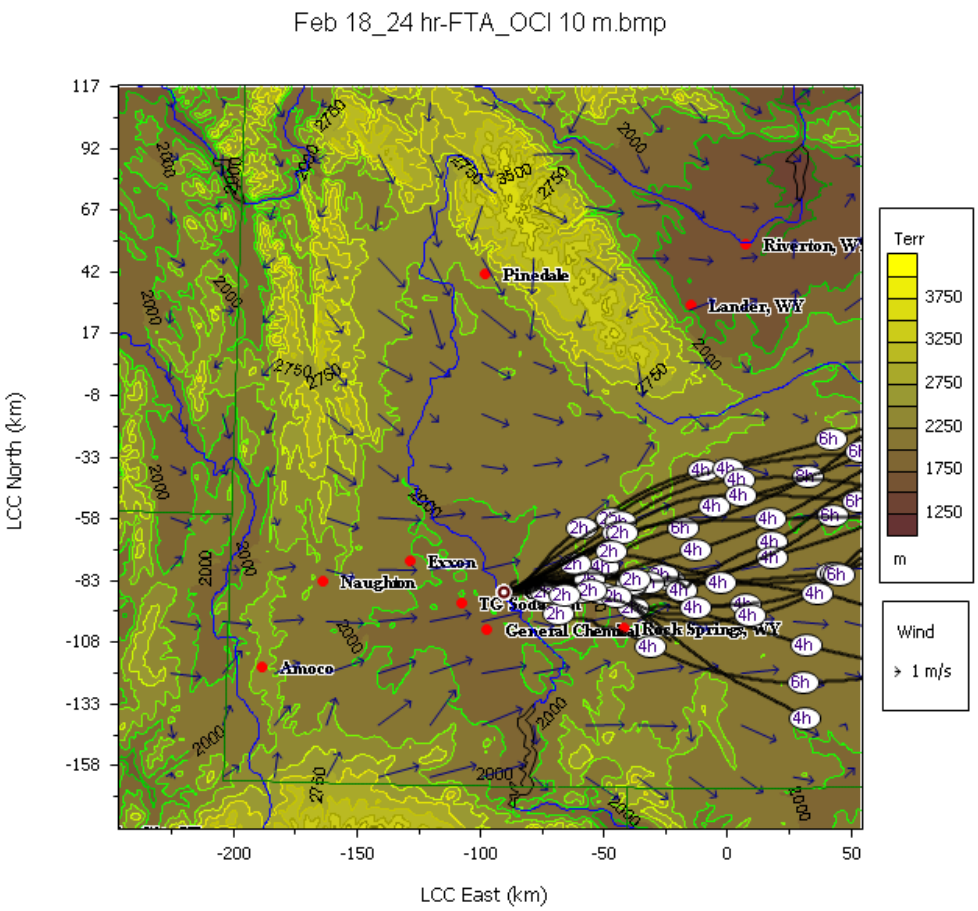


Figure S.7-21. 24-hour forward trajectory analysis at OCI Trona plant on February 18, 2008.

The trajectory analysis in Figure S.7-21 shows all modeled trajectories from OCI not entering the proposed nonattainment area.

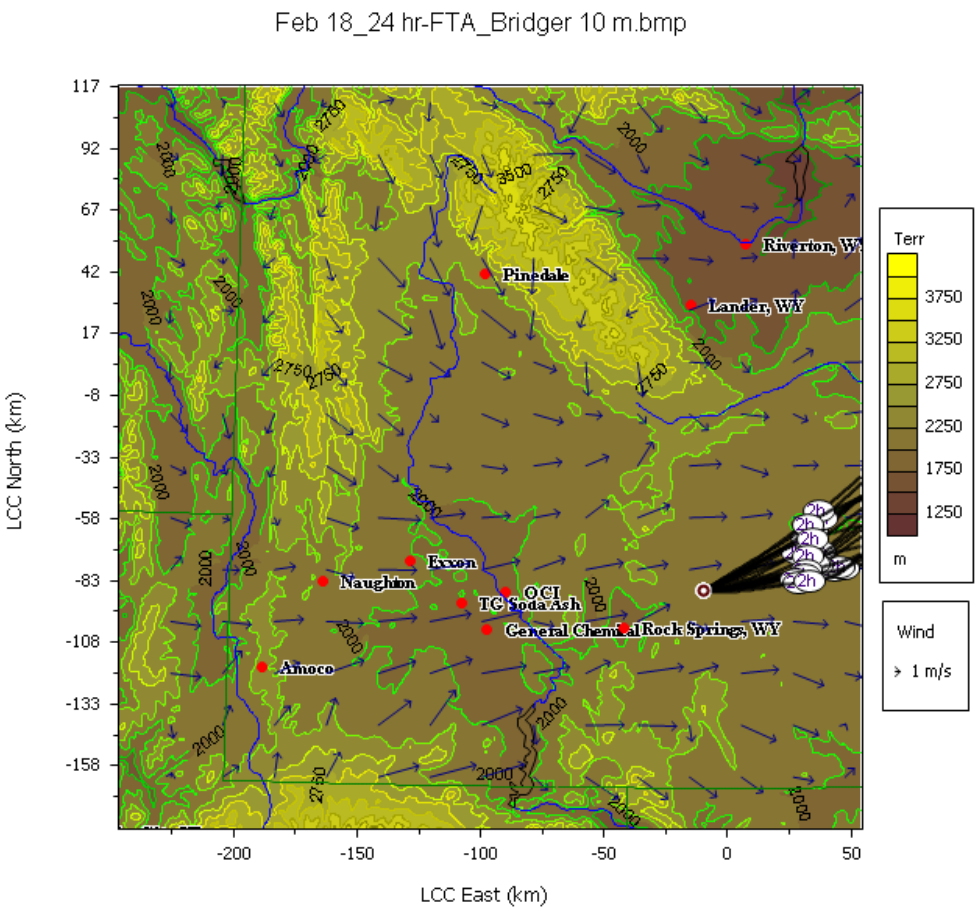


Figure S.7-22. 24-hour forward trajectory analysis at Bridger power plant on February 18, 2008.

The trajectory analysis in Figure S.7-22 shows all modeled trajectories from Bridger not entering the proposed nonattainment area.

CalDESK Forward Trajectory Analyses for February 19, 2008 are shown in Figures S.7-23 through S.7-29.

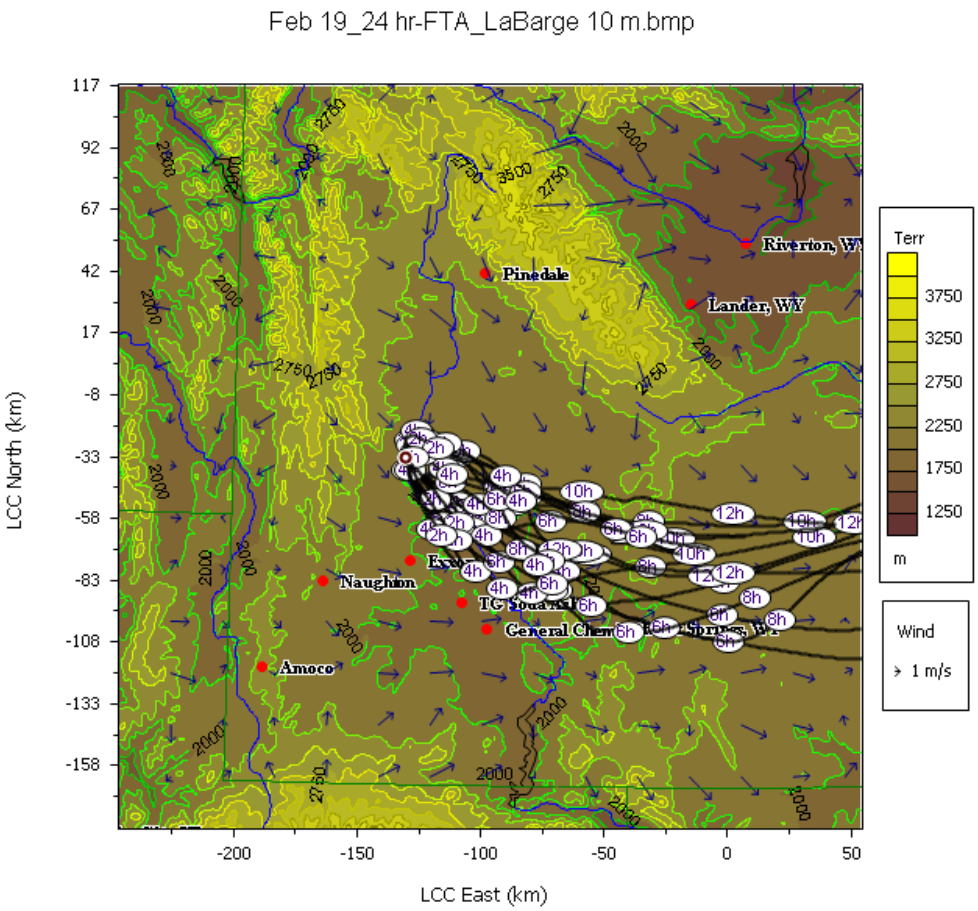


Figure S.7-23. 24-hour forward trajectory analysis at LaBarge, Wyoming on February 19, 2008.

As shown in Figures S.7-23 through S.7-27, the prevailing northwest winds on February 19th continue to limit air parcel transport into the UGRB from the south, which is reflected in the trajectory analysis for the LaBarge and Moxa Arch areas, the Naughton power plant, the OCI Trona processing facility, and the Bridger power plant.

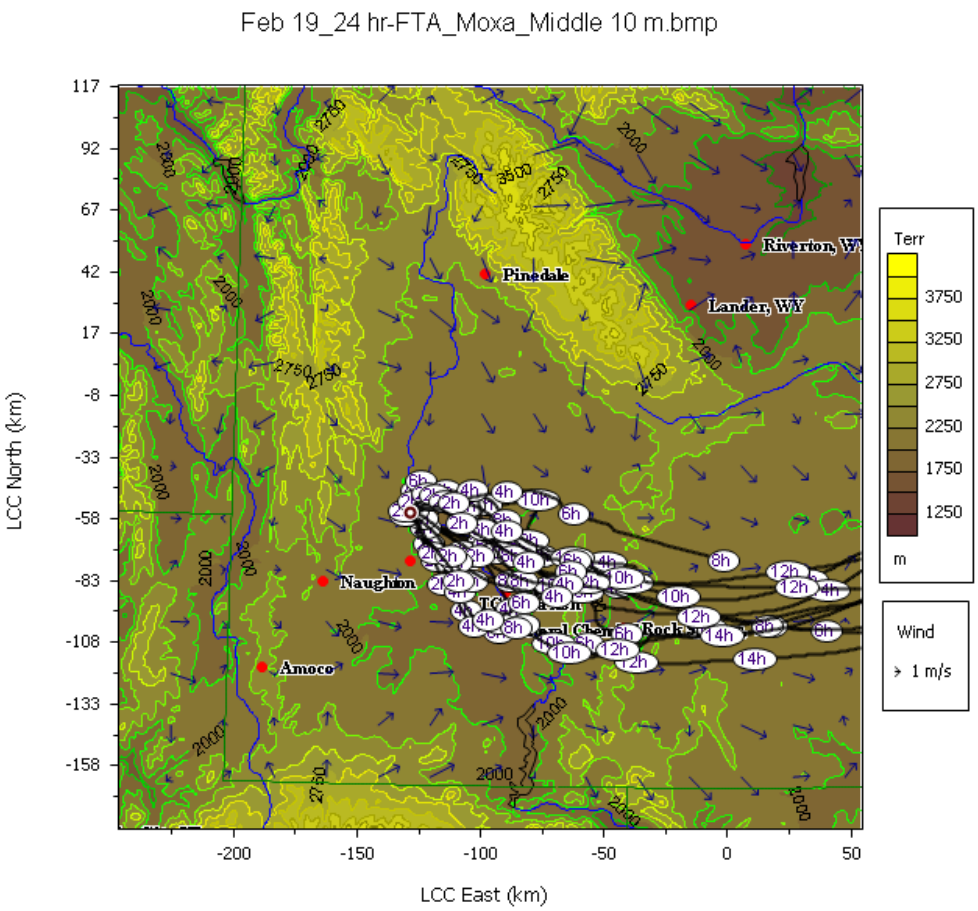


Figure S.7-24. 24-hour forward trajectory analysis in the Moxa Arch area on February 19, 2008.

The trajectory analysis in Figure S.7-24 shows all modeled trajectories from Moxa Arch not entering the proposed nonattainment area.

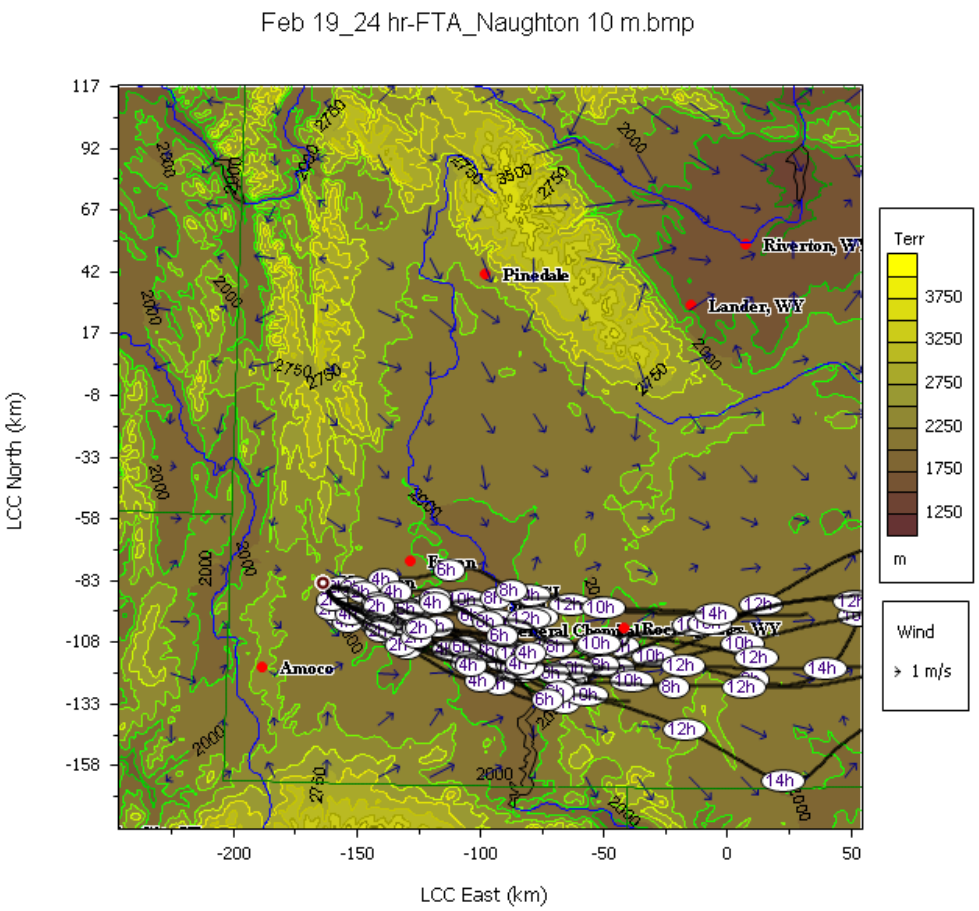


Figure S.7-25. 24-hour forward trajectory analysis at Naughton power plant on February 19, 2008.

The trajectory analysis in Figure S.7-25 shows all modeled trajectories from Naughton not entering the proposed nonattainment area.

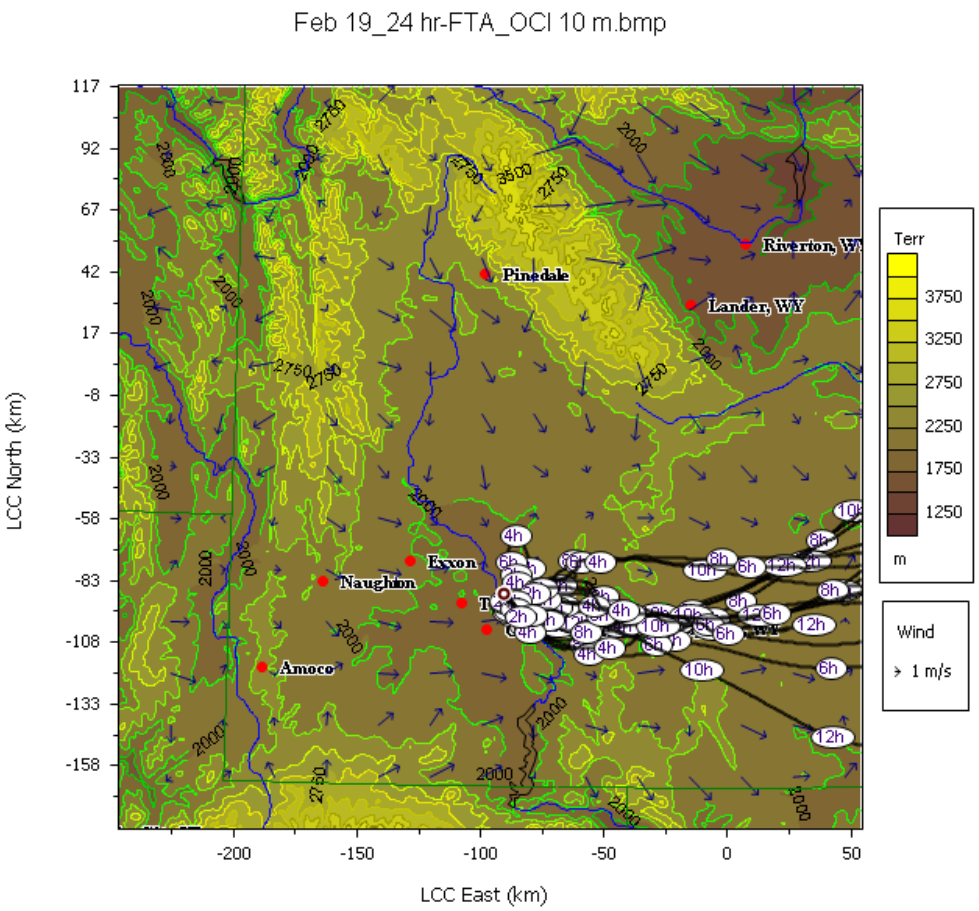


Figure S.7-26. 24-hour forward trajectory analysis at OCI Trona plant on February 19, 2008.

The trajectory analysis in Figure S.7-26 shows all modeled trajectories from OCI not entering the proposed nonattainment area.

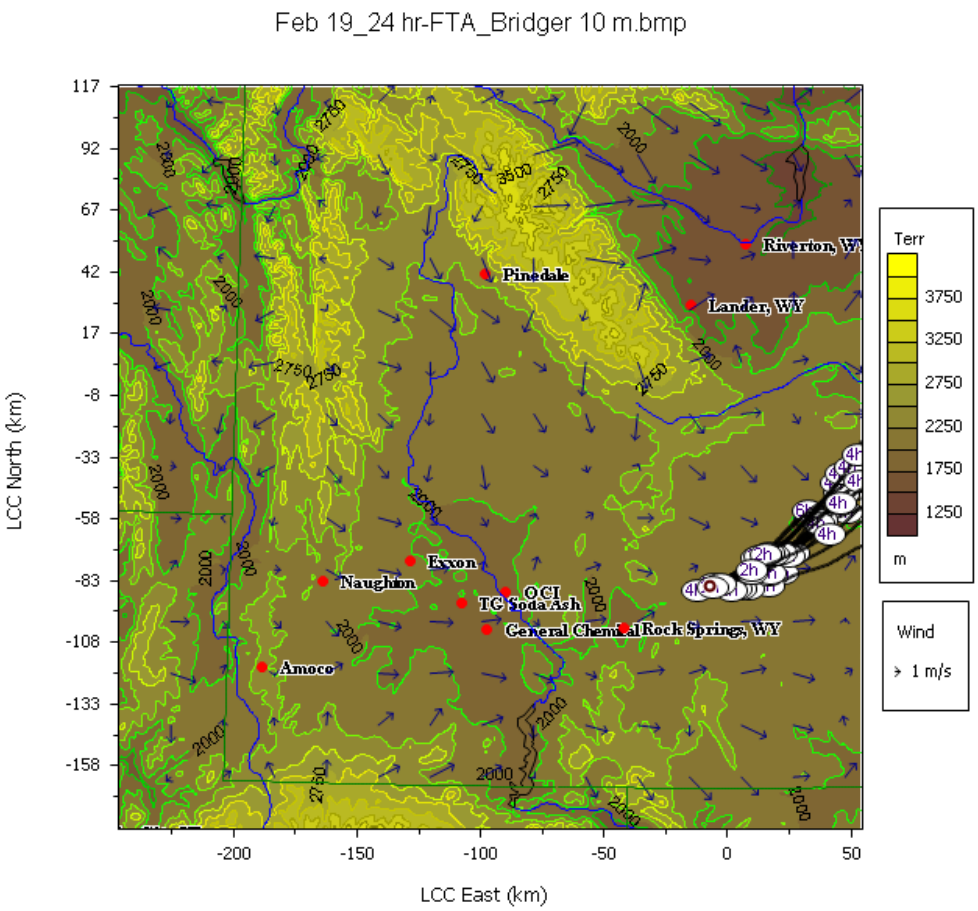


Figure S.7-27. 24-hour forward trajectory analysis at Bridger power plant on February 19, 2008.

The trajectory analysis in Figure S.7-27 shows all modeled trajectories from Bridger not entering the proposed nonattainment area.

CalDESK Forward Trajectory Analyses for February 20, 2008 are shown in Figures S.7-28 through S.7-32.

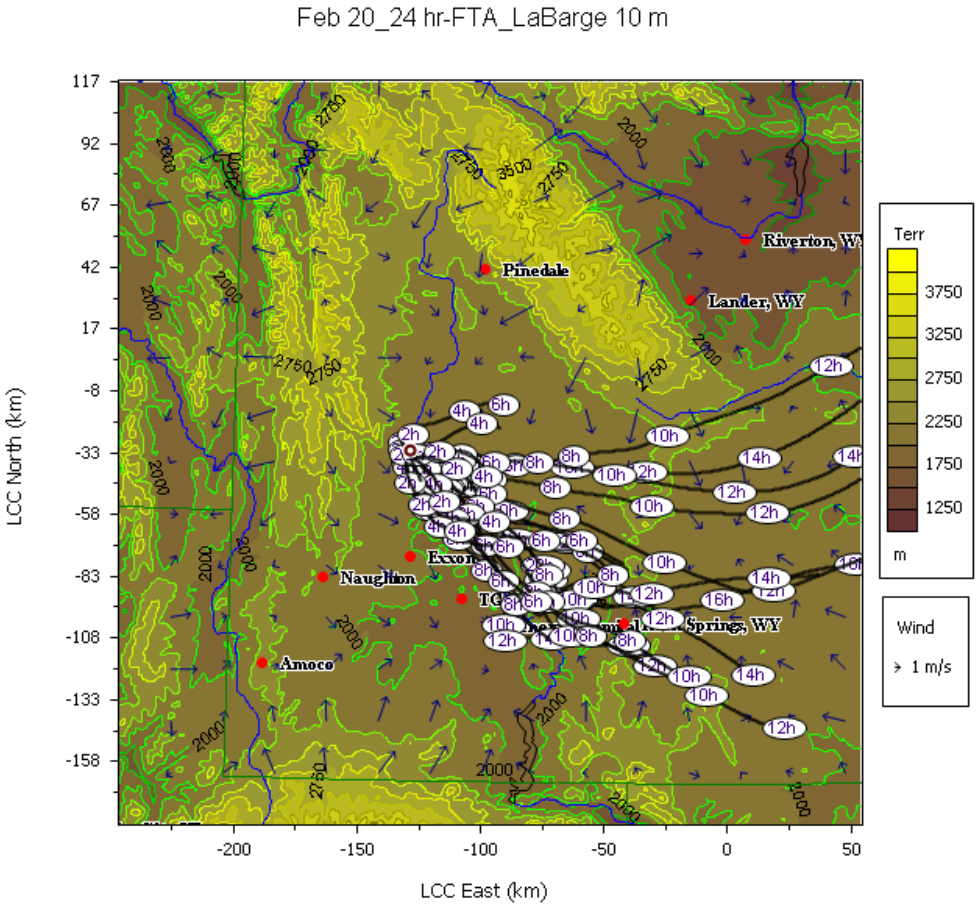


Figure S.7-28. 24-hour forward trajectory analysis at LaBarge, Wyoming on February 20, 2008.

As shown in Figure S.7-28, on February 20, 2008, the trajectory analysis for the LaBarge area begins to exhibit a few possible trajectory paths into the area west of the Jonah oil and gas field, indicating some potential for upwind emissions transport at the Jonah monitor. Figures S.7-29 through S.7-32 show the prevailing northwest winds continue to limit southerly transport of emissions into the UGRB, along with the prevailing southwesterly winds along the Interstate-80 corridor, which are reflected in the trajectory analysis for the Moxa Arch area, the Naughton power plant, the OCI Trona processing facility, and the Bridger power plant.

It is important to note that as the trajectory start point is located further south, and out of the UGRB, the dominant northwest winds taper off, and the airflow at the south end of the UGRB mixes with the prevailing winds along the Interstate-80 corridor, which tend to dominate air parcel transport once the air parcel is out of the UGRB, south of the Wyoming Range terrain influence.

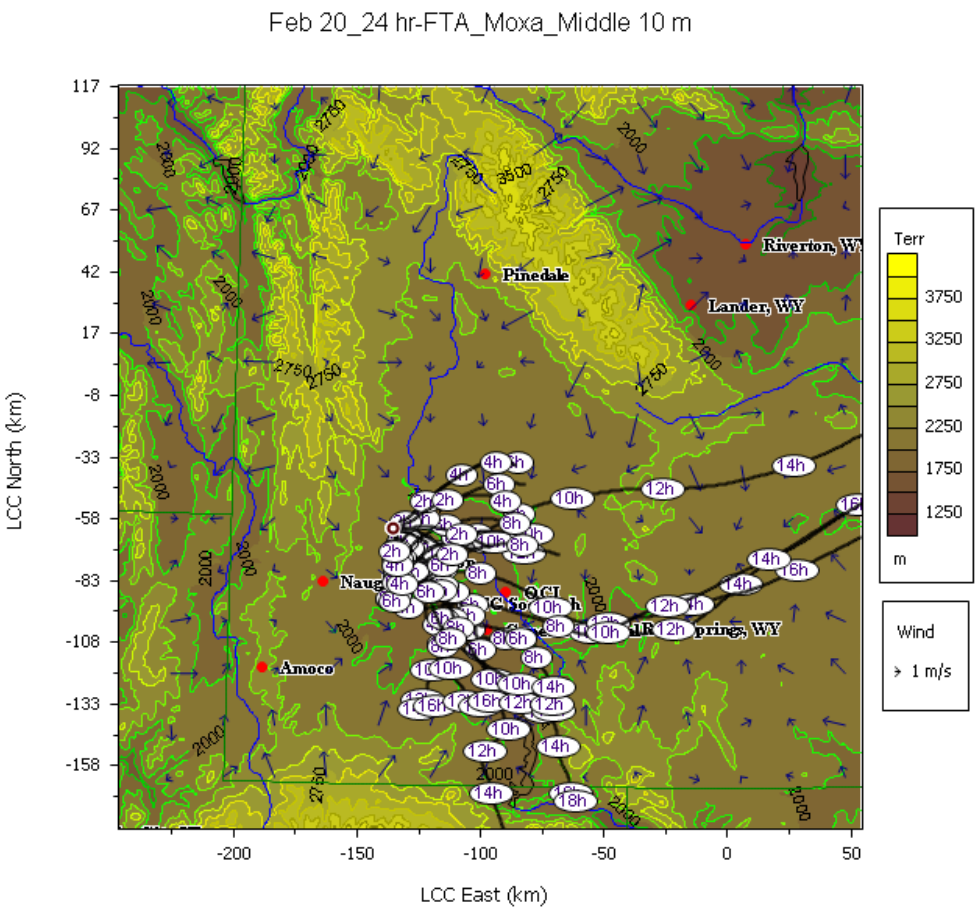


Figure S.7-29. 24-hour forward trajectory analysis in the Moxa Arch area on February 20, 2008.

The trajectory analysis in Figure S.7-29 shows all modeled trajectories from Moxa Arch not entering the proposed nonattainment area.

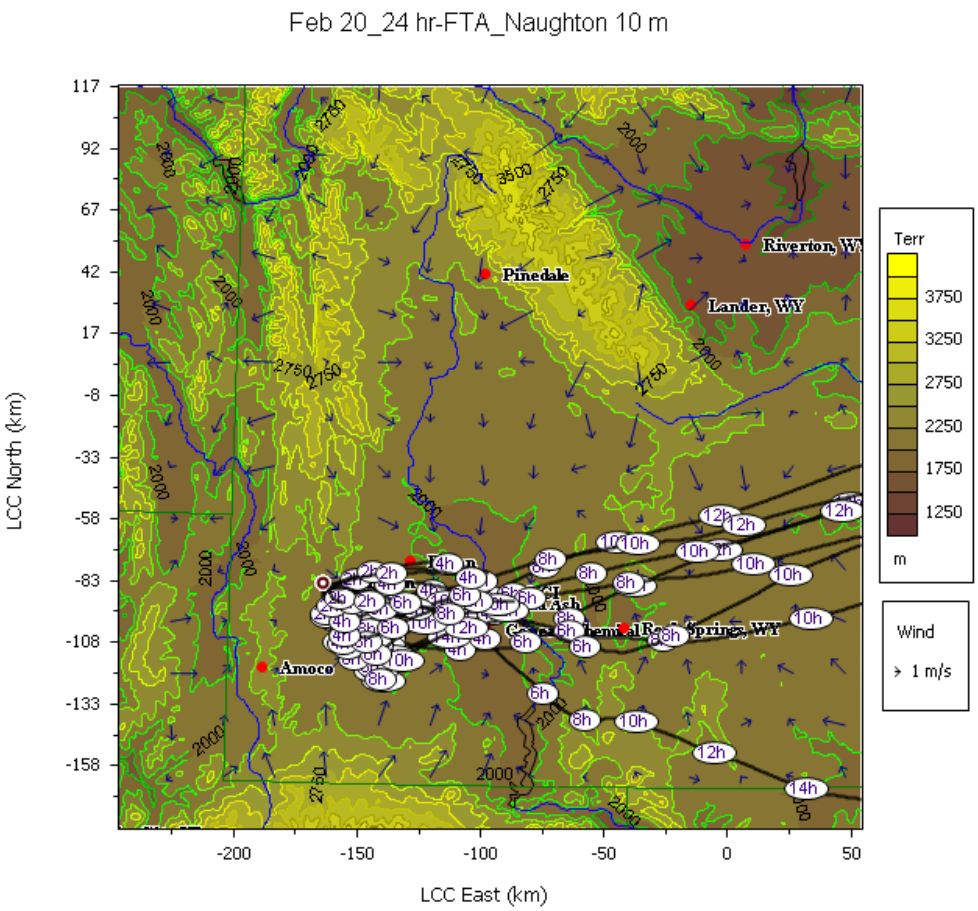


Figure S.7-30. 24-hour forward trajectory analysis at Naughton power plant on February 20, 2008.

The trajectory analysis in Figure S.7-30 shows all modeled trajectories from Naughton not entering the proposed nonattainment area.

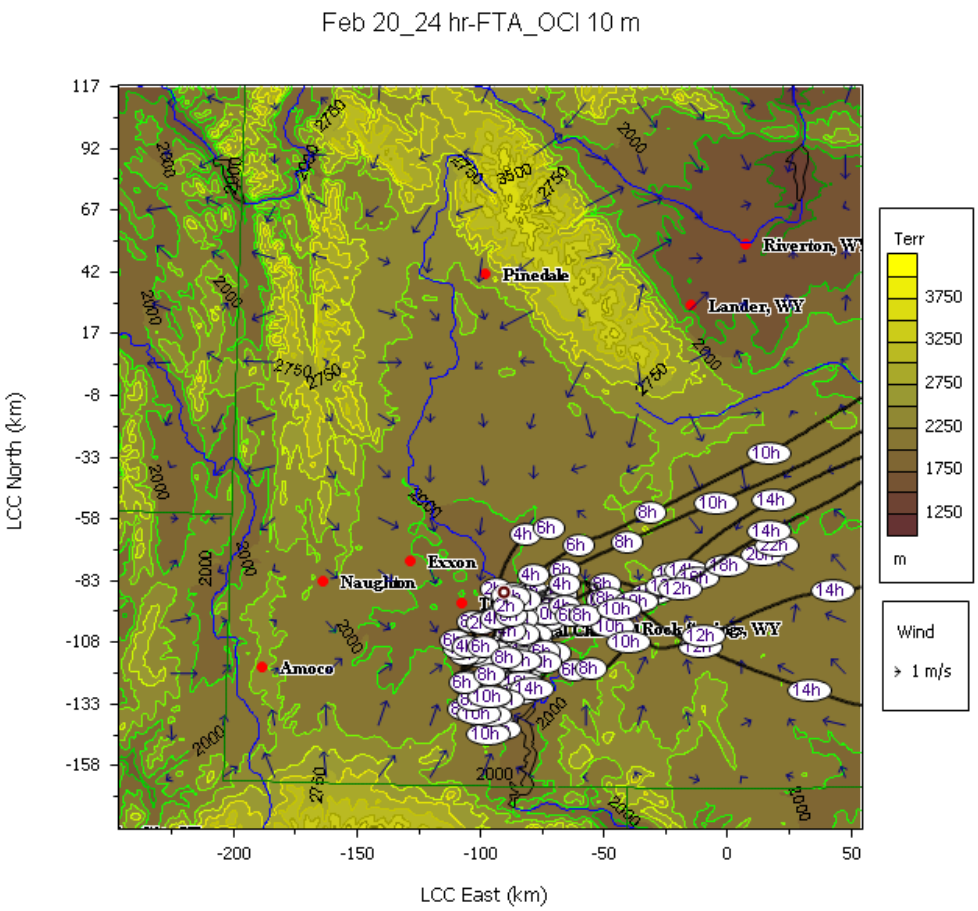


Figure S.7-31. 24-hour forward trajectory analysis at OCI Trona plant on February 20, 2008.

The trajectory analysis in Figure S.7-31 shows all modeled trajectories from OCI not entering the proposed nonattainment area.

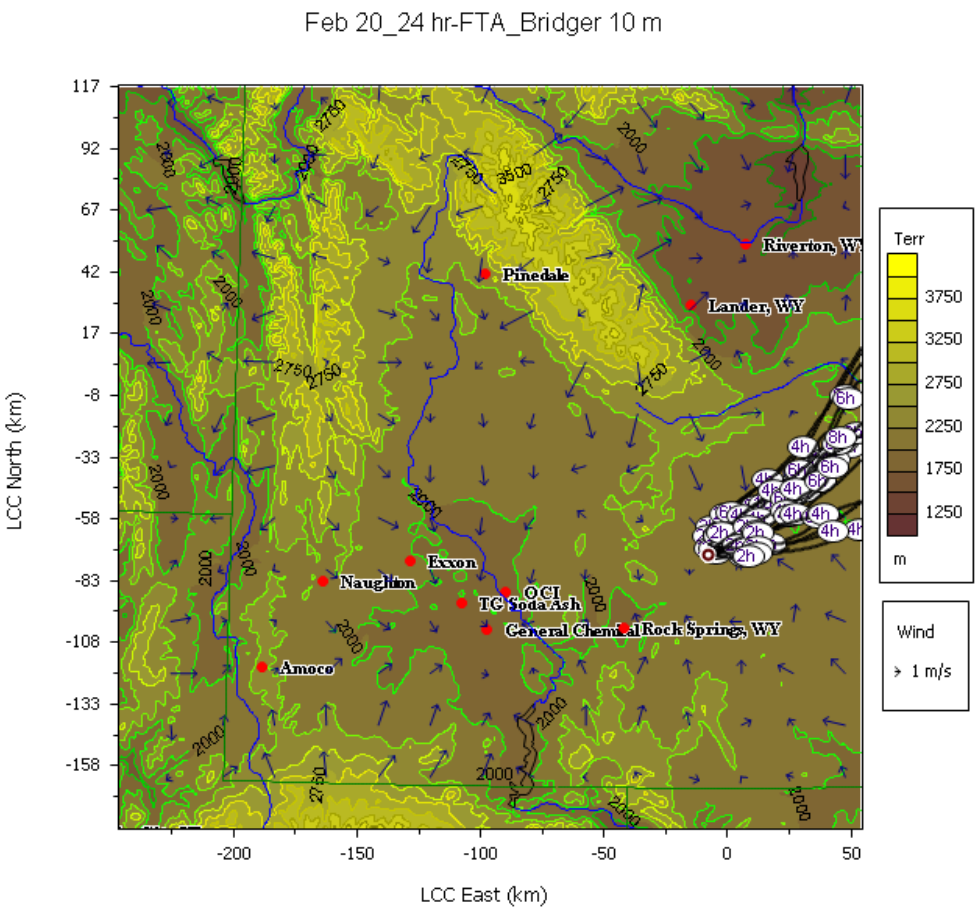


Figure S.7-32. 24-hour forward trajectory analysis at Bridger power plant on February 20, 2008.

The trajectory analysis in Figure S.7-32 shows all modeled trajectories from Bridger not entering the proposed nonattainment area.

CalDESK Forward Trajectory Analyses for February 21, 2008 are shown in Figures S.7-33 through S.7-37.

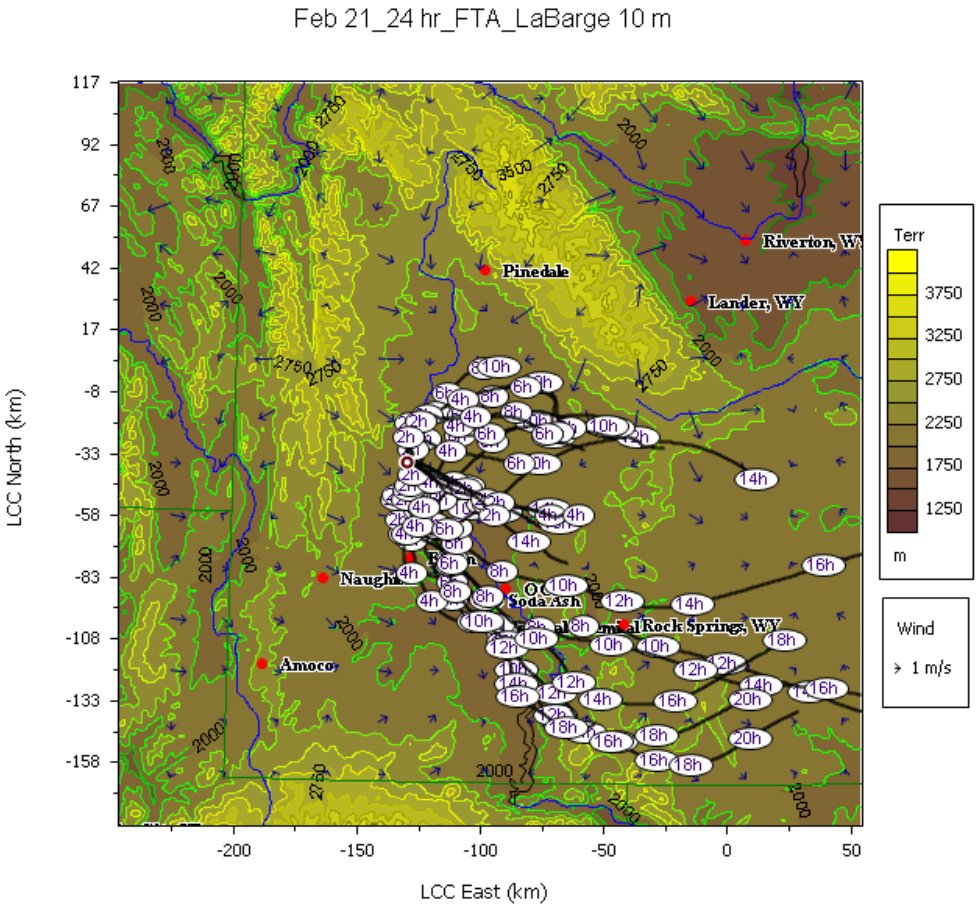


Figure S.7-33. 24-hour forward trajectory analysis at LaBarge, Wyoming on February 21, 2008.

By the afternoon of February 21, 2008, the high pressure ridge had weakened, and had also flattened, and the central ridge axis was over or just east of southwestern Wyoming through the entire day; the resulting light wind stagnant situation also enabled the highest ozone production recorded at the Boulder monitoring site to date. These conditions were monitored during the first IOP, conducted February 18-21, 2008, in which a set of intensive meteorological and ambient measurements were collected when meteorological conditions similar to those associated with high ozone episodes during 2005 – 2006 had been forecast to occur during the 2008 field study.

The low level inversion was not quite as strong as on February 19, 2008, but it did stay intact through the entire daylight period, keeping ground level emissions trapped near the surface. With the very light and variable winds above the inversion, localized flow patterns near the ground level developed during the day allowing emissions to transport along those pathways.

As shown in Figure S.7-33, the trajectory analyses for the LaBarge area exhibit several possible air parcel paths to the northwest on February 21, 2008. Figure S.7-34 shows the trajectory analysis for the Moxa Arch area, which exhibits a few trajectories initially moving into the southernmost portion of the UGRB, but the strong northerly winds in the UGRB dominate the flow. This limits northward air parcel transport into the UGRB, and the vast majority of the trajectories continue to travel south out of the UGRB. The trajectory start point at Moxa Arch is approximately fourteen (14) miles south of the LaBarge trajectory start point, where the dominant northwest wind influence in the UGRB valley is tapering off, and mixes with prevailing westerly winds.

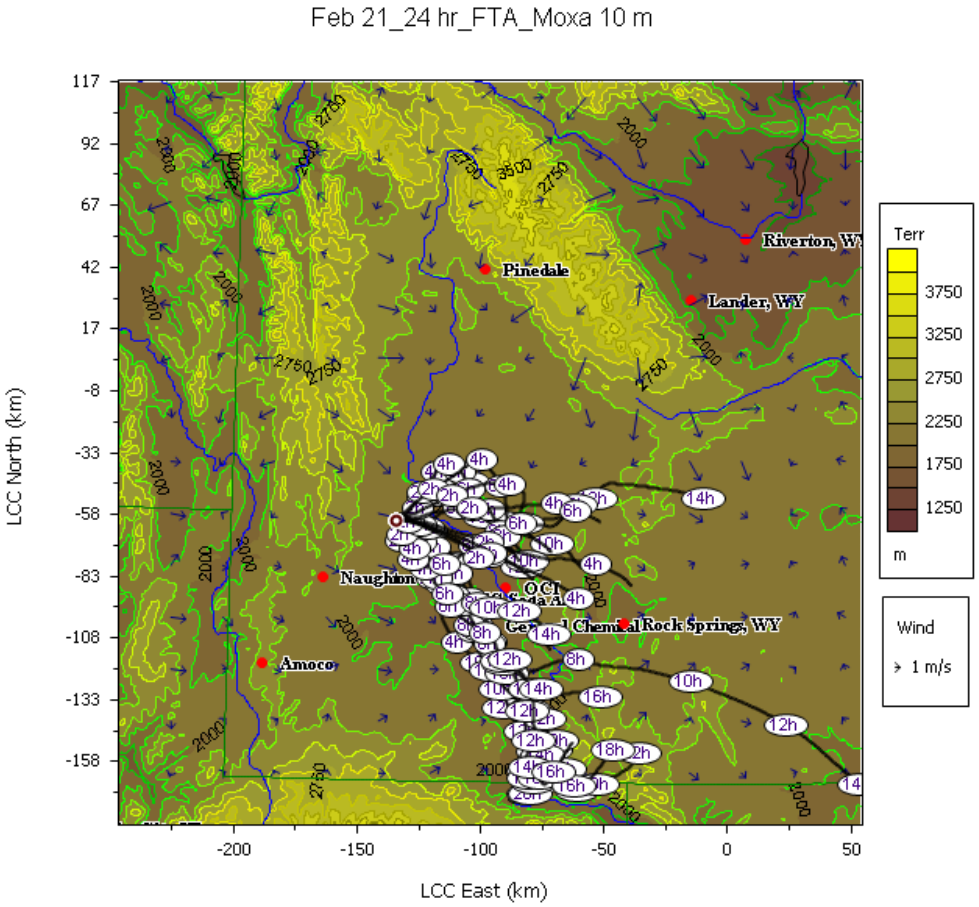


Figure S.7-34. 24-hour forward trajectory analysis in the Moxa Arch area on February 21, 2008.

Figure S.7-35 shows prevailing westerly winds at Naughton with air parcels moving eastward. The strong northwest winds in the UGRB and the terrain blocking effects of the Uinta Range to the south, collectively, influence the trajectory paths as they move from the Naughton power plant trajectory start point. The trajectory analysis in Figure S.7-35 shows all modeled trajectories from Naughton not entering the proposed nonattainment area

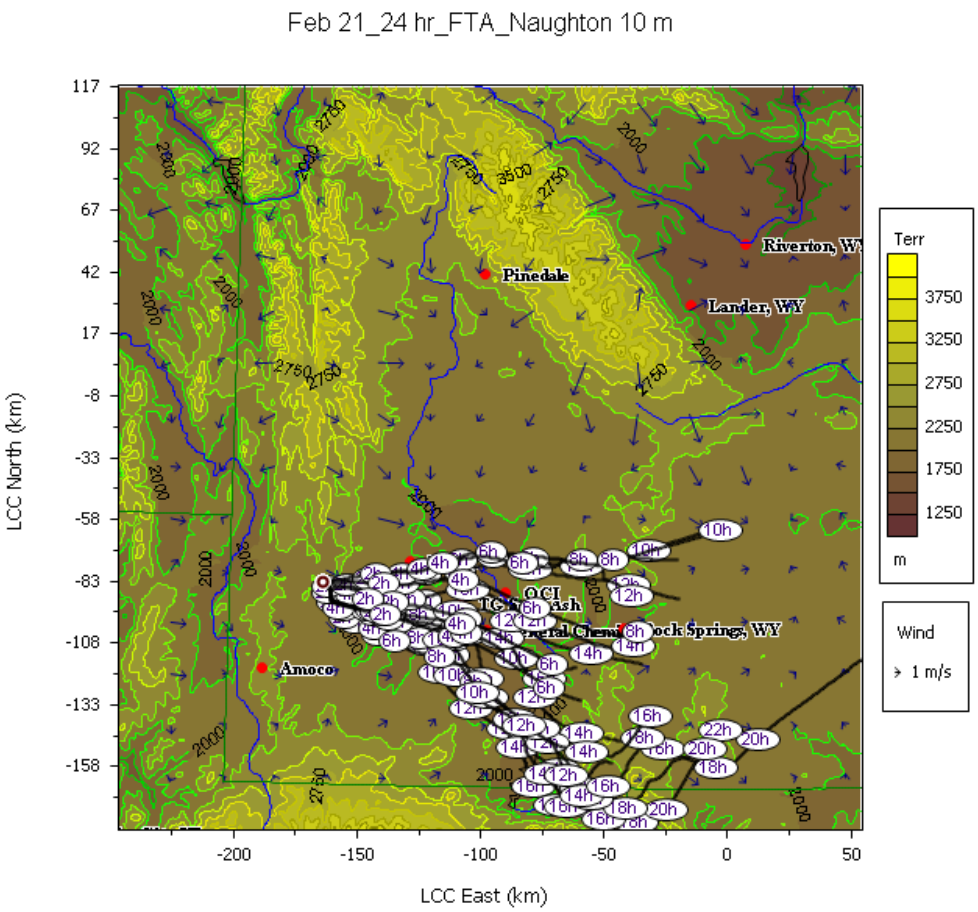


Figure S.7-35. 24-hour forward trajectory analysis at Naughton power plant on February 21, 2008.

Figures S.7-36 and S.7-37 show the prevailing westerly winds at the OCI Trona plant and the Bridger power plant, with the air parcels moving eastward and then northward. As noted with the forward trajectory paths from Naughton power plant, the strong northwest winds in the UGRB and the terrain blocking effects of the Uinta Range to the south continue to influence the trajectory paths as they move from the OCI and Bridger trajectory start points. The trajectory analysis in Figures S.7-36 and S.7-37 shows all modeled trajectories from OCI and Bridger not entering the proposed nonattainment area.

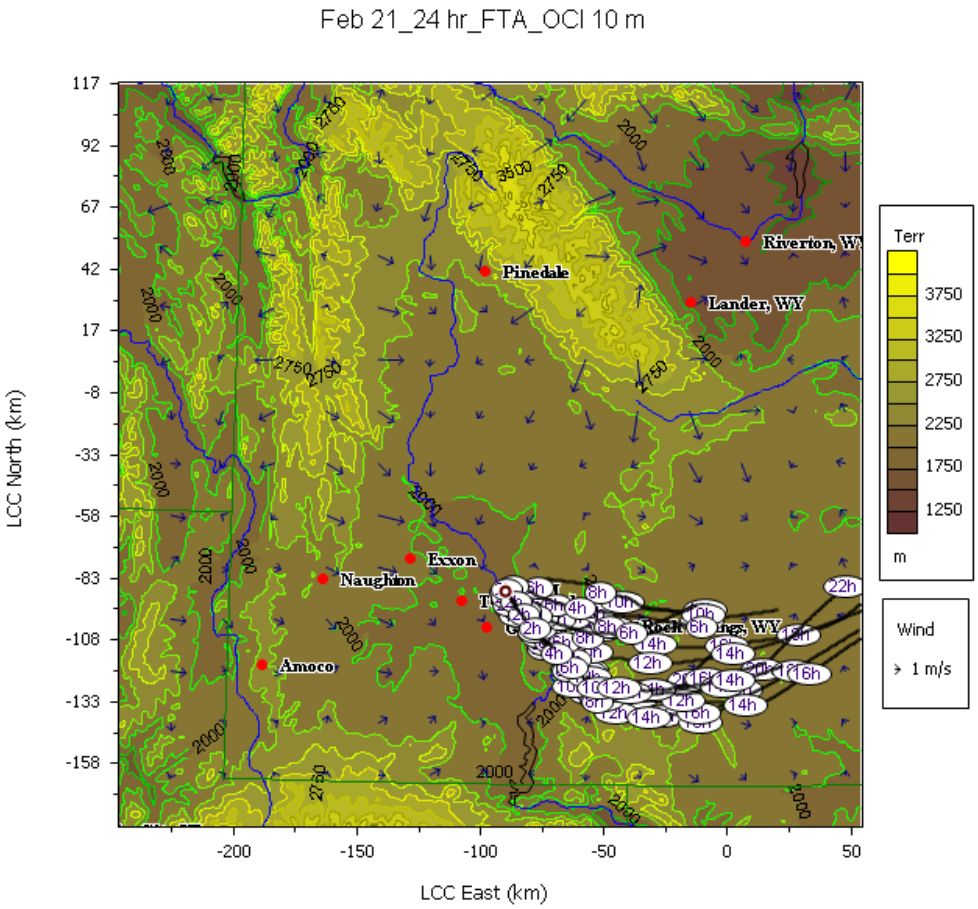


Figure S.7-36. 24-hour forward trajectory analysis at OCI Trona plant on February 21, 2008.

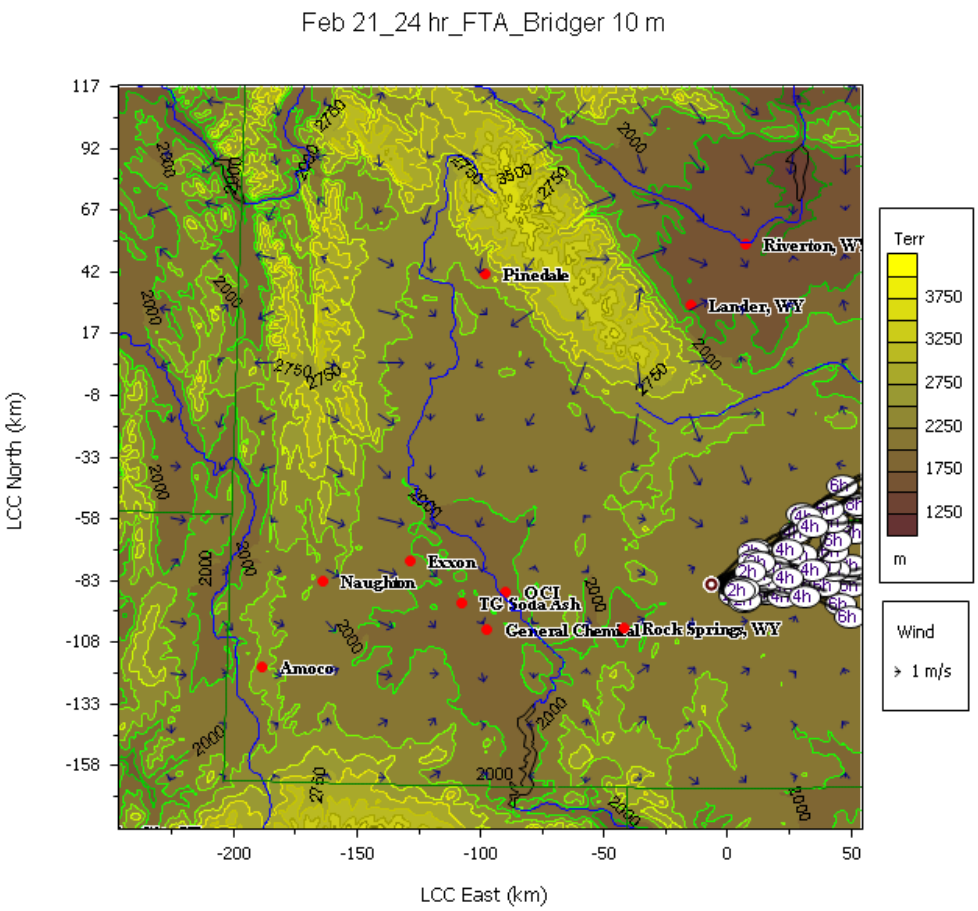


Figure S.7-37. 24-hour forward trajectory analysis at Bridger power plant on February 21, 2008.

As discussed previously, the localized meteorology within the UGRB during the ozone episodes influences air parcel movement within the UGRB, typically leading to shorter trajectory paths than if the trajectories were based on a start point located outside of the UGRB. CalDESK trajectory analyses that are initiated within the UGRB reflect the wind flow reversals and sustained low wind speeds; hence, shorter trajectory paths (and flow recirculation) are produced, which is consistent with the observed wind patterns.

During these wind reversals, the air flow changes direction. The winds are initially out of the northwest in the early morning, then out of the northeast, and then turn such that the winds flow out of the southeast later in the morning; the NW to SE wind flow reversal occurs approximately at 11:00 at the Boulder monitor on February 21, 2008.

CalDESK Forward Trajectory Analyses for February 22, 2008 are shown in Figures S.7-38 through S.7-42.

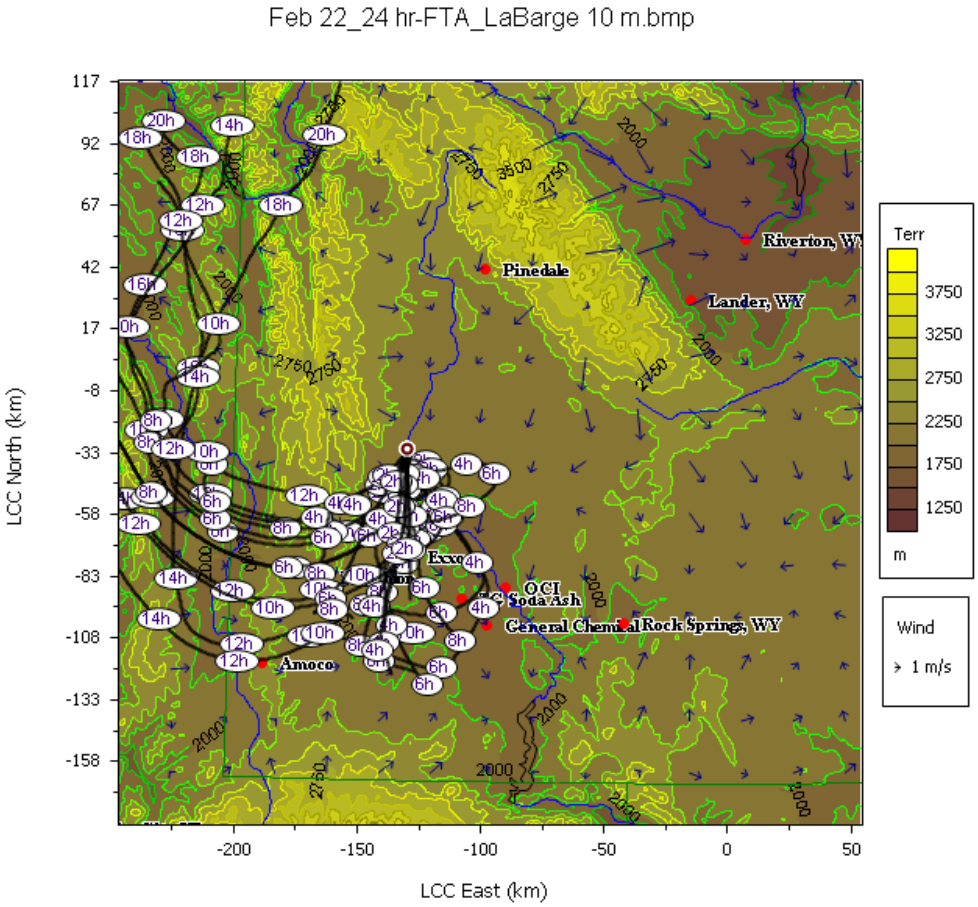


Figure S.7-38. 24-hour forward trajectory analysis at LaBarge, Wyoming on February 22, 2008

The high pressure ridge continued to weaken during February 22, 2008, while a shortwave low pressure trough approached southwestern Wyoming from the northwest. Skies became mostly cloudy during the morning hours and light precipitation spread over the area later in the afternoon. However, the low level inversion stayed intact well into the afternoon, and ozone concentrations remained high during most of the day. No IOP operations were conducted this day because it was anticipated that the stable layer would be mixed-out by the trough by early morning and, therefore, trapped emission would be dispersed. Instead, the late arrival of the trough allowed one more day of high ozone concentrations.

As shown in Figure S.7-38, the trajectory analysis for the LaBarge area shows that most of the possible forward trajectory paths are now moving away from the UGRB during February 22nd. Figures S.7-38 through S.7-40 show air parcels tend to be blocked and channeled westward and then northward around the Wyoming Range, with limited air parcel movement into the UGRB. There are 1-2 trajectory paths showing air parcel movement from the Moxa Arch and Naughton areas into the UGRB, however, the vast majority of the air parcel trajectories do not enter the UGRB, due to the significant terrain blocking and channeling effects of the terrain that make up the Wyoming Range and the Wasatch Range. Terrain blocking and channeling effects can also be seen in Figure S.7-42 in the forward trajectories originating from the OCI Trona plant.

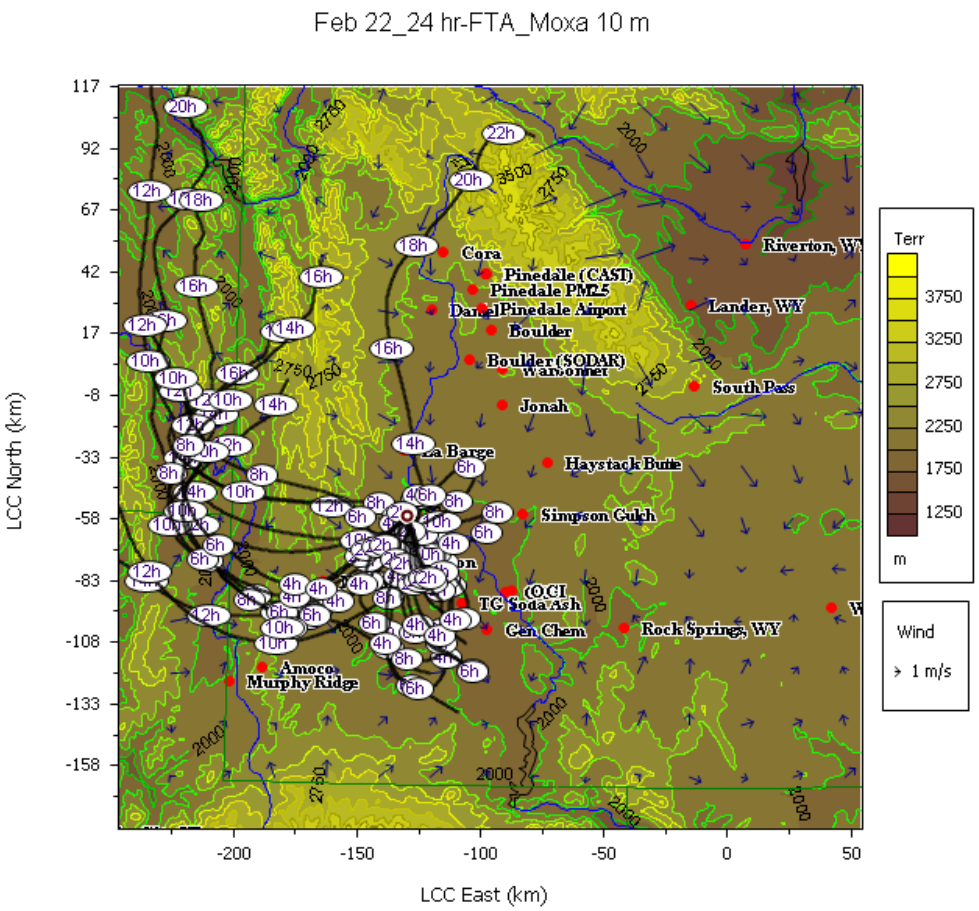


Figure S.7-39. 24-hour forward trajectory analysis in the Moxa Arch area on February 22, 2008.

Figure S.7-39 shows air parcels tend to be blocked and channeled westward and then northward around the Wyoming Range, with limited air parcel movement into the UGRB. There are 1-2 trajectory paths showing air parcel movement from the Moxa Arch into the UGRB, however, the vast majority of the air parcel trajectories do not enter the UGRB, due to the significant terrain blocking and channeling effects of the terrain that make up the Wyoming Range and the Wasatch Range.

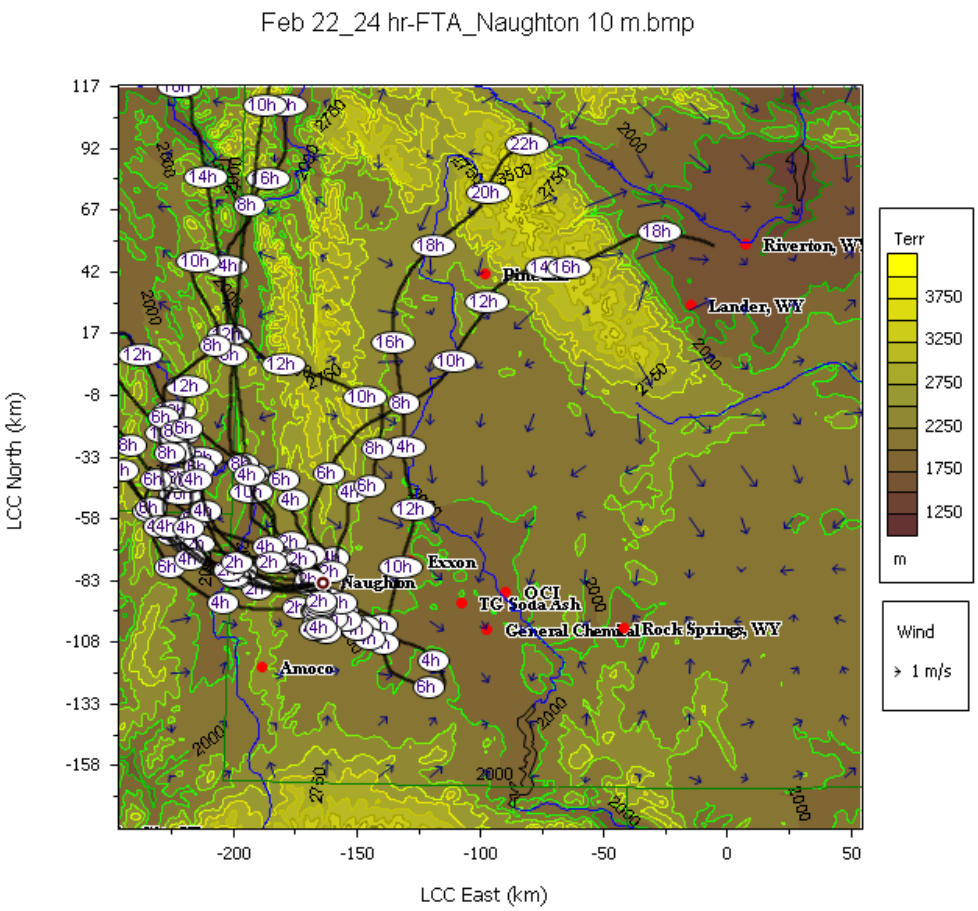


Figure S.7-40. 24-hour forward trajectory analysis at Naughton power plant on February 22, 2008.

There are two forward trajectory paths (2 am and 6 am) which show possible air parcel transport from the Naughton power plant into the UGRB. A 12-hour back trajectory analysis was performed at the Boulder monitor location (2 am – 2 pm) for February 22, 2008 to evaluate potential air parcel trajectories that could reach the Boulder monitor during this same time period (2 am and 6 am). The results of this back trajectory analysis are shown in Figure S.7-41.

Figure S.7-41 shows the calculated back trajectories of air parcels at the Boulder monitor tend to originate from within the UGRB, with very little air parcel movement occurring outside of the UGRB; the air parcels tend to stay within the UGRB during this 12 hour period (2 am – 2 pm) largely due to localized meteorological conditions in the UGRB. The back trajectory analysis in Figure S.7-41 shows a limited potential for sources outside the recommended nonattainment area to affect ozone measured at the Boulder monitor.

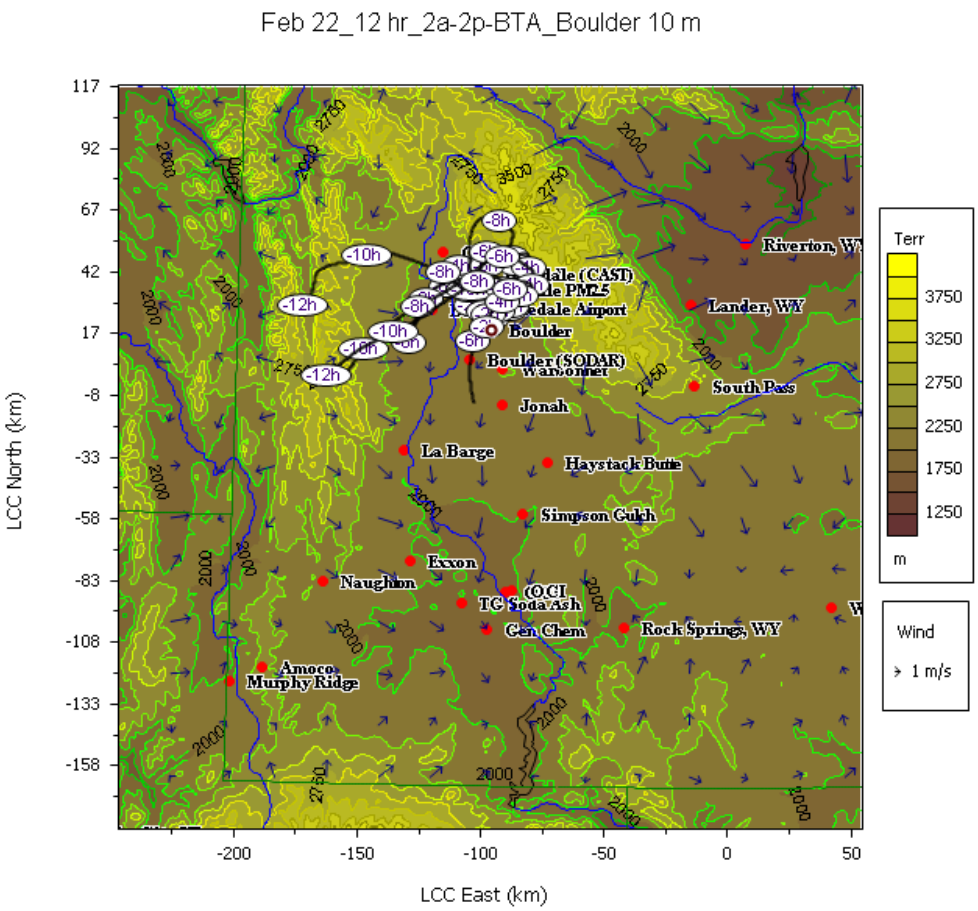


Figure S.7-41. 12-hour back trajectory analysis at Boulder monitor on February 22, 2008.

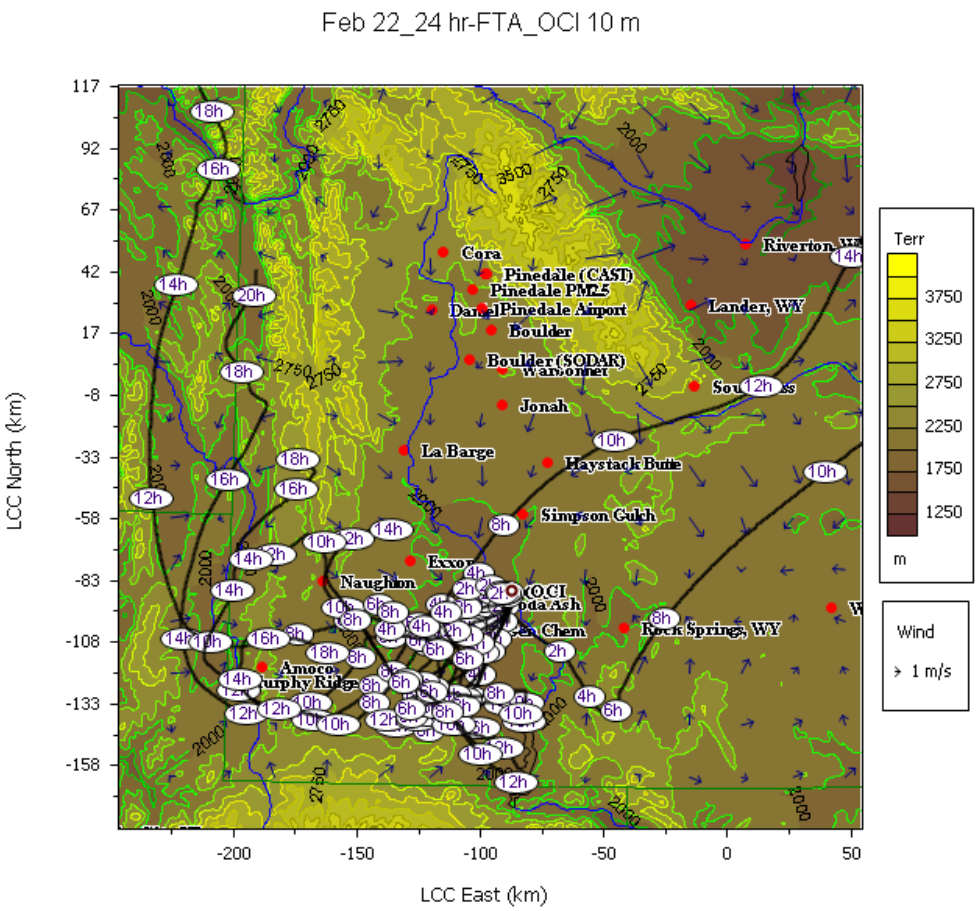


Figure S.7-42. 24-hour forward trajectory analysis at OCI Trona plant on February 22, 2008.

The predominant paths shown in the trajectory analysis shown in Figure S.7-42 trend to the south with northerly component to several of the modeled trajectories. Most of the possible forward trajectory paths are now moving away from the UGRB. Air parcels tend to be blocked and channeled westward and then northward around the Wyoming Range, with limited air parcel movement into the UGRB. There is one trajectory path showing air parcel movement from the OCI toward the UGRB. This trajectory generally parallels the southern boundary of the proposed nonattainment area along Pacific Creek. While some of the trajectory path may lie within the proposed nonattainment area, the path does not indicate that sources at OCI cause or contribute to elevated ozone levels within the proposed nonattainment area.

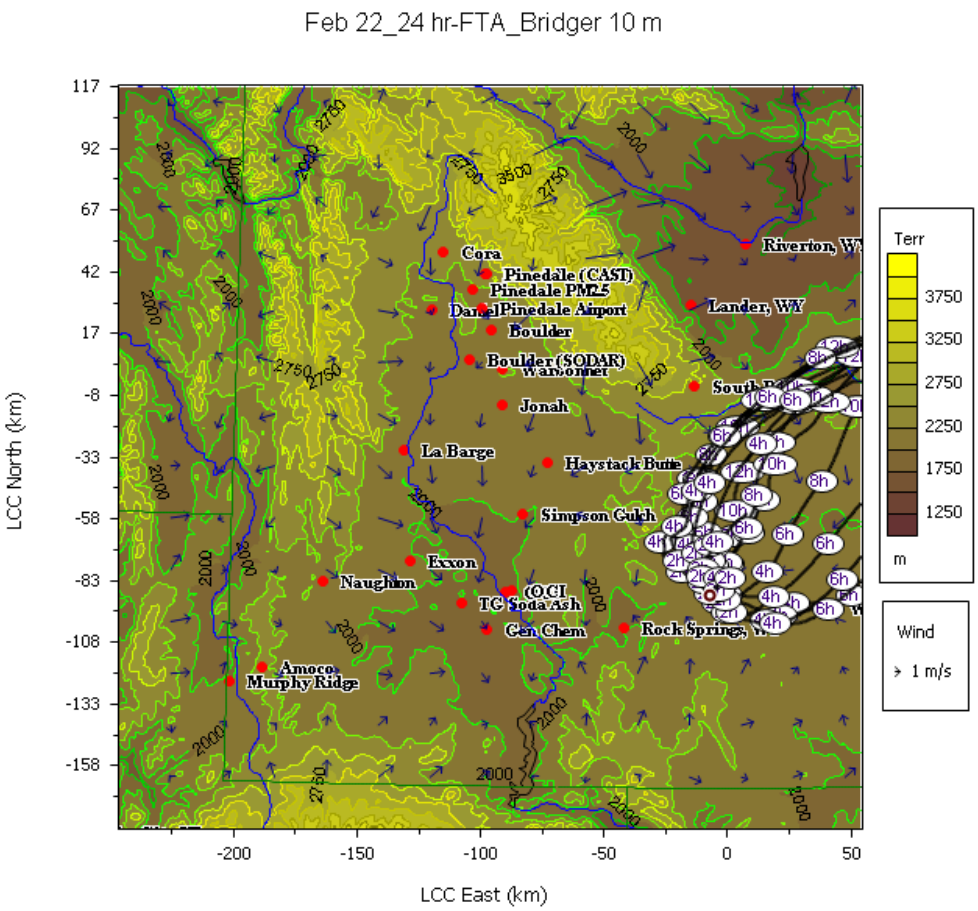


Figure S.7-43. 24-hour forward trajectory analysis at Bridger power plant on February 22, 2008.

The trajectory analysis in Figure S.7-43 shows all modeled trajectories from Bridger not entering the proposed nonattainment area.

CalDESK Forward Trajectory Analyses for February 23, 2008 are shown in Figures S.7-44 through S.7-48.

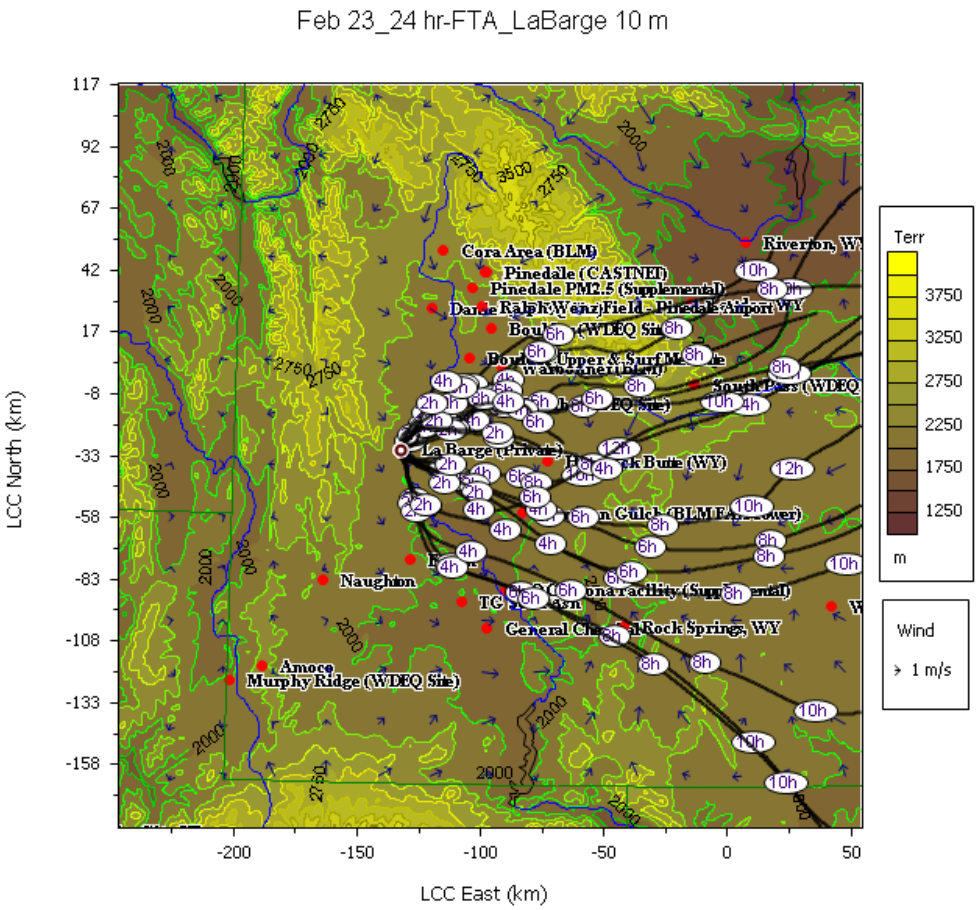


Figure S.7-44. 24-hour forward trajectory analysis at LaBarge, Wyoming on February 23, 2008.

Figure S.7-44 shows the trajectory analysis for the LaBarge area; there are a few forward trajectory paths going northeast during Feb 23, 2008, but most are channeled around the rising terrain at the south end of the UGRB and the Wind River Range. As shown in Figures S.7-45 through S.7-48, the prevailing west and southwest winds generally move air parcels eastward and then northward, as reflected in the trajectory analysis for the Moxa Arch area, the Naughton power plant, the OCI Trona processing facility, and the Bridger power plant.

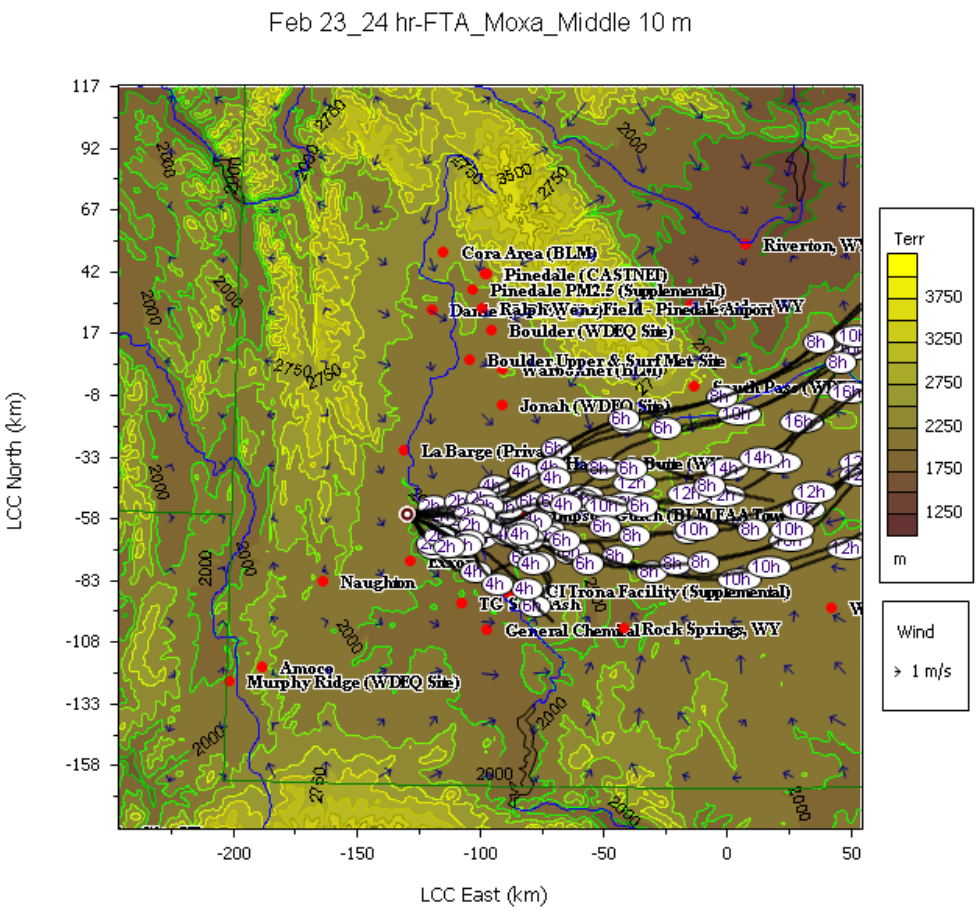


Figure S.7-45. 24-hour forward trajectory analysis in the Moxa Arch area on February 23, 2008.

The trajectory analysis shown in Figure S.7-45 places the initial air parcel release point in the northern part of the Moxa Arch field. The predominant paths shown trend to the east, and there is a slight northerly component to several of the modeled trajectories. These trajectories generally parallel the southern boundary of the proposed nonattainment area along Pacific Creek. While some of the trajectory paths lie within the proposed nonattainment area, none of the paths indicate that sources within the Moxa Arch cause or contribute to elevated ozone levels within the proposed nonattainment area.

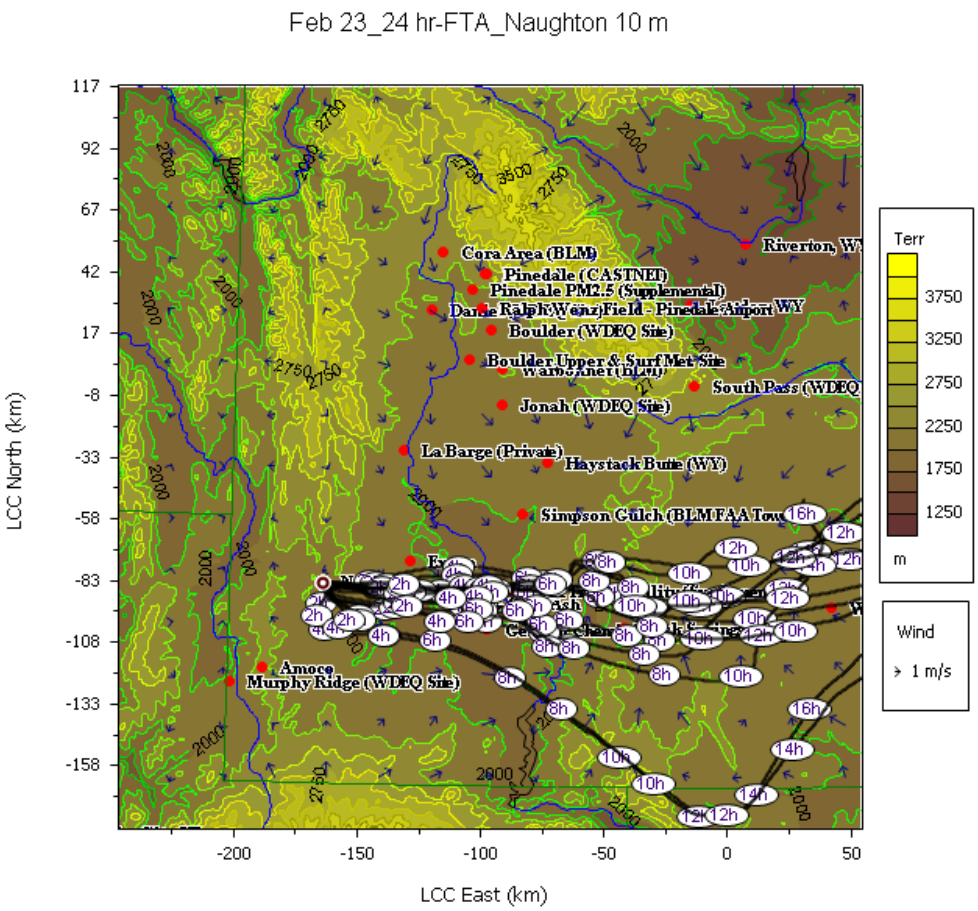


Figure S.7-46. 24-hour forward trajectory analysis at Naughton power plant on February 23, 2008.

The trajectory analysis in Figure S.7-46 shows all modeled trajectories from Naughton not entering the proposed nonattainment area.

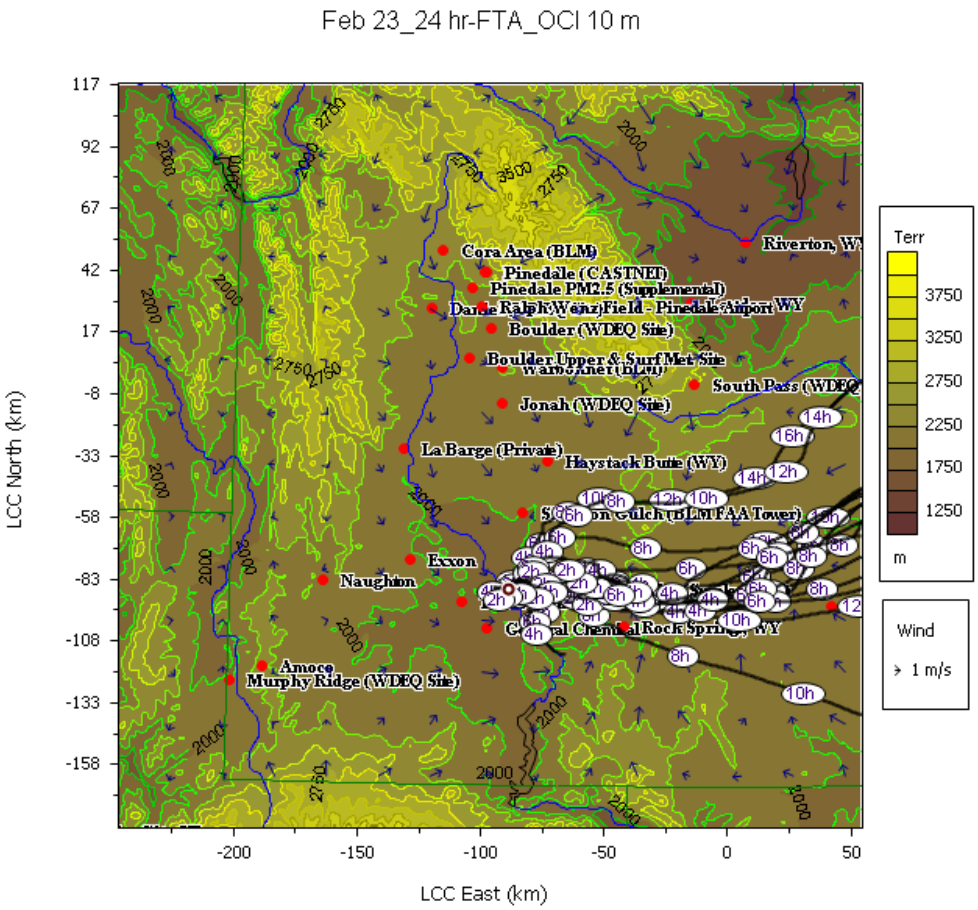


Figure S.7-47. 24-hour forward trajectory analysis at OCI Trona plant on February 23, 2008.

The trajectory analysis in Figure S.7-47 shows all modeled trajectories from OCI not entering the proposed nonattainment area.

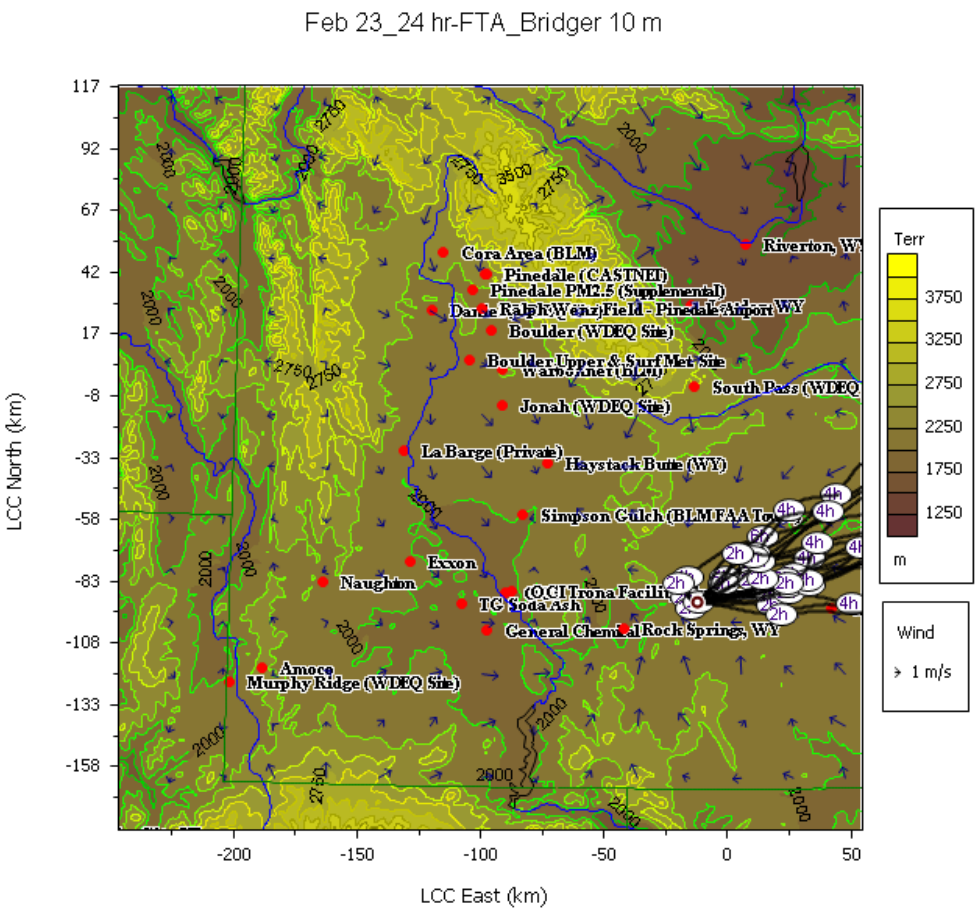


Figure S.7-48. 24-hour forward trajectory analysis at Bridger power plant on February 23, 2008.

The trajectory analysis in Figure S.7-48 shows all modeled trajectories from Bridger not entering the proposed nonattainment area.

<u>Summary of Trajectory Analyses</u>

The CalDESK trajectory analyses, based on a three dimensional wind field which incorporates the localized meteorological data collected during the 2008 field study have allowed AQD to evaluate air parcel movement as a means of evaluating precursor emissions and ozone transport into and out of the UGRB. These trajectories indicate that the southern boundary of the recommended nonattainment area defines an appropriate demarcation where emission sources within the nonattainment area may contribute ozone or ozone precursors to the Boulder monitor. Although the Fontenelle Creek, Little Sandy and Pacific drainages are not major topographic features, these drainage areas influence air movement into the UGRB from locations south of the recommended nonattainment area during the February 19-23, 2008 ozone episode and define a reasonable southern boundary for the nonattainment area. AQD has concluded that most, if not all, of the impact on the Boulder monitor just prior to and during these elevated ozone episodes is from emission sources located in the nonattainment area as described in this recommendation.

SECTION 8
JURISDICTIONAL BOUNDARIES

SYNOPSIS

The Sublette County jurisdictional boundary forms the northern and most of the western and eastern boundaries of the recommended nonattainment area. The remainder of the boundary is not jurisdictional but is based on topographical and meteorological considerations.

There is no existing local authority that transcends county boundaries, so the recommended nonattainment area has no single local administrative authority.

ANALYSIS

The Boulder monitor is located in Sublette County. Sublette County is governed by a three-person Commission. There are three incorporated towns in Sublette County: Pinedale, Big Piney and Marbleton. Approximately 80% of the land in Sublette County is owned by the government: BLM-40%; USFS-36%; State of Wyoming-4%. Federal and state land ownership in the surrounding counties follows a similar pattern.

The evaluation of the nonattainment area began with the Sublette County jurisdictional area as the presumptive boundary. This is consistent with EPA guidance in the December 4, 2008 memorandum which states: "Where a violating monitor is not located in a CBSA" (Core Based Statistical Area) "or CSA," (Combined Statistical Area) "we recommend that the boundary of the county containing the monitor serve as the presumptive boundary for the nonattainment area." The Boulder monitor is not in a CBSA or CSA.

The recommended nonattainment area includes all of Sublette County; the portion of Lincoln County northeast of the waterways of Aspen, Fontenelle, and Roney Creeks and northeast of Fontenelle Reservior and the Green River; and the portion of Sweetwater County northwest of the waterways of the Green River, the Big Sandy River, Little Sandy Creek, Pacific Creek, and Whitehorse Creek (see the detailed description in the introduction). This area includes the town of LaBarge in Lincoln County. The southern boundary of the recommended nonattainment area is defined based on topographical and meteorological considerations rather than jurisdictional boundaries. The Sublette County borders to the north, east, and west follow topographic features (mountain ranges) and are appropriate boundaries for the nonattainment area.

The six counties in Southwest Wyoming which were also included in the analysis are: Teton, Lincoln, Uinta, Sweetwater, and Fremont. Two Indian Tribal Nations are also located in the area, the Northern Arapahoe and Eastern Shoshone, at the Wind River Reservation in Fremont County. The reservation and the counties are shown in Figure S.1-1.

The recommended nonattainment area boundary does not fall under single authority, other than the State of Wyoming.

SECTION 9
LEVEL OF CONTROL OF EMISSION SOURCES

SYNOPSIS

Wyoming's NSR Program ensures that Best Available Control Technology (BACT) is utilized to reduce and eliminate air pollution emissions. Wyoming is fairly unique in that BACT is applied statewide to all new sources, both major sources and minor sources. Since 1995 all oil and gas production units that were constructed on or after May of 1974 require permits and BACT is utilized. In two of the gas fields in the proposed nonattainment area, more restrictive emission control requirements are already in effect. Wyoming has been focused on controlling emissions from oil and gas sources and has one of the most innovative and effective control programs in the nation.

While offset programs are traditionally limited to major source applications, the AQD issued an interim policy in August 2008 requiring offsets of ozone precursor emissions whenever a permit is issued for a new or modified source in Sublette County, regardless of major source applicability. This policy results in a net decrease in emissions of ozone precursors with every permit that is issued. This policy took effect after the ozone exceedances were recorded in the winter of 2008.

Data is not available for 2009, so it is too early to say with certainty whether this policy has contributed to reduced ozone concentrations at the Boulder monitor.

ANALYSIS

New Source Review Program

Wyoming's New Source Review (NSR) Program is a statewide permit program for the construction of new sources and modification of existing sources as established by Wyoming Air Quality Standards and Regulations (WAQSR) Chapter 6, Section 2, Permit requirements for construction, modification and operation and Chapter 6, Section 4, Prevention of significant deterioration. The primary purpose of the NSR Program is to assure compliance with ambient standards set to protect public health, assure that Best Available Control Technology is utilized to reduce and eliminate air pollution emissions, and to prevent deterioration of clean air areas. Any amount of air contaminant emissions from a facility subjects it to Wyoming's NSR Program.

Best Available Control Technology

Due to a desire to maintain and improve Wyoming's air quality, the Best Available Control Technology process is applied statewide to new sources, both major sources and minor sources, under the Wyoming NSR Program's permitting process. The BACT process is most appropriately defined as the elimination of pollutants from being emitted into the air whenever technically and economically feasible to do so. While the Air Quality Division takes the State

and federally-required BACT review in the Prevention of Significant Deterioration (PSD) permitting actions seriously, AQD takes the State-required BACT review in minor source permitting actions equally as seriously, as the bulk of AQD's permit applications are for minor sources.

Control of Oil and Gas Production Sources

Within the recommended nonattainment area, the bulk of the NSR Program activity is due to oil and gas production and is permitted per the *Oil and Gas Production Facilities Chapter 6, Section 2, Permitting Guidance* discussed below. The remainder of the activity is attributed to facility types such as the compressor stations, asphalt plants and crushing and screening operations, which are permitted per Chapter 6, Section 2 and Chapter 6, Section 4 as described above.

In October 1995, AQD initiated a program to ensure that all oil and gas production units in southwest Wyoming, as well as the entire state, that were constructed since May of 1974 (the effective date of Wyoming's NSR Permit Program) were permitted and that BACT is utilized to control or eliminate emissions from both major and minor sources. To guide oil and gas producers through the NSR permitting process, AQD developed an oil and gas industry guidance document (Guidance) that was released in June of 1997. The Guidance has been revised several times since it was originally released in June of 1997. The most recent revision took effect in August of 2007 and includes requirements that apply statewide as well as specifically to the Jonah and Pinedale Anticline Development (JPAD) Area. The emphasis of the Guidance relies on a "Presumptive BACT" process, which results in more emissions being controlled earlier in the life of the production site. This is accomplished by allowing start up or modification of the production site to occur prior to obtaining a construction permit, provided the operators of such facilities meet certain emission control requirements, including timely installation of controls, which have been established through the Presumptive BACT process. Within the JPAD Area, emission control requirements are more restrictive and become effective upon start up or modification of the production site.

Under the WAQSR, applicants for permits are required to demonstrate to the Administrator of the Air Quality Division, that "[t]he proposed facility will not prevent the attainment or maintenance of any ambient air quality standard." [WAQSR Chapter 6, Section 2(c)(ii)] To allow applications for new or modified emission sources of VOC and/or NOx to be processed while the Division and industry initiatives are taken to reduce the overall emission levels for VOC and/or NOx in Sublette County, AQD adopted the *Interim Policy on Demonstration of Compliance with WAQSR Chapter 6, Section 2(c)(ii) for Sources in Sublette County* on July 21, 2008. The Interim Policy describes options that AQD will consider as an adequate WAQSR Chapter 6, Section 2(c)(ii) demonstration for permit applications (i.e., new as well as applications currently under AQD analysis) for new or modified emission sources in Sublette County.

Options for the Chapter 6, Section 2(c)(ii) demonstration include:

a. Ambient ozone modeling for any application requesting increases in VOCs and/or NOx emissions.

b. Emission reductions for VOCs and/or NOx emissions.

c. Applicants may propose alternate innovative demonstrations to the AQD.

To date, most applicants have chosen to offset VOC and/or NOx emissions and permit conditions have been established to make the commitments to control emissions federally enforceable.

During the implementation of the Interim Policy, other long-term approaches (e.g., development of a regional ozone model and implementation of additional control strategies) to deal with unacceptable ozone levels in the recommended nonattainment area, will continue to be pursued by AQD.

Statewide and Industry-wide Control of Volatile Organic Compounds (VOC)

WAQSR Chapter 13 establishes minimum requirements for motor vehicle emission control.

The following federal rules which are incorporated by reference in WAQSR Chapter 5 by reference contain performance or emission standards for VOCs that may apply to sources within the recommended nonattainment area and in adjacent areas:

40 CFR Part 60, Subpart D - Standards of Performance for Fossil-Fuel-Fired Steam Generators for Which Construction is Commenced After August 17, 1971

40 CFR Part 60, Subpart Da - Standards of Performance for Electric Utility Steam Generating Units for Which Construction is Commenced After September 18, 1978

40 CFR Part 60, Subpart Db - Standards of Performance for Industrial- Commercial-Institutional Steam Generating Units

40 CFR Part 60, Subpart Dc - Standards of Performance for Small Industrial-Commercial-Institutional Steam Generating Units

40 CFR Part 60, Subpart I - Standards of Performance for Hot Mix Asphalt Facilities

40 CFR Part 60, Subpart K - Standards of Performance for Storage Vessels for Petroleum Liquids for Which Construction, Reconstruction, or Modification Commenced After June 11, 1973, and Prior to May 19, 1978

40 CFR Part 60, Subpart Ka - Standards of Performance for Storage Vessels for Petroleum Liquids for Which Construction, Reconstruction, or Modification Commenced After May 18, 1978, and Prior to July 23, 1984

40 CFR Part 60, Subpart Kb - Standards of Performance for Volatile Organic Liquid Storage Vessels (Including Petroleum Liquid Storage Vessels) for Which Construction, Reconstruction, or Modification Commenced After July 23, 1984

40 CFR Part 60, Subpart GG - Standards of Performance for Stationary Gas Turbines

40 CFR Part 60, Subpart WWW - Standards of Performance for Municipal Solid Waste Landfills

40 CFR Part 63, Subpart F - National Emission Standards for Organic Hazardous Air Pollutants From the Synthetic Organic Chemical Manufacturing Industry

40 CFR Part 63, Subpart H - National Emission Standards for Organic Hazardous Air Pollutants for Equipment Leaks

40 CFR Part 63, Subpart M - National Perchloroethylene Air Emission Standards for Dry Cleaning Facilities

40 CFR Part 63, Subpart R - National Emission Standards for Gasoline Distribution Facilities (Bulk Gasoline Terminals and Pipeline Breakout Stations)

40 CFR Part 63, Subpart T - National Emission Standards for Halogenated Solvent Cleaning

40 CFR Part 63, Subpart HH - National Emission Standards for Hazardous Air Pollutants From Oil and Natural Gas Production Facilities

40 CFR Part 63, Subpart OO - National Emission Standards for Tanks - Level 1

40 CFR Part 63, Subpart PP - National Emission Standards for Containers

40 CFR Part 63, Subpart QQ - National Emission Standards for Surface Impoundments

40 CFR Part 63, Subpart RR - National Emission Standards for Individual Drain Systems

40 CFR Part 63, Subpart SS - National Emission Standards for Closed Vent Systems, Control Devices, Recovery Devices and Routing to a Fuel Gas System or a Process

40 CFR Part 63, Subpart TT - National Emission Standards for Equipment Leaks - Control Level 1

40 CFR Part 63, Subpart UU - National Emission Standards for Equipment Leaks - Control Level 2 Standards

40 CFR Part 63, Subpart VV - National Emission Standards for Oil-Water Separators and Organic-Water Separators

40 CFR Part 63, Subpart WW - National Emission Standards for Storage Vessels (Tanks) - Control Level 2

40 CFR Part 63, Subpart HHH - National Emission Standards for Hazardous Air Pollutants From Natural Gas Transmission and Storage Facilities

40 CFR Part 63, Subpart UUU - National Emission Standards for Hazardous Air Pollutants for Petroleum Refineries: Catalytic Cracking Units, Catalytic Reforming Units, and Sulfur Recovery Units

40 CFR Part 63, Subpart VVV - National Emission Standards for Hazardous Air Pollutants: Publicly Owned Treatment Works

40 CFR Part 63, Subpart AAAA - National Emission Standards for Hazardous Air Pollutants: Municipal Solid Waste Landfills

40 CFR Part 63, Subpart EEEE - National Emission Standards for Hazardous Air Pollutants: Organic Liquids Distribution (Non-Gasoline)

40 CFR Part 63, Subpart YYYY - National Emission Standards for Hazardous Air Pollutants for Stationary Combustion Turbines

40 CFR Part 63, Subpart ZZZZ - National Emission Standards for Hazardous Air Pollutants for Stationary Reciprocating Internal Combustion Engines

40 CFR Part 63, Subpart CCCCC - National Emission Standards for Hazardous Air Pollutants for Coke Ovens: Pushing, Quenching, and Battery Stacks

40 CFR Part 63, Subpart GGGGG - National Emission Standards for Hazardous Air Pollutants: Site Remediation

40 CFR Part 63, Subpart HHHHH - National Emission Standards for Hazardous Air Pollutants: Miscellaneous Coating Manufacturing

40 CFR Part 63, Subpart LLLLL - National Emission Standards for Hazardous Air Pollutants: Asphalt Processing and Asphalt Roofing Manufacturing

<u>Statewide and Industry-wide Nitrogen Oxides (NOx)</u>

WAQSR Chapter 2 establishes ambient air quality standards for those areas under WDEQ's jurisdiction. The standard for nitrogen oxides (NOx) is 100 ug/m^3 as an annual arithmetic mean. All facilities that are required to obtain a New Source Review (NSR) permit or a Title V permit under WAQSR Chapter 6 must demonstrate compliance with the State's ambient air quality standard before a permit can be issued.

WAQSR Chapter 3, Section 3 specifies nitrogen dioxide emission standards. Permitting rules require sources to meet NOx emission standards.

The following federal rules, which are incorporated by reference into Chapter 5, Sections 2 and 3

contain performance or emission standards for NOx that may apply to sources in the proposed nonattainment area and in the surrounding counties:

40 CFR Part 60, Subpart D - Standards of Performance for Fossil-Fuel-Fired Steam Generators for Which Construction is Commenced After August 17, 1971

40 CFR Part 60, Subpart Da - Standards of Performance for Electric Utility Steam Generating Units for Which Construction is Commenced After September 18, 1978

40 CFR Part 60, Subpart Db - Standards of performance for Industrial- Commercial-Institutional Steam Generating Units

40 CFR Part 60, Subpart Dc - Standards of Performance for Small Industrial-Commercial-Institutional Steam Generating Units

40 CFR Part 60, Subpart GG - Standards of Performance for Stationary Gas Turbines

The following federal New Source Performance Standards have not yet been adopted into State rules, but are scheduled for adoption. The federal standards will still apply.

NSPS Subpart IIII - Standards of Performance for Stationary Compression Ignition Internal Combustion Engines

NSPS Subpart JJJJ - Standards of Performance for Stationary Spark Ignition Internal Combustion Engines

NSPS Subpart KKKK - Standards of Performance for Stationary Combustion Turbines)

Contingency Plans

AQD requested that producers in parts of the proposed nonattainment area prepare emission reduction plans to be implemented when an ozone advisory is issued. The BLM adopted a contingency plan requirement in the Pinedale Anticline ROD. Producers, which cumulatively account for greater than 99% of production in the Pinedale Anticline, submitted contingency plans to the AQD. During the first quarter of 2009, the AQD issued ozone advisories on February 4th and 5th. The contingency plans were implemented and no 8-hour ozone values above 0.075 ppm were recorded at FRM monitors for those days.

CONCLUSIONS

The information presented in the preceding nine-factor analysis provides documentation and compelling evidence supporting a finding that the UGRB, as shown on the map in the Introduction, should be designated as nonattainment for the 2008 ozone NAAQS. It is important to note that only areas over which Wyoming has direct air quality jurisdiction are included in this nonattainment finding and recommendation. The Northern Arapahoe and Eastern Shoshone Indian Tribes are distinct nations or entities and consequently such Tribal lands (the Wind River Reservation) are specifically excluded from this designation recommendation.

The Wyoming AQD bases this recommendation on a careful review of the circumstances surrounding the incidence of elevated ozone events. Elevated ozone in the UGRB is associated with distinct meteorological conditions. These conditions have occurred in February and March in some (but not all) of the years since monitoring stations began operation in the UGRB in 2005. Our determination of an appropriate nonattainment area boundary is focused on an evaluation of EPA's recommended nine factors, applied to the first quarter of the year, during which winter ozone episodes occur. This timing does not change how the factors are reviewed, except for emissions inventory and meteorology. It is important to evaluate inventory and meteorology during the first quarter of the year in order to focus on the very specific conditions that lead to high ozone.

The most compelling reasons for the boundary recommendation are based on the meteorological conditions in place during and just prior to elevated ozone events. Elevated ozone episodes occurred in 2005, 2006 and 2008; they were associated with very light low-level winds, sunshine, and snow cover, in conjunction with a strong low-level surface-based temperature or "capping" inversion. The longest such event, which also resulted in the highest measured ozone of 122 ppb as an 8-hour average at the Boulder station, has been reviewed in detail and summarized in Section 7 of this document. Section 7 demonstrates that sources outside the recommended nonattainment area would not have a significant impact on the Boulder monitor due to the presence of the inversion and very low winds, which significantly limit emissions and ozone transport from sources located outside of the UGRB. Using detailed meteorological data collected during the February 19-23, 2008 ozone episode, a 1 kilometer high resolution (spatial and temporal) 3-dimensional gridded wind field was developed and used in trajectory analyses. The trajectory analyses show that air parcels originating at sources located south of the recommended nonattainment area – including power plants, Trona facilities, and the Moxa Arch gas field – are generally transported eastward and do not enter the UGRB just prior to and during the February 19-23, 2008 ozone episode. The meteorological conditions present during this multi-day ozone episode are representative of the meteorological conditions that were present during previous wintertime elevated ozone events that occurred in 2005 and 2006. From the trajectory analyses, it is concluded that emission sources located outside of the recommended nonattainment boundary could only have a very limited impact on the Boulder monitor, as the mountains to the west, north and east, along with the observed low wind speeds, would greatly limit the possibility of emissions transport.

The nine-factor analysis also concluded the following:

1. Ozone monitoring outside of the UGRB throughout Wyoming shows attainment of the 2008 NAAQS.
2. Emissions inventories of ozone precursors indicate that sources within the UGRB emit significant levels of precursors. Emissions from outside of the UGRB (while comparable to [for VOCs] or greater than [for NOx] emissions from within the UGRB) do not significantly influence the formation of ozone during and immediately preceding episodes of elevated ozone.
3. Population densities in Sublette and surrounding counties are very low and are not expected to be an important factor in ozone formation. This is also true of traffic and commuting patterns, which would be expected to be more important in urban areas rather than the rural communities and open spaces of southwest Wyoming.
4. The pace of growth in the oil and gas industry is significantly higher in the UGRB than in surrounding areas, which would correspond to a more rapid increase in emissions within the recommended nonattainment area in recent years.
5. Significant terrain features influence the meteorology throughout southwest Wyoming. Under a stagnating high pressure system, strong temperature inversions and low mixing heights tend to produce limited atmospheric mixing and precursor emissions can build up to high concentrations.

The elevated ozone episodes within the UGRB represent a unique situation which is quite different from other ozone nonattainment areas. The UGRB is rural with a very low population density; the only significant industry present is oil and gas. The significant terrain features surrounding the UGRB and the very low wind speeds associated with elevated ozone episodes may limit the ability of trajectory models, such as the HYSPLIT model, to accurately represent movement of air parcels within, into and out of the UGRB during these winter ozone events.

Due to the importance of meteorology to the formation of elevated ozone at the Boulder monitor – that is, ozone at levels that result in an exceedance of the NAAQS occurs during periods characterized by low mixing heights, temperature inversions and sustained low wind speeds – any emission reduction applied to sources outside of the UGRB will not result in any meaningful change in ozone levels at the Boulder monitor during these episodic conditions.

The information presented in this technical support document provides a strong weight-of-evidence basis for the recommended nonattainment boundary.

Appendix S.1.
Final Report 2008 Upper Green River Winter Ozone Study

http://deq.state.wy.us/aqd/Monitoring%20Data.asp

Appendix S.3
Population Density by Census Tract

Appendix S.4.A.
2007 Vehicle Miles on State Highways By County

Appendix S.4.B.
Commuting Patterns in Sublette County

Appendix.
Glossary