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2.5 Meteorology, Climatology and Air Quality

This section describes meteorology, climatology, and air quality in the region in which the Project is located. Both regional (long-term) and site-specific data (one year) are discussed to describe climatological conditions at the Permit Area. Where site-specific data are not available, data from the closest representative location are presented.

The Project is located in the Great Divide Basin, in south-central Wyoming. The Permit Area is located in the intermountain semi-desert ecoregion (Wyoming State Climate Office, 2005), which has cold winters and short, hot summers (Bailey, 1995). The average annual temperatures range from 40 to 52 degrees Fahrenheit (°F) in this ecoregion. The average annual precipitation ranges from five to 14 inches (Bailey, 1995). The nearest water bodies of any size are Pathfinder and Seminoe Reservoirs, shown on **Figure 2.5-1,** which are on the order of 50 miles downwind of the Lost Creek site and on the other side of the Continental Divide. It is unlikely these water bodies have any impact on meteorological measurements at Lost Creek. All other water bodies shown on **Figure 2.5-1** are seasonal, at best, and unlikely to have any impact on the measurements.

2.5.1 Meteorology and Climatology

Meteorological stations within 50 miles of the Project site are shown in **Figure 2.5-1**. The National Weather Service (NWS) meteorological station closest to the Permit Area with a long period of record is Muddy Gap, Wyoming (High Plains Regional Climate Center [HPRCC], 2007a). This station is 28 miles northeast of the Permit Area; and temperature, precipitation, snowfall and snow depth data have been collected since 1949. The Muddy Gap station is in the same Climate Division as the Project location, Climate Division 10 (CLIMAS, 2005), which means that these locations have similar climatic characteristics. Camp Creek is at a higher elevation in somewhat more rugged terrain (WRCC RAWS, 2010), and is not representative of conditions at the Project site.

The Lost Soldier (LS) meteorological station was installed at a location near Bairoil in April 2006, based on anticipated project development. The LS meteorological station is about 12 miles northeast from the Permit Area (**Figure 2.5-1**). After deciding to permit the Lost Creek Project before the Lost Soldier Project, the Lost Creek (LC) meteorological station was installed within the Lost Creek Permit Area in May 2007 to collect on-site data (**Figure 2.5-1**). Information collected from the LS and Muddy Gap stations was originally used to describe on-site conditions, due to the relatively short duration of the LC record at that time; additional data from the LC station has since been incorporated in this document. NRC also requested information as to the applicability of the LS data to the LC site [Request for

Additional Information (RAI) from NRC (Nov 2008 RAI Section 2.9 #7)], and that information has also been incorporated. The original presentation of the data (in either tables or figures) has been retained, and the more recent comparisons added. For example, the original comparison of temperature data from the LS and Muddy Gap stations was included in **Table 2.5-1**. That table has been renumbered as **Table 2.5-1a,** and the comparison of temperature data from the LC, LS, Muddy Gap, Jeffrey City, and Rawlins stations added as **Table 2.5-1b**.

Meteorological instrumentation at the LS and LC stations consists of the following sensors mounted on a 10 m tower:

- Vaisala Temperature and Relative Humidity Probe: temperature range of -40 to 60°C; accurate to ±2% at 10-90% relative humidity and to ±3% at greater than 90% humidity; shielded by RM Young 10-Plate Gill Solar Radiation Shield and mounted at 2 m.
- Dual Met One Model 062 Temperature Probes: used for measurement of differential temperature (ΔT) for dispersion and inversion modeling; temperature range of -50 to 50° C; sensors accurate to ±0.05° C; sensors co-calibrated for a maximum error per degree of differential temperature of 0.02° C; shielded by Met One Model 077 Aspirated Shields and mounted at 2 m and 10 m.
- Met One 3-Cup Anemometer and Wind Vane: range of 0 to 50 m/s (0 to 110 mph); anemometer accurate to ±0.11 m/s when less than 10.1 m/s or ±1.1% of true when greater than 10.1 m/s; vane accurate to ±4°; mounted at 10 m.
- Texas Electronics Tipping Bucket Rain Gage with 8" Orifice: accurate to ±1% at rain fall rates up to 1 inch/hour; resolution of 0.01 inches; mounted on freestanding post approximately 1 m high, and 5 m from tower.
- LI-COR Silicon Pyranometer: measures incoming radiation with wavelengths in the daylight spectrum; measures wavelengths between 400 and 1100 nm; accurate to within 3-5%; mounted at 10 m.

The sensors were connected to a Campbell Scientific CR10X data logger at the LS station and a CR1000 data logger at the LC station. The data recovery rate for each station was greater than 90 percent.

2.5.1.1 Temperature

Based on the Muddy Gap data, July is the warmest month; the average maximum daily temperatures are approximately 85°F; and the average minimum daily temperatures are approximately 55°F. January is the coldest month; the average daily maximum temperatures are 30 to 35°F; and the average minimum daily temperatures are approximately 10 to 15°F. The maximum temperature on record is 100°F in July, while the minimum temperature on record is -40°F in December. The average monthly temperatures at the LS station collected in 2006 and 2007 were generally within range of the long-term averages at Muddy Gap. Temperature data from these stations that was available at the time the TR was originally submitted, in October 2007, are compared in **Table 2.5-1a**.

Average monthly high and low temperatures from LC and four of the closest stations (LS, Muddy Gap, Jeffrey City, and Rawlins), including data available after October 2007, are compared in **Table 2.5-1b**. The LC data is generally within the range of the other stations, with the exception that temperatures in the winter months appear to be somewhat lower. However, that is probably due to the short record for LC (in some cases just one month), as compared to the other stations.

2.5.1.2 Precipitation

The Permit Area is drier than many areas in the State of Wyoming. **Figure 2.5-2a** shows the total monthly precipitation for available Muddy Gap and LS data at the time the TR was originally submitted in October 2007.

The mean annual precipitation at the Muddy Gap station from 1949 through 2005 was 10.0 inches. Precipitation is distributed throughout the year, but the mean monthly precipitation exceeds one inch only in April, May, and June. May is the wettest month, with 1.9 inches of mean precipitation. Actual annual moisture may be somewhat higher, since precipitation gages capture only a small proportion of snowfall under windy conditions.

The precipitation at the LS station from May 2006 to April 2007 showed that precipitation for this period was much lower than normal. Regional data showed the area received 50 to 70 percent less rainfall than average (HPRCC, 2007b).

Average monthly precipitation data from LC and four of the closest stations (LS, Muddy Gap, Jeffrey City, and Rawlins), including data available after October 2007, are compared in **Figure 2.5-2b**. The LC data is within the range of the other stations, taking into account the variability in precipitation amounts due to local thunderstorms and the recent regionally low precipitation.

2.5.1.3 Humidity and Evaporation

The average relative humidity at the Permit Area is low in the summer, with the lowest average occurring in June (30.2 percent). The relative humidity is elevated during the winter, where the highest average occurred in February (75.6 percent). The monthly maximum and minimum humidity measured at the LS meteorological station is provided in **Table 2.5-2a** and the average monthly maximum and minimum humidity measured at the LC and LS meteorological stations is provided in **Table 2.5-2b**.

Information on total evaporation by month is included in **Section 3.7.1.5** and **Table 3.7-4** of the Lost Creek Environmental Report (ER).

2.5.1.4 Wind, Mixing, and Stability

The annual average wind speed at a height of ten meters measured between April 2006 and April 2007 was 23 feet per second (ft/s) (7.0 meters per second [m/s]) at the LS meteorological station located near Bairoil, about 15 miles from the Permit Area. The wind speed is highest in February and November (29.9 and 29.2 ft/s or 9.1 and 8.9 m/s, respectively). The lowest wind speeds occur in July and August (16.4 and 16.7 ft/s or 5.0 and 5.1 m/s, respectively). The prevailing wind direction is from the west-northwest and west for most of the year (**Figure 2.5-3a**), with some variability occurring in the spring. The wind data from the LC station is compared to that from the LS station in **Figure 2.5-3b**. The predominant wind at the LC station is from the west-northwest and from the west-southwest at the LS station. The differences may be due to topographic variability or due to the relatively short period of record, particularly given the weather variability over short distances (e.g., summer thunderstorms)

Atmospheric stability was categorized into six classes according to Pasquill (Pasquill, 1961). Calculations were made using wind speed and solar radiation data collected at the site. The data show that relatively stable conditions (stability class D, E, or F), which contribute to good dispersion conditions, occur 87 percent of the time, making atmospheric inversion conditions unlikely. The stability class distribution at the LS station for January 2007 through December 2007 is shown in **Table 2.5-3.** The stability classes for the two stations are essentially the same (**Figure 2.5-4**). Data collected for Lander/Riverton Wyoming indicated that the average annual mixing height is 348 meters in the morning and 2,300 meters in the afternoon. These can also be considered the inversion heights (Holzworth, 1972).

2.5.1.5 Violent Weather

Tornadoes are more prevalent in eastern Wyoming than in western Wyoming, because mountain ranges in western Wyoming are barriers to the flow of warm, moist air that causes tornadoes. In Sweetwater County, 19 tornados were reported in a 55-year period, none of which caused an injury or death. An individual tornado would affect only a portion of the County; therefore, chances are small that the Permit Area would experience a tornado. The Fujita Scale is used to rate the intensity of a tornado by examining the damage caused to man-made structures (The Tornado Project, 2003). The most destructive tornado recorded in Sweetwater County from 1950 to 2004 was an F-1 “moderate” tornado, which would be unlikely to cause extensive damage to the Project.

The Permit Area is located in an area that has statistically shown lower density of lightning strikes. The probability of hail is also low, with six occurrences recorded in a 24-year period (Curtis and Grimes, 2007).

Although severe winter storms are generally less violent than summer storms, the relative duration of the winter storms (a day or more) compared to summer storms (generally a few hours) and the combination of heavy snow, strong winds, and low temperatures require that all Wyoming residents be aware of and prepared for the possibility. A history of blizzards in Wyoming is provided in Chapter 19 of the State of Wyoming Multi-Hazard Mitigation Plan (WOHS, 2008).

2.5.2 Air Quality - Non-Radiological Parameters

The overall air quality in the Project region is good. The area is sparsely populated and is not heavily developed with industrial sources of air pollution. Air quality for radiological parameters is discussed in Section 2.5.9. (Measurement of natural gamma and Rn-222 was originally discussed in this section, but has been moved to Section 2.9 (Background Radiological Characteristics).)

Air Quality Standards

National Ambient Air Quality Standards (NAAQS) exist for sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), ozone (O_3), lead, and particulate matter small enough to move easily into the lower respiratory tract (particles less than ten micrometers in aerodynamic diameter, designated Particulate Matter [PM_{10}]). The NAAQS are expressed as pollutant concentrations that are not to be exceeded in the ambient air, that is, in the outdoor air to which the general public has access (40 CFR Part 50.1(e)). Primary NAAQS are designated to protect human health; secondary NAAQS are designated to protect human welfare by safeguarding environmental resources (such as soils, water, plants, and animals) and manufactured materials. Primary and secondary NAAQS are presented in **Table 2.5-4**. The closest monitoring station to the Permit Area is in Rawlins, and shows that regional air quality is in compliance with the NAAQS and Wyoming Ambient Air Quality Standards (WAAQS) (BLM, 2004c).

In addition to ambient air quality standards, which represent an upper bound on allowable pollutant concentrations, there are national standards for the Prevention of Significant Deterioration (PSD) of air quality (40 CFR § 51.166). The PSD standards differ from the NAAQS in that the NAAQS provide maximum allowable concentrations of pollutants, while PSD requirements provide maximum allowable increases in concentrations of pollutants for areas already in compliance with the NAAQS. PSD standards are, therefore, expressed as allowable increments in the atmospheric concentrations of specific pollutants.

Allowable PSD increments currently exist for three pollutants: NO_2, SO_2, and PM_{10}. Increments are particularly relevant when a major proposed action (involving either a new source or a major modification to an existing source) may degrade air quality without exceeding the NAAQS, as would be the case, for example, in an area where the ambient air is very clean. One set of allowable increments exists for Class II areas, which cover most of the US. A much more stringent set of allowable increments exists for Class I areas, which are specifically designated areas where the degradation of ambient air quality is severely restricted. Class I areas include certain national parks and monuments, wilderness areas, and other areas as described in 40 CFR § 51.166(e) and 40 CFR Part 81:400-437. Maximum allowable PSD increments for Class I and Class II areas are given in **Table 2.5-5**. Class I areas, as designated in the Rawlins Resource Management Plan (RMP), include the Savage Run Wilderness and Rocky Mountain National Park. PSD Class I areas receive the highest degree of protection from air pollution; only small amounts of particulate, SO_2, and NO_2 air pollutants are allowed in these areas (BLM, 2004c).

Air Particulate (PM_{10}) Sampling

Air particulate matter in the Permit Area was sampled using two Mini Volumetric (MiniVol) samplers with ten micron (PM_{10}) filters. Dust trapped by these filters is the size considered most detrimental to human health. Two samplers were used as a pair, with samples collected concurrently, upwind and downwind of the Permit Area, at three locations: Northern (LCAIR9&10); Central (LCAIR13&14); and Southern (LCAIR11&12). The sampling duration was approximately 24 hours, and the results were time-adjusted for a 24-hour period. **Figure 2.5-5** shows the sampling locations, and the results are presented in **Table 2.5-6**.

The average PM_{10} concentration in June 2006, including both upwind and downwind sampling locations, was 8.5 micrograms per cubic meter ($\mu g/m^3$). The maximum value was 10.5 $\mu g/m^3$ and the minimum value was 5.4 $\mu g/m^3$. For comparison, the average PM_{10} in Casper Wyoming was 18.8 $\mu g/m^3$ from 1990 through 1994 (Natural Resources Defense Council, 2007). At the northern sampling location, the PM_{10} concentration in the upwind sample was more than 70% higher than the downwind sample. At the central and southern sampling locations, the upwind and downwind samples differed by 15% or less. The sample collection runs lasted between 21.5 to 28 hours. In February 2007, the PM_{10} concentration at the central sampling location was about one-half of the concentration in June 2006, possibly due to slightly damper soil conditions.

The NAAQS criteria for PM_{10} set a limit of 150 $\mu g/m^3$ for a 24-hour period, not to be exceeded more than once per year on an average over three years. The data show that for both upwind and downwind locations, this standard was not exceeded. More information on dust and emissions from Project activities are covered in **Section 7.1.7** of this TR, and also in **Section 4.7** of the ER.

Figure 2.5-2a Total Monthly Precipitation in The Project Region

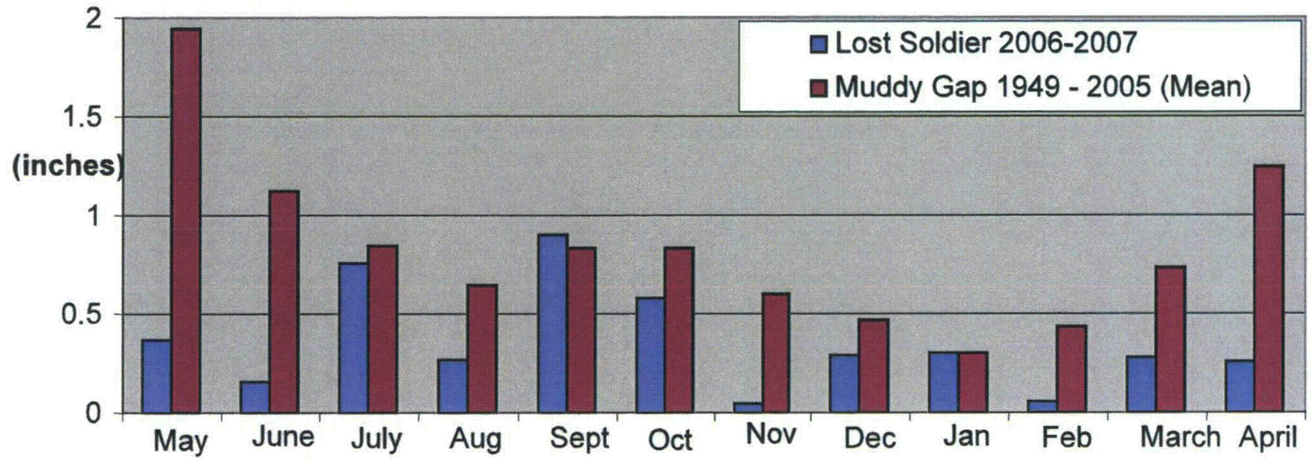


Figure 2.5-2b Total Monthly Precipitation
LC, LS, Muddy Gap, Jeffrey City, and Rawlins Meteorological Stations

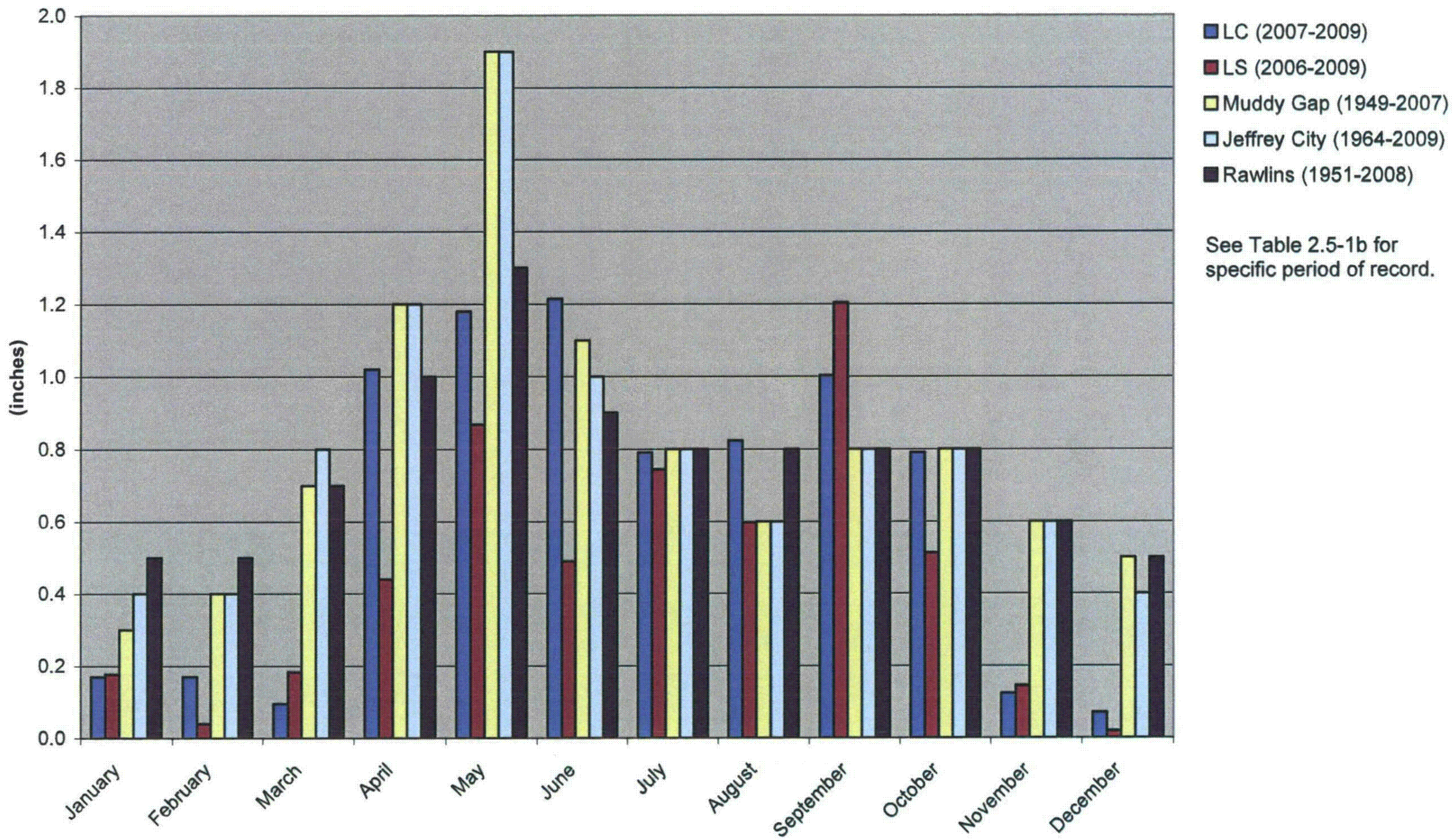


Figure 2.5-3a Wind Speed and Direction at the Lost Soldier Meteorological Station (May 2006-April 2007)

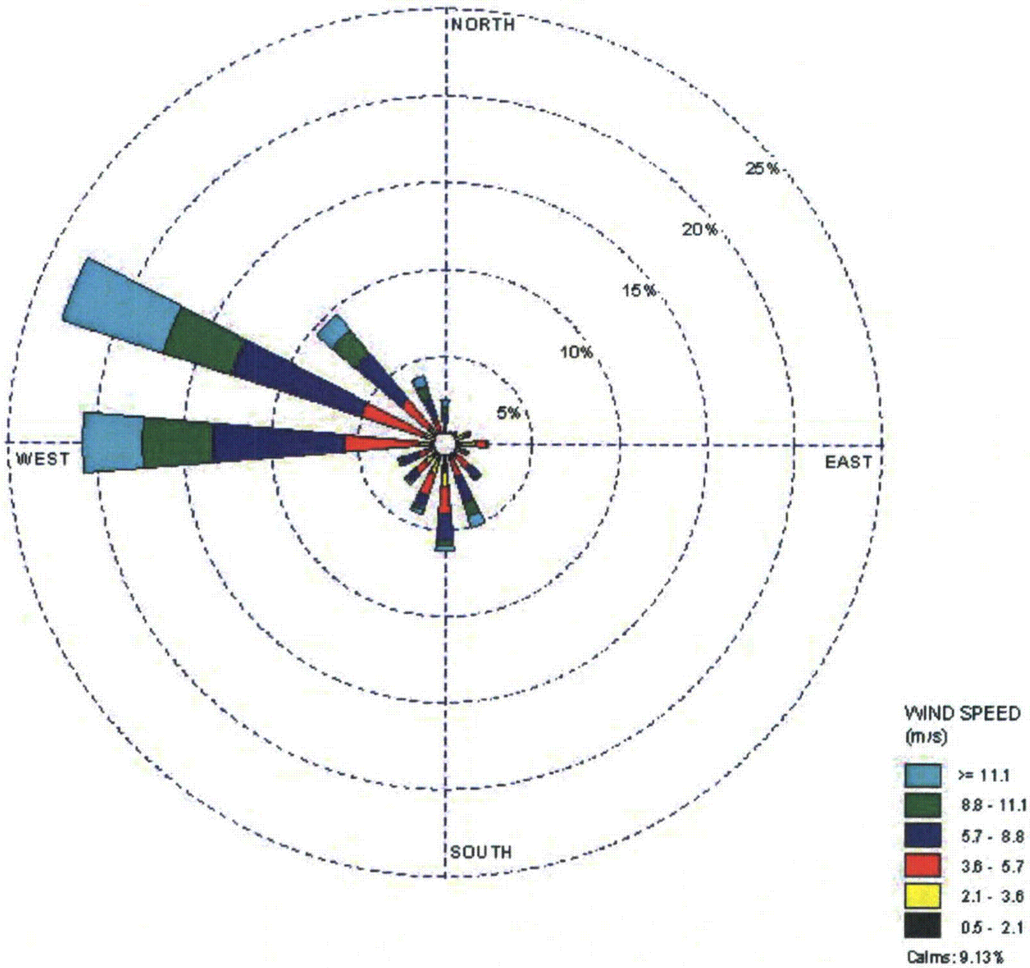
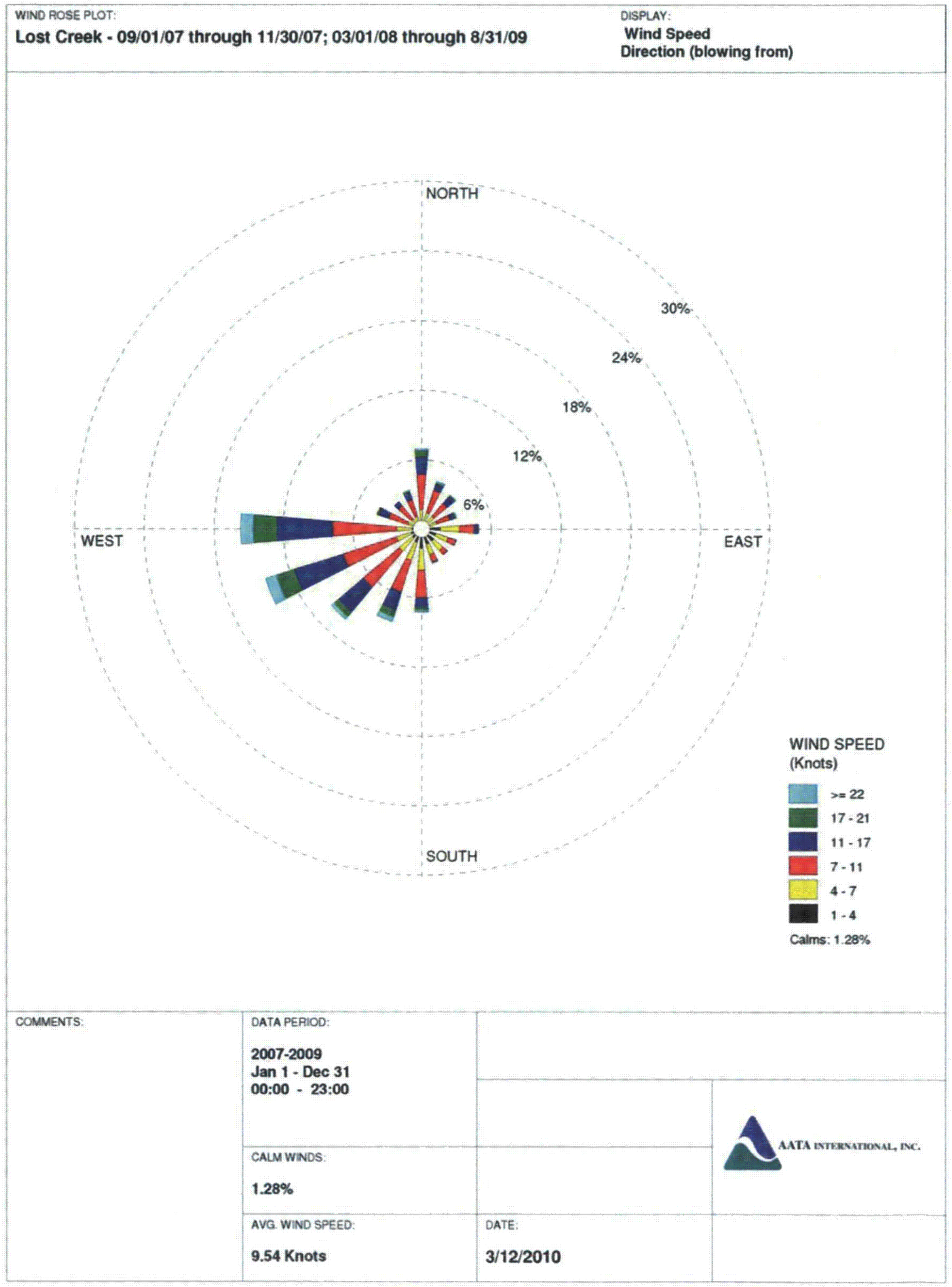


Figure 2.5-3b Wind Speed and Direction at the LS and LC Meteorological Stations



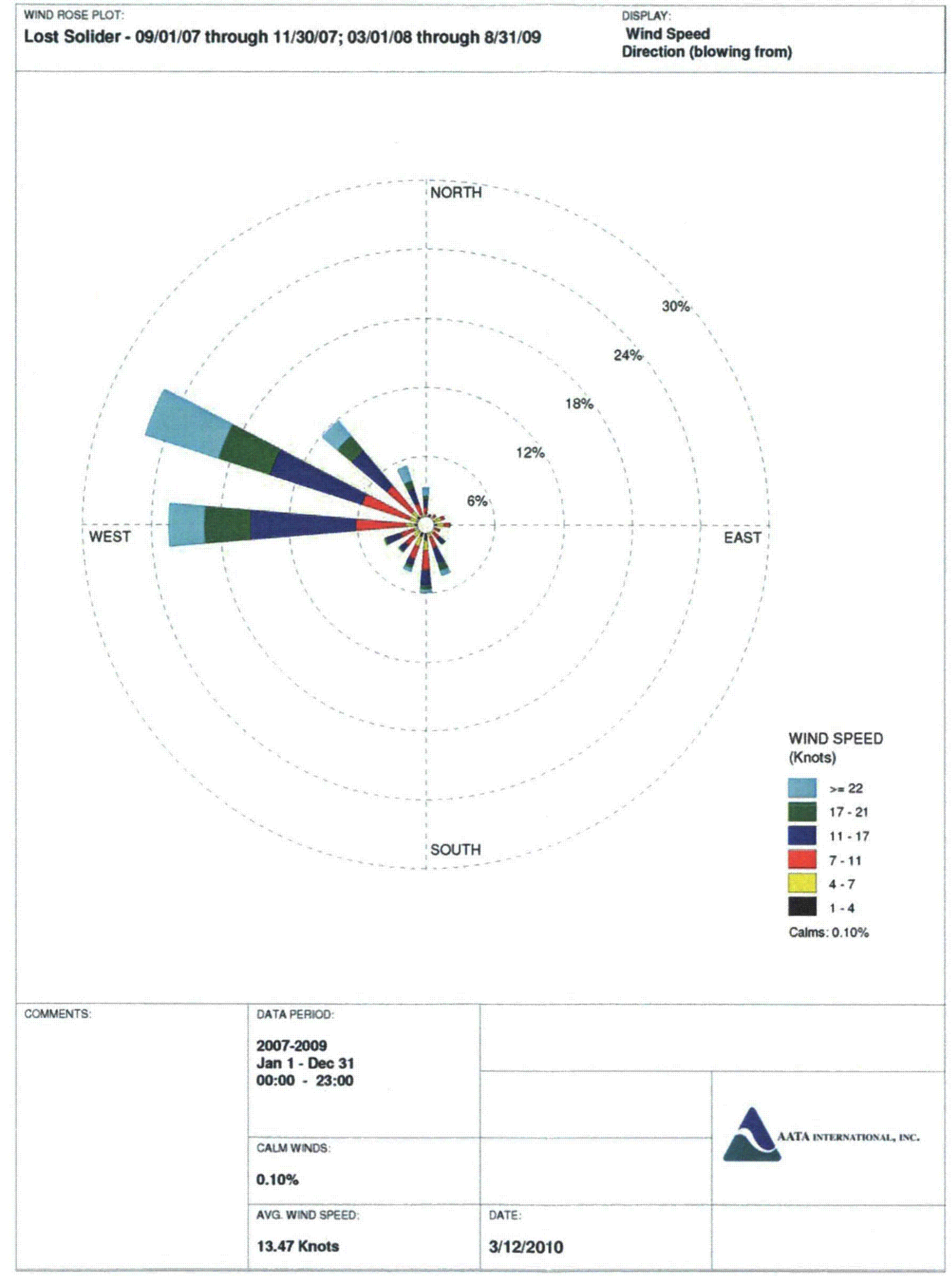
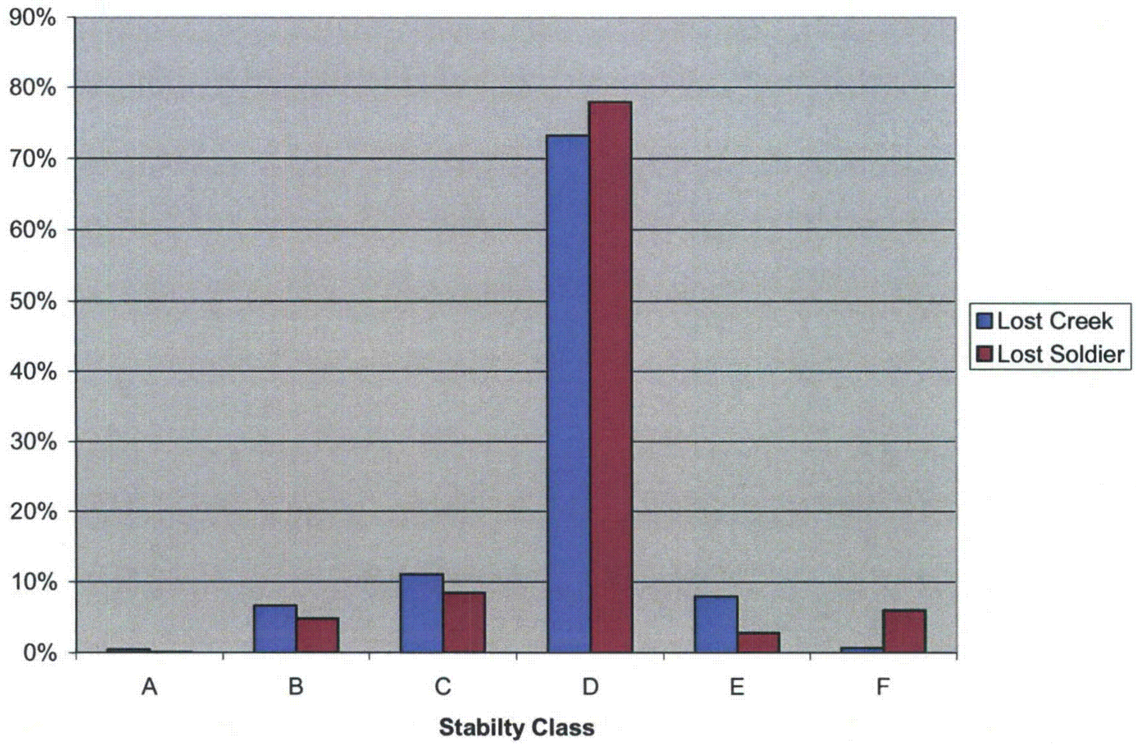


Figure 2.5-4 Comparison of LC and LS Stability Data



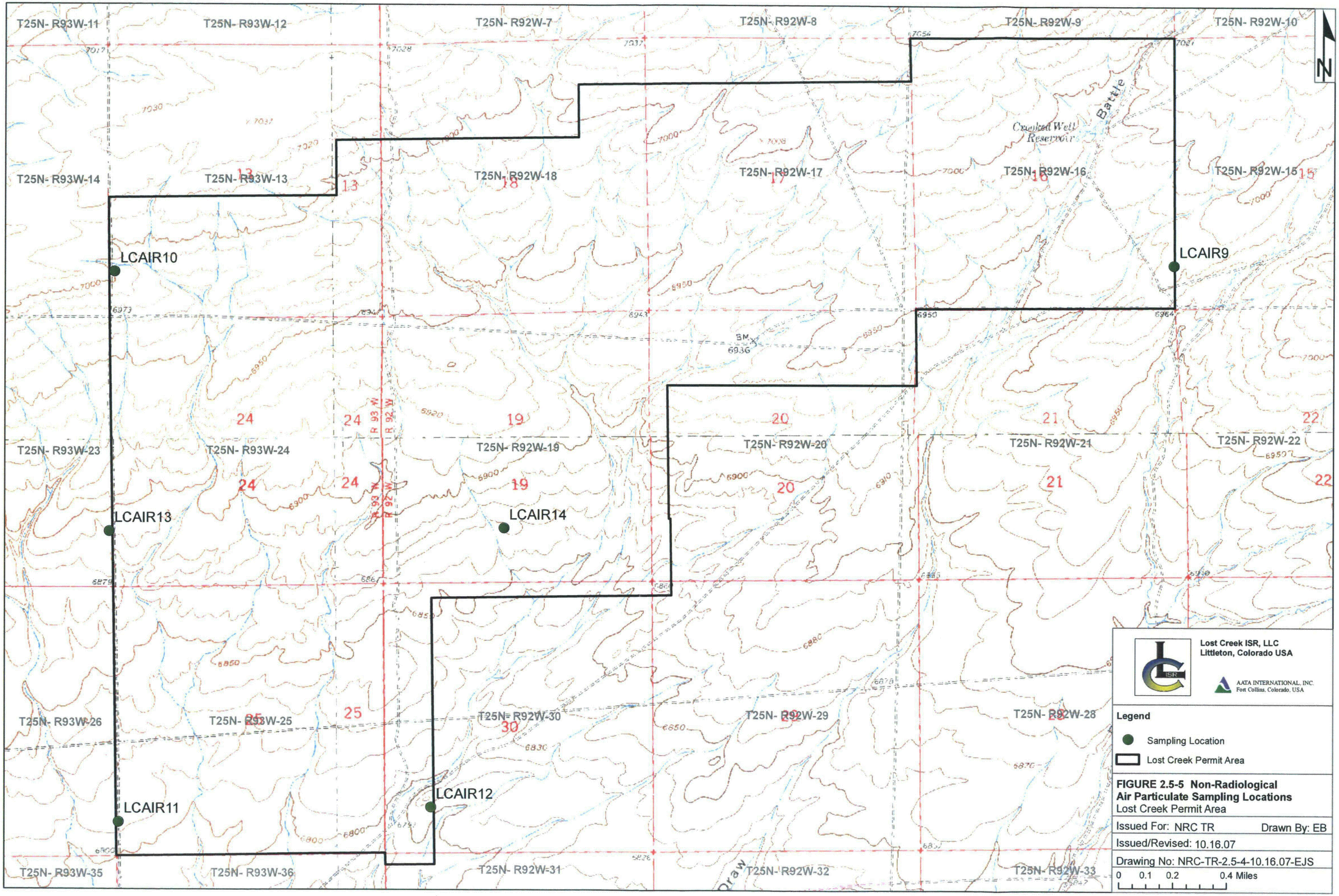


FIGURE 2.5-5 Non-Radiological Air Particulate Sampling Locations
Lost Creek Permit Area

Issued For: NRC TR Drawn By: EB
Issued/Revised: 10.16.07
Drawing No: NRC-TR-2.5-4-10.16.07-EJS

Table 2.5-1a Comparison of Temperature Data

Month	Lost Soldier Meteorological Station (2006)			Muddy Gap (1949 through 2005)		
	Average Temperature (° F)	Maximum Temperature (° F)	Minimum Temperature (° F)	Mean Temperature (° F)	Mean Maximum Temperature (° F)	Mean Minimum Temperature (° F)
April [1]	42.1	54.7	30.1	42.6	55.5	29.6
May	51.8	64.0	39.5	52	66	37.9
June	64.2	77.6	50.2	62.5	78	46.9
July	70.0	82.0	57.3	69.6	85.5	53.6
August	65.1	78.4	52.2	68.3	83.9	52.7
September	51.3	61.9	40.7	58.3	73	43.6
October	39.0	49.6	29.8	46.9	60	33.7
November	32.0	40.6	23.3	32.3	41.8	22.8
December	21.9	34.3	49.9	23.8	32.7	14.9
January	12.6	18.7	4.0	22.7	31.4	14
February	23.7	31.6	16.6	26.2	35.5	16.8
March	34.8	45.8	26.4	34.6	45.5	23.7
April [1]	35.1	45.9	23.8	42.6	55.5	29.6
Annual	41.8	52.7	34.1	45	57.4	32.5

[1] partial month

Table 2.5-1b Comparison of Temperature Data (degrees Farenheit)
LC, LS, Muddy Gap, Jeffrey City, and Rawlins Meteorological Stations

Station	Lost Creek		Lost Soldier		Muddy Gap		Jeffery City		Rawlins	
	Avg. High	Avg. Low	Avg. High	Avg. Low	Avg. High	Avg. Low	Avg. High	Avg. Low	Avg. High	Avg. Low
Period of Record included in Comparison	7/07 - 11/07; 3/08 - 11/09		5/06 - 11/08; 1/09 - 8/09		10/19/1949 - 12/31/2007		4/10/1964 - 6/30/2009		3/6/1951 - 5/31/2008	
January	31.8	5.6	22.4	7.0	31.3	13.8	30.6	8.5	30.8	12.6
February	34.1	9.8	29.5	14.1	34.9	15.9	34.1	10.6	33.8	14.7
March	35.9	11.9	38.0	20.1	43.4	21.4	43.5	18.5	41.3	20.4
April	47.3	22.7	47.0	26.0	55.2	29.2	54.5	26.3	52.6	27.6
May	61.1	34.4	61.0	37.9	66.0	37.9	64.6	34.8	63.9	36.3
June	70.4	41.1	72.4	46.7	76.2	46.4	75.2	42.6	75.4	44.6
July	84.3	50.6	81.6	55.5	85.1	53.5	85.2	49.6	83.8	51.5
August	80.7	48.3	78.4	52.6	83.1	52.2	82.9	48.3	81.1	50.0
September	69.7	38.7	64.7	41.7	72.8	42.5	71.7	38.2	70.5	40.8
October	52.4	26.4	52.6	31.7	59.9	32.9	59.2	28.8	57.0	31.2
November	44.8	18.1	42.5	23.6	42.1	22.1	41.0	17.2	40.7	20.4
December	27.9	4.0	26.0	10.2	32.7	15.2	30.9	9.3	32.0	14.0

Table 2.5-2a Monthly Maximum and Minimum Humidity Measured at the Lost Soldier Meteorological Station

Month	Maximum Humidity (percent)	Minimum Humidity (percent)
Apr 2006	98.6	9.4
May 2006	97.5	6.8
Jun 2006	87.3	5.8
Jul 2006	98.5	8.1
Aug 2006	94.7	6.3
Sep 2006	98.8	8.9
Oct 2006	98.8	11.7
Nov 2006	98.5	13.3
Dec 2006	97.4	28.9
Jan 2007	97.6	37.7
Feb 2007	99.2	31.0
Mar 2007	98.8	15.9
Apr 2007	98.4	12.6

Table 2.5-2b Average Monthly Maximum and Minimum Percent Humidity Measured at the LS and LC Meteorological Stations

		Lost Creek		Lost Soldier	
	Years of Record	Maximum Humidity	Minimum Humidity	Maximum Humidity	Minimum Humidity
January	2009	99.7	17.5	99.8	12.5
February	2009	99.0	20.6	97.3	28.0
March	2008, 2009	97.8	20.7	97.0	22.5
April	2008, 2009	99.1	10.3	98.9	11.6
May	2008, 2009	97.8	20.7	99.3	10.3
June	2008, 2009	97.5	6.5	99.8	7.1
July	2007, 2008, 2009	97.3	5.9	96.3	5.8
August	2007, 2008, 2009	96.8	7.3	95.7	7.2
September	2007, 2008	99.4	8.8	98.7	8.9
October	2007, 2008	97.8	20.7	98.4	11.1
November	2007, 2008	97.9	20.7	99.2	14.8
December	2008	98.4	30.8	96.3	30.5

Table 2.5-3 Distribution of Pasquill Stability Classes at LS (Jan – Dec 2007)

Stability Class	Percent
A	0.1
B	5.1
C	7.5
D	78.4
E	3.0
F	6.0

Table 2.5-4 Primary and Secondary Limits for National Ambient Air Quality Standards (NAAQS) and the state of Wyoming (EPA, 2007)

Pollutant	National			State of Wyoming		
	Primary Standards	Averaging Times	Secondary Standards	Primary Standards	Averaging Times	Secondary Standards
Carbon Monoxide	9 ppm (10 mg/m^3)	8-hour [1]	None	9 ppm (10 mg/m^3)	8-hour [1]	None
	35 ppm (40 mg/m^3)	1-hour [1]	None	35 ppm (40 mg/m^3)	1-hour [1]	None
Lead	1.5 μg/m^3	Quarterly Average	Same as Primary	1.5 μg/m^3	Quarterly Average	Same as Primary
Nitrogen Dioxide	0.053 ppm (100 μg/m^3)	Annual (Arithmetic Mean)	Same as Primary	0.05 ppm (100 μg/m^3)	Annual (Arithmetic Mean)	Same as Primary
Particulate Matter (PM_{10})	Revoked [2]	Annual [2] (Arithmetic Mean)		50 μg/m^3	Annual [2] (Arithmetic Mean)	
	150 μg/m^3	24-hour [3]		150 μg/m^3	24-hour [3]	
Particulate Matter ($PM_{2.5}$)	15.0 μg/m^3	Annual [4] (Arithmetic Mean)	Same as Primary	15.0 μg/m^3	Annual [4] (Arithmetic Mean)	Same as Primary
	35 μg/m^3	24-hour [5]		65 μg/m^3	24-hour [5]	
Ozone	0.08 ppm	8-hour [6]	Same as Primary	0.08 ppm	8-hour [6]	Same as Primary
	0.12 ppm	1-hour [7] (Applies only in limited areas)	Same as Primary			
Sulfur Oxides	0.03 ppm	Annual (Arithmetic Mean)	-------	0.02 ppm (60 μg/m^3)	Annual (Arithmetic Mean)	
	0.14 ppm	24-hour [1]	-------	0.10 ppm (260μg/m^3)	24-hour [1]	
	-------	3-hour [1]	0.50 ppm (1300μg/m^3)	0.50 ppm (1300μg/m^3)	3-hour [1]	

[1] Not to be exceeded more than once per year.
[2] Due to a lack of evidence linking health problems to long-term exposure to coarse particle pollution, the agency revoked the annual PM10 standard in 2006 (effective December 17, 2006).
[3] Not to be exceeded more than once per year on average over 3 years.
[4] In this standard, the 3-year average of the weighted annual mean PM2.5 concentrations from single or multiple community-oriented monitors must not exceed 15.0 μg/m3.
[5] To attain this standard, the 3-year average of the 98th percentile of 24-hour concentrations at each population-oriented monitor within an area must not exceed 35 μg/m3 (effective December 17, 2006).
[6] To attain this standard, the 3-year average of the fourth-highest daily maximum 8-hour average ozone concentrations measured at each monitor within an area over each year must not exceed 0.08 ppm.
[7] a. The standard is attained when the expected number of days per calendar year with maximum hourly average concentrations above 0.12 ppm is < 1, as determined by appendix H.
b. As of June 15, 2005 EPA revoked the 1-hour ozone standard in all areas except the fourteen 8-hour ozone nonattainment Early Action Compact (EAC) Areas.

Table 2.5-5 Allowable Increments for Prevention of Significant Deterioration of Air Quality

Pollutant	Averaging Time	Prevention of Significant Deterioration Increment					
		Class I			Class II		
		µg/m³	ppm	ppb	µg/m³	ppm	ppb
Nitrogen Dioxide NO_2	Annual	2.5	0.0013	1.3	25	0.013	13
Particulate Matter PM_{10}	24-hour	8			30		
	Annual	4			17		
Sulfur Dioxide SO_2	3-hour	25	0.0096	9.6	512	0.1956	196
	24-hour	5	0.0019	1.9	91	0.0348	35
	Annual	2	0.0008	0.8	20	0.0076	8

Table 2.5-6 PM_{10} Concentrations at Lost Creek

Location	Date	Wind Speed (mi/hr)	Upwind Sample	Concentration (μg/m^3)	Downwind Sample	Concentration (μg/m^3)
Northern	6/24/2006	10.1	LCAIR10	9.3	LCAIR9	5.4
Central	6/26/2006	10.3	LCAIR13	10.5	LCAIR14	9.1
Southern	6/25/2006	n/a	LCAIR11	8.0	LCAIR12	8.9
Central	2/7/2007	7.2	LCAIR16	4.7	LCAIR15	3.7