Fugitive Dust Accumulation in Drifted Snow at the Red Dog Mine, Winter 2004- 2005

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Introduction

Dark gray dust in snow has been observed annually in Spring at the Red Dog Mine. See Photo 2 and 3. Soil samples gathered in the summer of 2005 suggested that metal values from soils under snow drift areas downwind of the Mine were higher than non-drifted areas. Logic suggests that because both snow and fugitive dust are airborne particles they should both accumulate in greater abundance in quiet areas on the lee sides of buildings and hills. In April of 2005 Teck Cominco Alaska Incorporated sampled five different snow accumulations to investigate the concentration of fugitive dust in drift and non-drift areas.

Methodology

Field Sampling

Three sample locations were selected for this investigation. (see Photo #4)

- An upwind site was chosen 7,800 feet east-northeast of the gyratory crusher.
- A downwind site was chosen 3,000 feet west-northwest of the gyratory crusher
- A third site was chosen 7,200 feet southwest of the gyratory crusher west of the tailings pond.

The upwind site was expected to have less lead and zinc in it than the downwind site. The tailings pond site was from an area that had moderately elevated fugitive values from dust fall jar accumulations.

At the upwind location three samples were taken. One sample was from a drifted area with 69 inches of snow and two where taken from a non-drifted area with 6.6 inches of snow, one of which was a field duplicate.

At the downwind location two samples were taken, one from a drift with 39.8 inches of snow and the other a non-drift area with 10.5 inches of snow.

At the west tailings location two samples were taken from a drift with 42.9 inches of snow, one of which was a field duplicate.

At each sample site ten incremental sample plunges were made with a U. S. Department of Agriculture Soil Conservation Service 1.5 inch diameter snow coring tool from an area that was nominally 30 by 30 feet. The snow from each area was composited into one sample and placed in plastic bags. Coordinates were recorded on opposite corners of each sample area using a hand-held GPS receiver. The contained water was determined in the field by weighing the core tube with a scale calibrated in inches of water.

Laboratory

Each snow composite was melted, weighed and then boiled to dryness in a large beaker. The dry sample was weighed again to determine the mass of solids.

The dried solids were dissolved in 50 ml of deionized H_2O + 20 ml of HCl +10 ml of HNO_3 for 15 minutes then diluted to 100 ml and analyzed by Atomic Absorption methods to determine mg/l of Zn, Pb and Cd.

Results of the analyses are shown in Table 1.

Discussion of Results

Weather

In order to properly interpret the results of the snow sampling an examination of snow events and wind speed and direction at Red Dog is required.

Wind direction and precipitation from the Bons and Mill weather stations for the winter of 2004 was examined to determine the hourly wind direction for hours when it snowed more than 0.2 mm per hour vs. hours when it did not snow or snowed less than 0.2 mm per hour. Snow at less than 0.2 mm per hour is often associated with ice fog and low wind velocity.

During snow periods the winds at Red Dog were from the southeast and average 6.8 meters per second (15.2 mph). During non-snow periods the winds averaged from the east-northeast at 4.9 meters per second (10.9 mph). See Chart 1.

Most of the snow drifts at Red Dog are formed during snow storms. Only a minimal amount of wind will form drifts during snow fall because the snow particles are already in suspension. During snow storms very little fugitive dust is released because the snow covers the exposed dust sources and the absolute humidity is higher. Between storms, fugitive dust can settle out on top of previously accumulated snow. Cross sections of snow drifts at Red Dog show alternating thick layers of clean snow deposited during storms with thinner layers of snow discolored by dust.

When comparing concentrations the data indicates non-drift areas have a higher concentration of dust than drift areas. This is most likely attributed to the non-drift areas accumulating less snow than drift areas during storm events. The extra snow in drift areas from storm events dilutes the fugitive dust component. See Table 1, Solids in snow mg/l, Zn in snow mg/l, Pb in snow mg/l and Cd in snow mg/l.

Because the drifts contain much more snow than the non-drift areas the total load of solids in drift areas is higher than the non-drift areas even though the drifts have less in terms of concentration.

Tapered Element Oscillating Microbalance (TEOM) readings of Total Suspended Particulates (TSP) have shown that on calm days with temperature inversions dust concentration in the air increases. This dust most likely falls uniformly on the snow in the mine area and along the Red Dog Creek valley. When the wind is greater than 3.6 meters per second (8 mph), snow and the fugitives within it become airborne and move to the drift areas. Therefore the remobilization of the dust on non-snow days occurs when winds at Red Dog exceed 3.6 meters per second (8 mph) which is bout 48% of the time. See Table 2 and Chart 2.

When fugitives move with snow on non-snow days they typically move on east-northeast winds and accumulate in north-northwest trending drifts. Drifts formed during snow events tend to accumulate in northeast trending drifts. This would imply that north-northwest trending drifts might have more fugitive concentration than northeast trending drifts. This thesis was not tested in this study.

Dust Composition

The zinc to lead metal ratios in dust in the downwind and tailings pond sample areas are very close to the values measured at the PAC and Tailings TEOM monitors. Ratios of zinc to lead in all the sample areas are 2-4 to 1, very similar to the range of metal ratios determined in TSP samples. The presence of elevated total metal values in the upwind location supports the idea that much of the dust accumulation in that area occurs on inversion days when dust from operations moves outward in all directions from the source areas. Accumulation from inversions is evident in the oblique Photo 1.

For each pair of samples in the upwind and downwind areas the metal concentration in the total solids (total mass of dust) from drift and non-drift areas was approximately equal. Both samples of the west tailings area were also similar. Concentration of metals in dust appears to be dependent on the source(s) of dust that settles in a particular area and not on the accumulation rate in an area.

Dust Accumulation Rates

For each sample collected the total area of the sample can be calculated knowing the diameter of the snow sampler and the number of plunges taken at each site. Each sample consisted of ten plunges and the resultant calculated area sampled was 0.0114 m^2. The first snow fall that was substantial enough not to melt fell on September 13, 2004, and the snow samples were taken April 16, 17 and 18, 2005. Therefore the number of days that fugitives collected in the sampled snow was 215 – 217 days. Dust accumulation rates were calculated as follows and are contained in Table 1.

$$D_a = C / A / S$$

Where:

“D_a” is the accumulation rate in mg/m^2/day
“C” is the sample concentration in mg

"A" is the area of the sampler times ten in meters squared (0.0114)
"S" is the number of days of snow fall

Dust accumulation rates were determined from dust fall jars for the period November 11, 2004 to May 20, 2005 and the lead accumulation rates are plotted with the lead accumulation rates determined from snow samples in Figure 1. The data indicates accumulation rates from non-drift snow samples are higher than rates from nearby dust fall jars. It is suspected that accumulation rates determined from dust fall jars are minimum values because of the potential for wind scouring inside the jar which may remove some previously deposited dust.

Accumulation of fugitives on snow appears to be more representative than accumulation in dust fall jars however accumulation of fugitives in snow is affected by drifting. All of the drift sample accumulation rates were significantly higher than non-drift sample accumulation rates and nearby dust fall jars accumulation rates.

Table 1 Location, Analysis and calculated parameters for each snow sample.

Lab Num	02-22	02-23	02-27	02-24	02-28	02-25	02-26	02-29
Site Name	Upwind Scour 1	Upwind Scour 2	Upwind Drift	Downwind Scour	Downwind Drift	W. Tailings Pond 1 Drift	W. Tailings Pond 2 Drift	Blank
Easting (ft.)	591,757	591,757	591,656	581,447	581,354	578,504	578,504	NA
Northing (ft.)	5,148,104	5,148,104	5,148,032	5,146,311	5,146,223	5,141,118	5,141,118	NA
Date	18-Apr-05	18-Apr-05	17-Apr-05	17-Apr-05	17-Apr-05	16-Apr-05	16-Apr-05	NA
Snow depth	6.6	6.6	69	10.5	39.75	42.9	42.9	NA
inches H20	3.75	3.75	30.75	3	15.75	13.2	13.2	NA
Snow gm	1091.49	1012.14	7138.65	1037.82	3754.54	3518.09	3463.84	1053.34
Solids mg	50.00	80.00	260.00	90.00	200.00	200.00	240.00	10.00
Zn mg	0.45	0.26	1.57	2.60	7.88	10.46	12.68	0.04
Pb mg	0.10	0.09	0.65	0.78	2.47	2.67	3.22	<0.01
Cd mg	0.01	0.01	0.03	0.04	0.11	0.12	0.15	<.01
Solids in snow mg/l	45.81	79.04	36.42	86.72	53.27	56.85	69.29	9.49
Zn in snow mg/l	0.41	0.26	0.22	2.51	2.10	2.97	3.66	0.04
Pb in snow mg/l	0.09	0.09	0.09	0.75	0.66	0.76	0.93	BD
Cd in snow mg/l	0.01	0.01	0.00	0.04	0.03	0.03	0.04	BD
% Zn in solids	0.90%	0.33%	0.60%	2.89%	3.94%	5.23%	5.28%	0.40%
% Pb in solids	0.20%	0.11%	0.25%	0.87%	1.24%	1.34%	1.34%	BD
% Cd in solids	0.02%	0.01%	0.01%	0.04%	0.06%	0.06%	0.06%	BD
Zn Deposition mg/m2/day	1.82	1.05	6.38	10.56	32.00	42.67	51.73	NA
PB Deposition mg/m2/day	0.40	0.36	2.67	3.17	10.03	10.89	13.14	NA
Cd Deposition mg/m2/day	0.04	0.04	0.12	0.16	0.45	0.49	0.61	NA
Solids Deposition mg/m2/day	202.10	323.36	1055.80	365.47	812.15	815.93	979.11	NA

Table 2 Distribution of hourly wind speeds during No Snow and Snowing events. Shaded area indicates wind speeds at which drifting is unlikely to occur.

No Snow < 0.2 mm / hr	**Frequency Hours**	**Percent**	**Cumulative Percent**
Wind speed Meters per second	*4,792*	*96.77*	*96.77*
0 to 1	363	7.58	7.58
1 to 2	820	17.11	24.69
2 to 3	675	14.09	38.77
3 to 4	447	9.33	48.10
4 to 5	402	8.39	56.49
5 to 6	416	8.68	65.17
6 to 7	418	8.72	73.89
7 to 8	332	6.93	80.82
8 to 9	297	6.20	87.02
9 to 10	238	4.97	91.99
10 to 11	186	3.88	95.87
11 to 12	87	1.82	97.68
12 to 13	51	1.06	98.75
13 to 14	32	0.67	99.42
14 to 15	8	0.17	99.58
15 to 16	8	0.17	99.75
16 to 17	4	0.08	99.83
17 to 18	6	0.13	99.96
18 to 19	1	0.02	99.98
19 to 20	1	0.02	100.00

Snow > 0.2 mm / hr	*160*	*3.23*	*100.00*
0 to 1	4	2.50	2.50
1 to 2	7	4.38	6.88
2 to 3	12	7.50	14.38
3 to 4	14	8.75	23.13
4 to 5	9	5.63	28.75
5 to 6	11	6.88	35.63
6 to 7	28	17.50	53.13
7 to 8	26	16.25	69.38
8 to 9	15	9.38	78.75
9 to 10	9	5.63	84.38
10 to 11	6	3.75	88.13
11 to 12	5	3.13	91.25
12 to 13	9	5.63	96.88
13 to 14	2	1.25	98.13
14 to 15	2	1.25	99.38
15 to 16	0	0.00	99.38
16 to 17	0	0.00	99.38
17 to 18	1	0.63	100.00
18 to 20	0	0.00	100.00

Chart 1. Histogram of hourly wind direction for periods of less than 0.2 mm per hour and greater than 0.2 mm per hour.

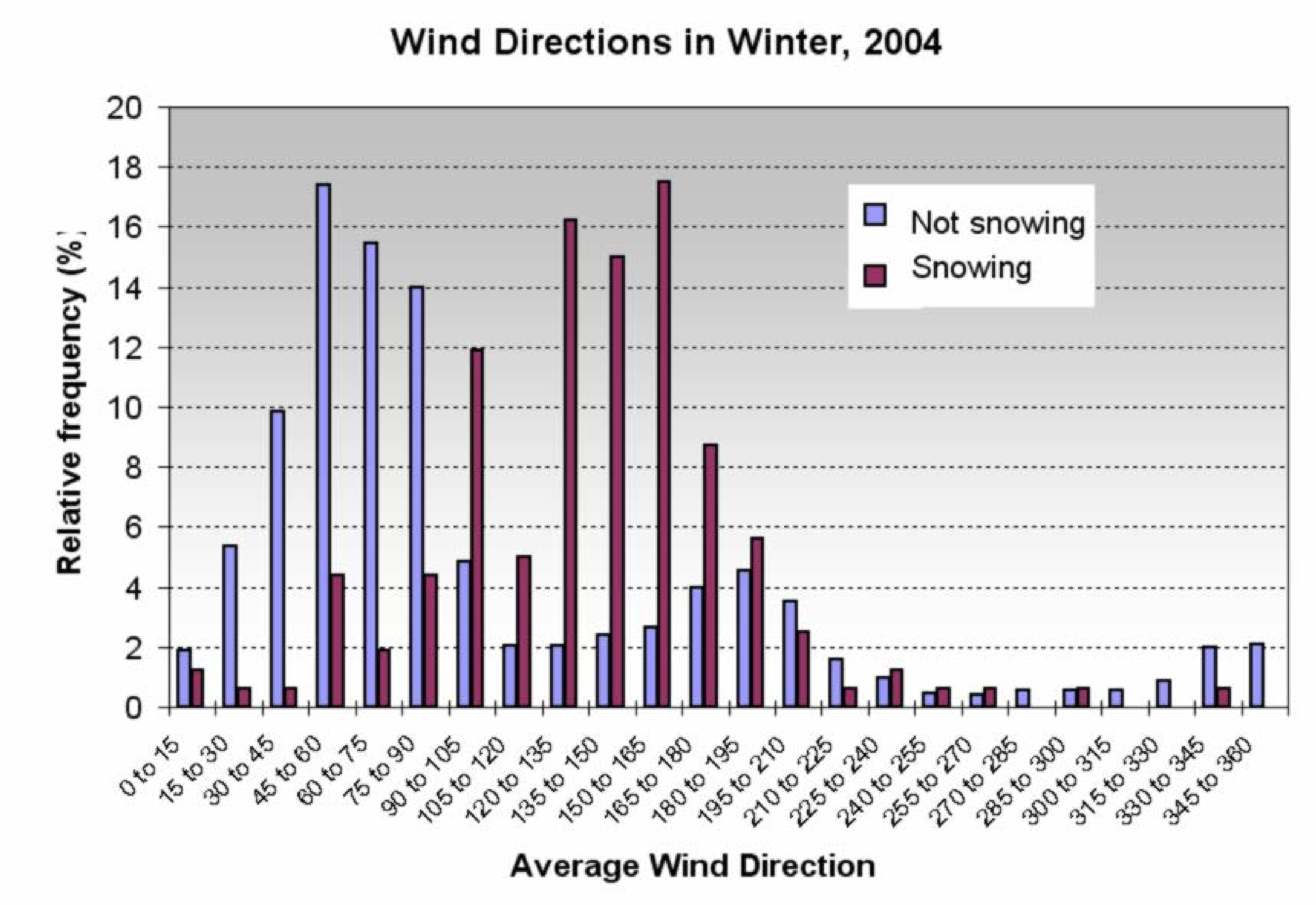
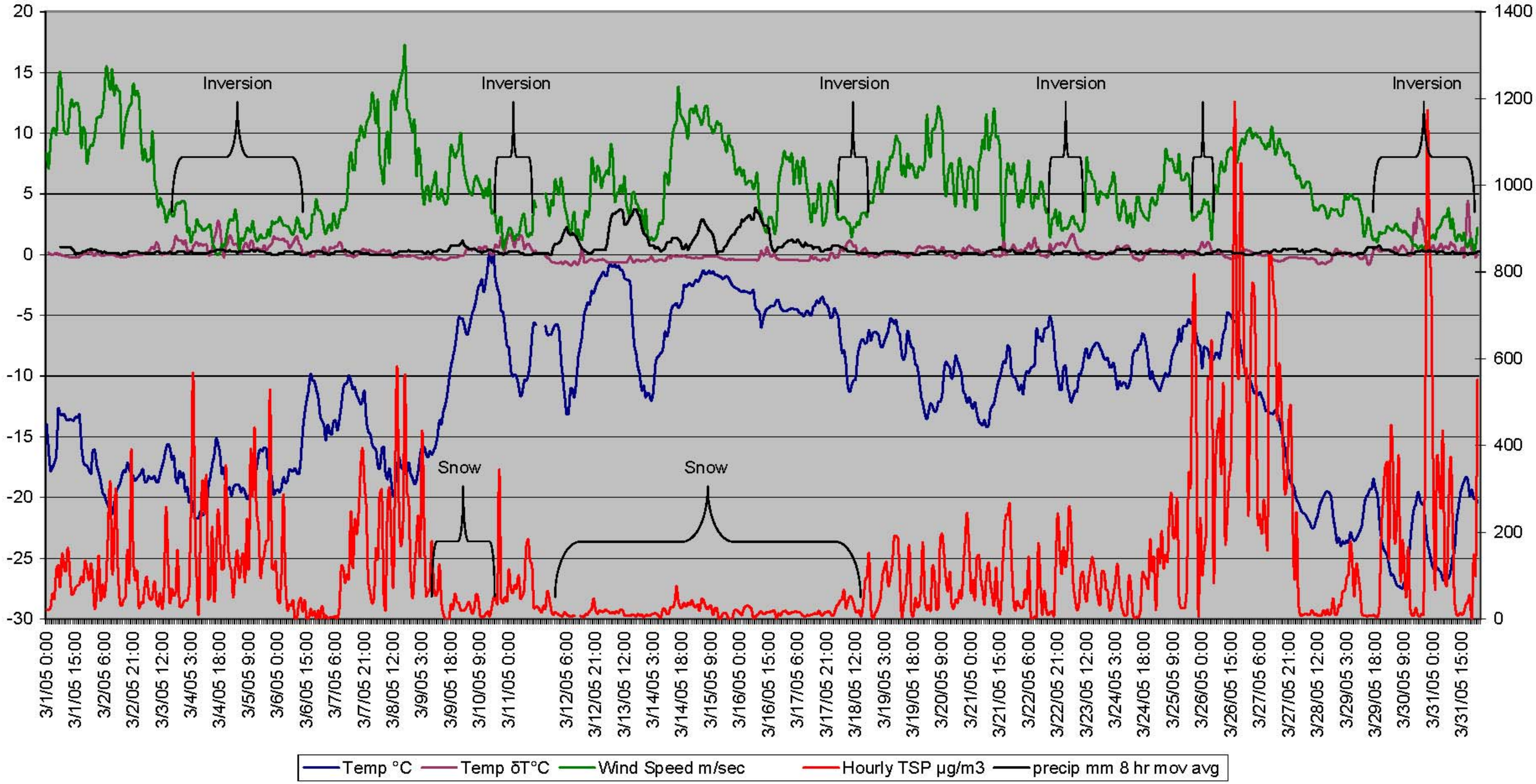


Chart 2. Dust as ug/m^3 vs. weather data showing decreases in dust during snow events and increased dust during inversion and windy events.



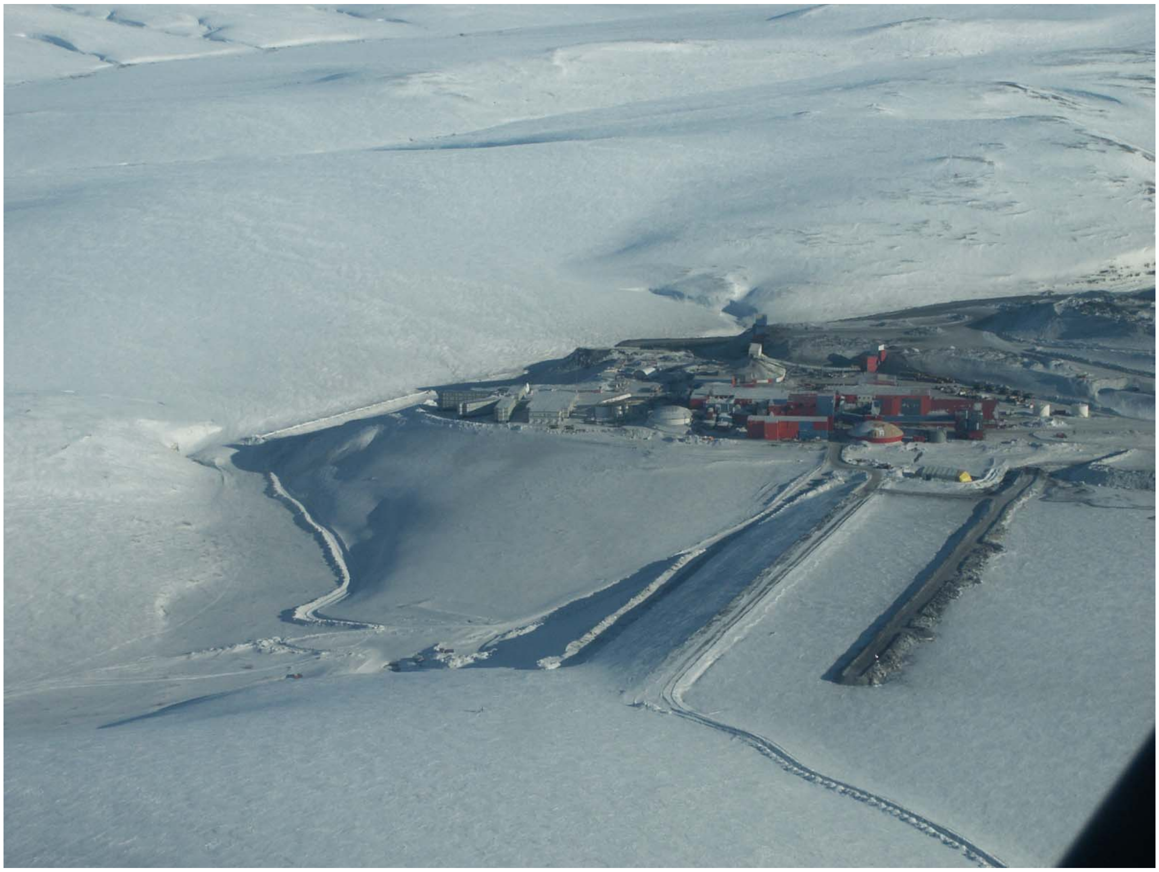


Photo1. Fugitive dust after one week of no new snow March 7, 2005.

Photo 2. Fugitive dust discoloration in snow drifts along Red Dog Creek May 5, 2005.

Photo 3. Fugitive dust discoloration below the PAC . Lighter colored snow is new snow. May 1, 2005

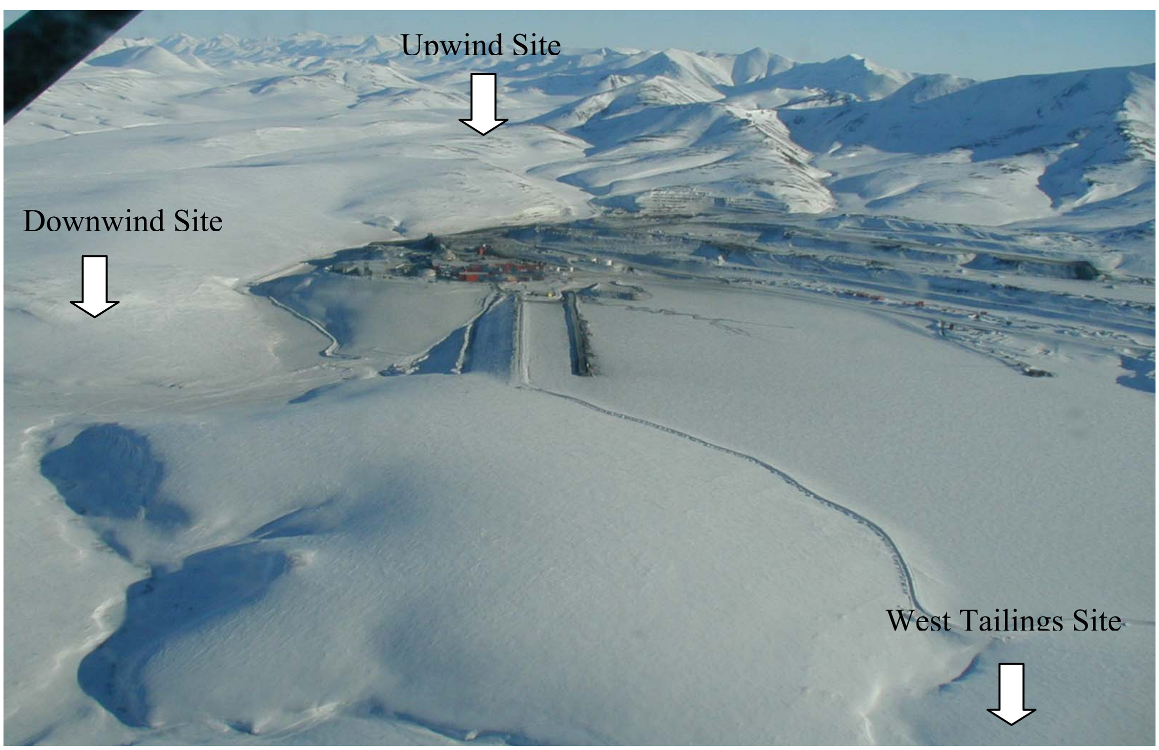
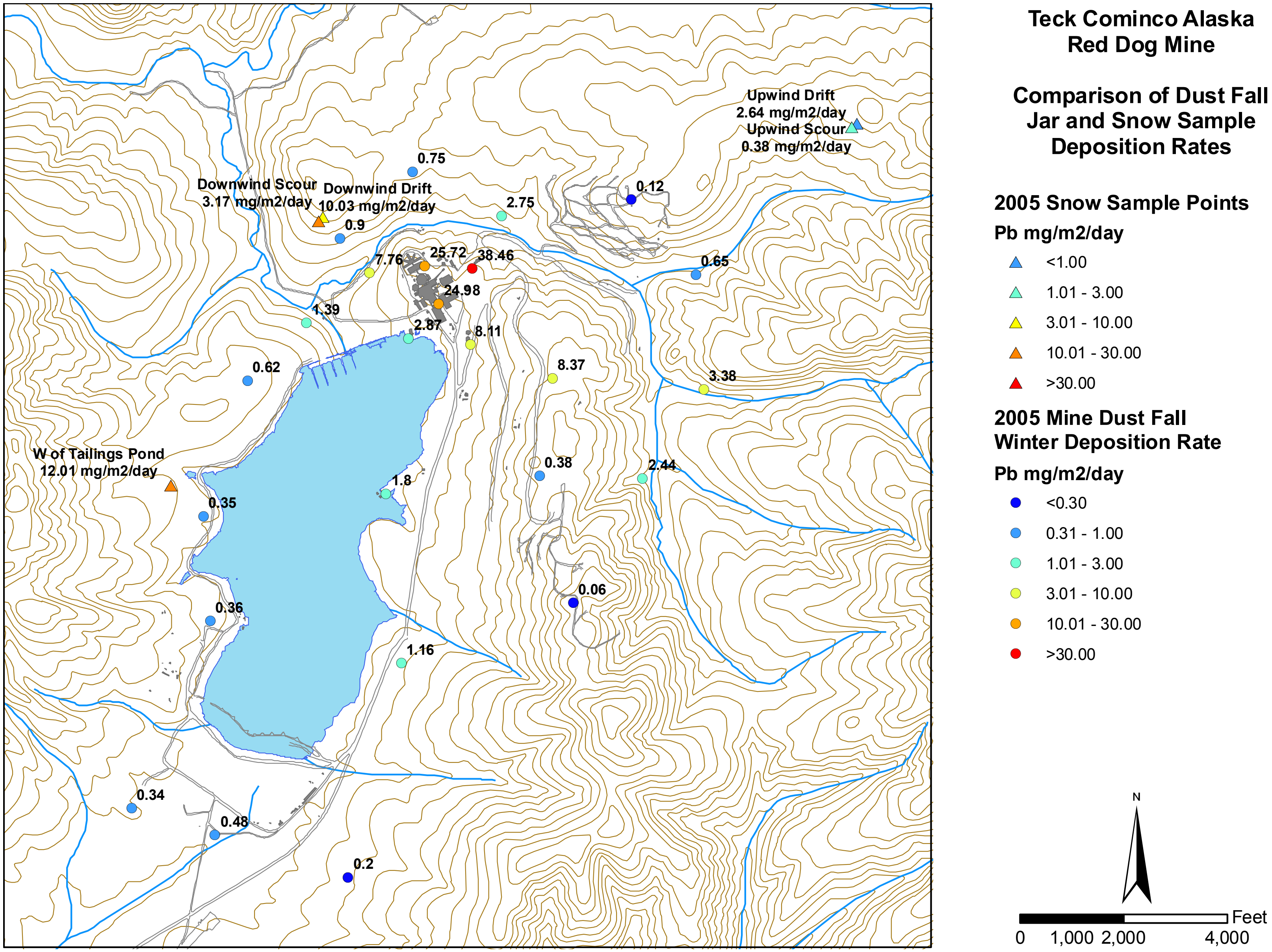


Photo 4. Oblique of Red Dog March 7, 2005 showing snow sample locations.



Upwind Drift
2.64 mg/m2/day
Upwind Scour
0.38 mg/m2/day
0.75
0.12
Downwind Scour
3.17 mg/m2/day
Downwind Drift
10.03 mg/m2/day
2.75
0.9
7.76
25.72
38.46
0.65
24.98
1.39
2.87
8.11
8.37
0.62
3.38
W of Tailings Pond
12.01 mg/m2/day
0.38
2.44
1.8
0.35
0.06
0.36
1.16
0.34
0.48
0.2
Teck Cominco Alaska
Red Dog Mine
Comparison of Dust Fall
Jar and Snow Sample
Deposition Rates
2005 Snow Sample Points
Pb mg/m2/day
<1.00
1.01 - 3.00
3.01 - 10.00
10.01 - 30.00
>30.00
2005 Mine Dust Fall
Winter Deposition Rate
Pb mg/m2/day
<0.30
0.31 - 1.00
1.01 - 3.00
3.01 - 10.00
10.01 - 30.00
>30.00
N
Feet
0
1,000
2,000
4,000

Figure 1.