Environment Canada
Environmental Protection Service
Pacific Region
Yukon Branch

A SURVEY AND COMPARISON OF ARSENIC CONCENTRATIONS IN WATER, SOILS AND VEGETATION BETWEEN THE VENUS MINE PROPERTY AND THE MOUNT NANSEN PROPERTY, YUKON

by

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October 1985

ABSTRACT (cont'd)

arsenic levels (mean of 24.4 mg/kg wet weight) which indicates systemic uptake by the algae.

The results and some of the implications with regard to public health concerns are discussed.

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1 INTRODUCTION

1.1 Background

An August 31, 1983 arcticle in the local Whitehorse newspapers revealed a story of raspberries picked by a Whitehorse resident, from the shores of Windy Arm in the vicinity of Venus Mines abandoned tailing ponds. Two of these three samples (fresh picked raspberries) assayed by Bondar-Clegg, had elevated levels of arsenic (15 and 4.7 mg/kg). The third, (preserved jam from berries picked 1.5 km away) registered within acceptable limits (0.20 mg/kg) as outlined by Health and Welfare Canada (personal comm.). The arsenic levels in these three samples were confirmed by the Toxicological Evaluation Division of Health and Welfare Canada. Additional samples by Environmental Protection Service (EPS) staff were taken from five selected sites in the vicinity of the Venus Mines property. A total of 65 samples of raspberries, rosehips, gooseberries, juniper berries, high bush cranberries, black currants, mushroom and foliage were collected, as well as 15 water and 15 sediment samples. Results of replicate samples identified only one of the sites as having consistent contamination (2.3-40 mg/kg). One additional sample (a mushroom) from outside the contaminated area registered elevated arsenic levels. All the samples having elevated arsenic (As) readings were reported to contain visible amounts of sand.

Within two weeks, warning signs were posted in the area (Figure 1), printed notices were circulated to Carcross residents and a media campaign informed Whitehorse area residents of the concerns of possible arsenic contamination in the berries. Free clinics were set up in affected communities of the Territory to test hair and fingernail samples for arsenic. Results of these samples proved negative.

From the arsenic test results, a hypothesis was proposed that direct external contamination of the berries by sand and dust was responsible for the elevated readings. A proposal to test this hypothesis was prepared by the Environmental Protection service (Appendix I) and the 1984 study was undertaken.

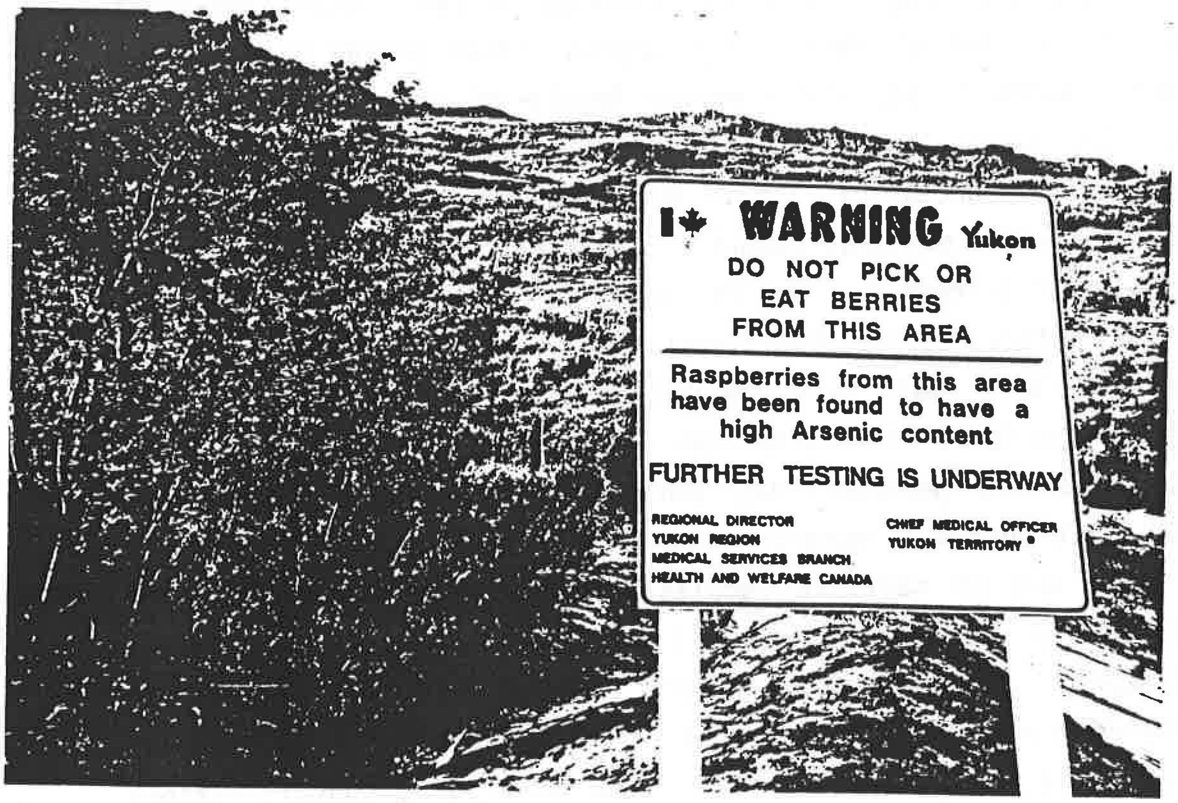

FIGURE 1 WARNING SIGN ERECTED AT THE ARSENIC CONTAMINATED AREA OF THE ABANDONED VENUS MINES TAILINGS PONDS.

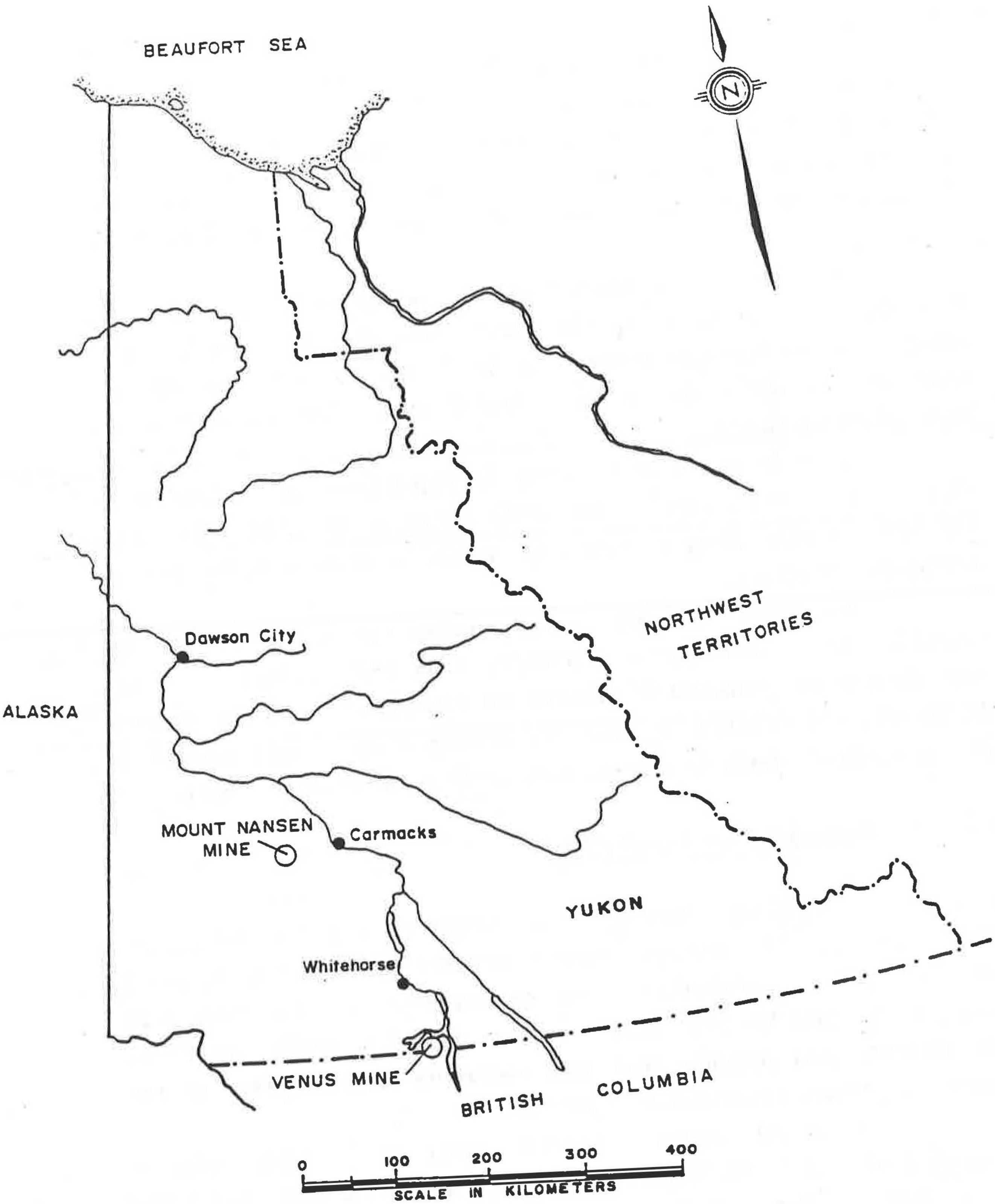

FIGURE 2: LOCATION OF THE VENUS MINES AND MOUNT NANSEN STUDY AREA WITHIN THE YUKON

The investigation selected Venus Mines and Mount Nansen properties (Figure 2) as study areas because of the presence of abandoned tailings areas, rich in arsenic, at these locations. The two locations vary in age, from recent to greater than a decade since abandonment and will show varying degrees of natural revegetation and stability.

To test if contamination of the berries was caused by systemic uptake or by dust, the study areas were selected to be in areas of known elevated arsenic levels. The approach required only that soil and water samples be collected to confirm the presence of these elevated levels.

To test if systemic uptake by vegetation would occur under high natural arsenic levels, the study included collecting vegetation and soil samples along a transect, across a known arsenic bearing geological structure.

The arsenic present on the berries may be in the form of sulphides or as arsenopyrite (arsenic, iron and sulphur). If so, availability when consumed is reduced and considered non-toxic (element is bound). Arsenic-bearing sulfides oxidize readily when exposed to air to release arsenic to unbound more toxic forms (Fowler, 1983).

1.2 Mineralization Description

1.2.1 Venus Mines. Mining first started in this area during the first decade of this century. More recent mining activities began in the mid 1960's and culminated in the construction of a 272 tonne (300 ton) per day capacity mill which operated from 1970 until June 1971. The tailings pond remnants from this operation are the sites of the suspected arsenic contaminated raspberries.

The 46,000 tonnes (50,000 tons) of tailings contain 2.80 gm/t gold (Au), 40.74 gm/t silver (Ag) and 0.37% zinc (Zn) (UKHM Ltd., 1980). The ore is associated with 8% iron pyrite, 10% arsenopyrite and quartz (Jack, 1981).

The country rock in the mine workings consists primarily of pale green to green, competent, cherty andesite breccia, alternating with dark green andesite flows and possibly minor tuff (UKHM Ltd., 1980).

1.2.2 Mount Nansen Mineral Body. Vein structures, consisting of sulphide-bearing quartz lenses, veins and stockworks, cut highly altered quartz-feldspar porphyry (Unit 13, Bostock, 1936a) and Yukon Group quartz-biotite schists and gneisses. Ore-bearing structures occur in two forms. Sulphides are associated with discontinuous quartz lenses and stringers in fractured, altered zones up to several feet wide. Arsenopyrite, pyrite, galena, and sphalerite are the principal metallic minerals. Various silver-bearing minerals such as friebergite, acanthite, native silver, andorite and argentiferous tetrahedrite have been identified in the ores (Green, 1966).

The Mount Nansen mine site has been inactive and abandoned since 1976.

2 STUDY AREA

2.1 Venus Mines Property

The Venus Mines Property lies approximately 24 km (15 miles) south of Carcross, Yukon Territory, at the headwaters of the Yukon River on Windy Arm, Tagish Lake (Figure 3).

The property has easy access via the Klondike Higwhay, 96 km (60 miles) south of Whitehorse Y.T. The sample stations for this study are located within a 2 km area (Figure 3) affected by historical mining. The Venus Mines Property lies at an elevation of 660 metres to 850 metres.

Sampling stations (Figure 3) were selected to test the hypothesis that arsenic contamination was occurring by wind blown dust settling on vegetation. Station 1 (Figure 4) was a revegetated access road area representing a stable site 80 metres from the abandoned tailings ponds. Station 2 (Figure 3 and 5), to the northeast of Station 1 is in a disturbed area with confirmed arsenic showings in the soil but in an area not affected by wind from the pondings. Station 3 (Figure 6) represents a small area of revegetation in the middle of and down wind of the abandoned tailings ponds. Station 4 (Figure 3 and 7) and Station 5 (Figure 3) are of the abandoned and active adits respectively which represent stations at known arsenic bearing geological structures. The sample site descriptions and sample materials collected are described in Table 1.

2.2 Mount Nansen Property

The Mount Nansen property lies approximately 50 km (30 miles) west of Carmacks, Yukon Territory, at the headwaters of the Nisling and Klaza Rivers on the west slopes of Mount Nansen (Figure 2). The property has easy access via a 64 km (40 mile) dirt road which leaves the Carmacks-Mount Freegold road immediately west of the Nordenskiold River bridge at Carmacks.

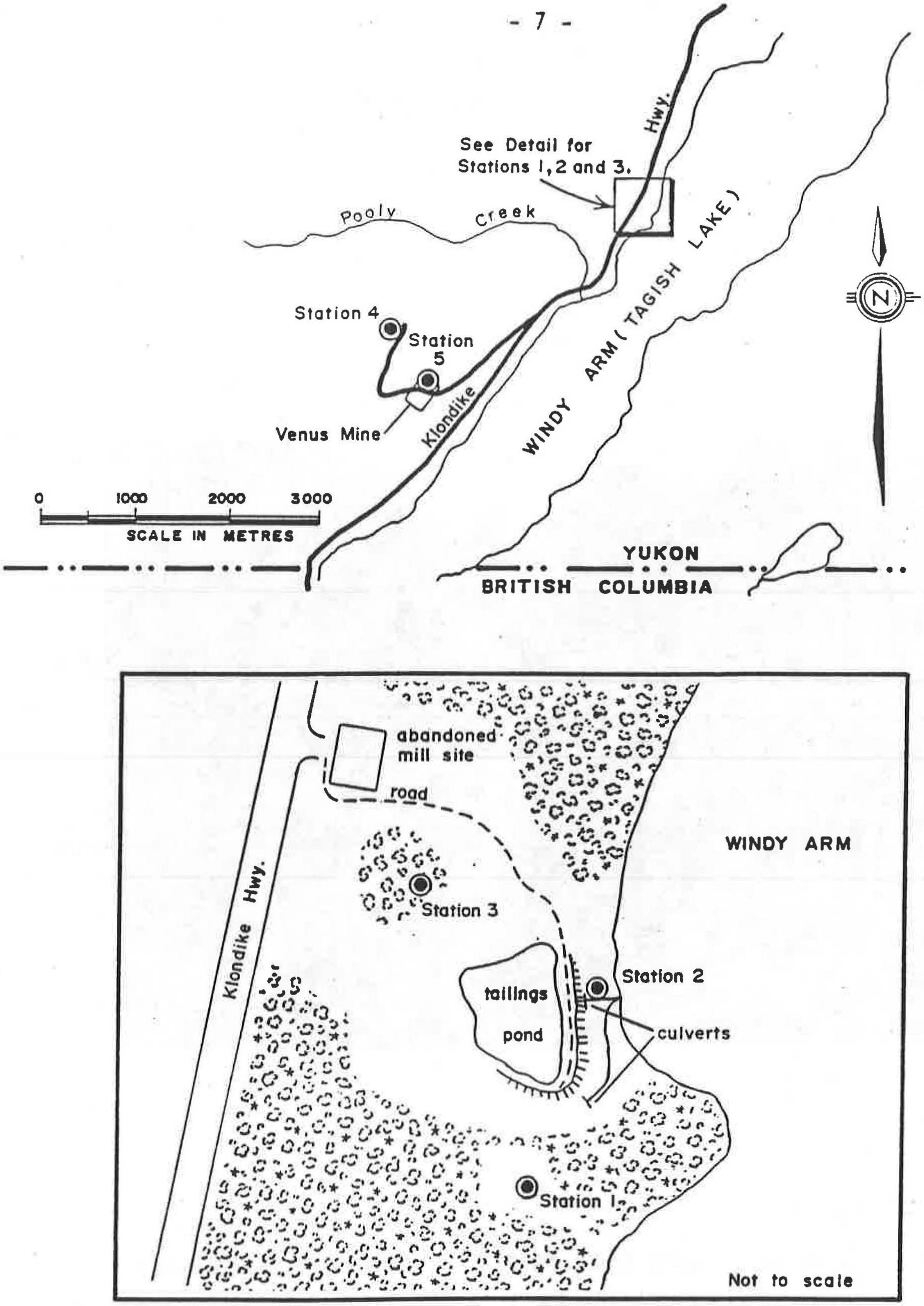

FIGURE 3: LOCATION OF SAMPLING STATIONS AT THE VENUS MINES PROPERTY, YUKON

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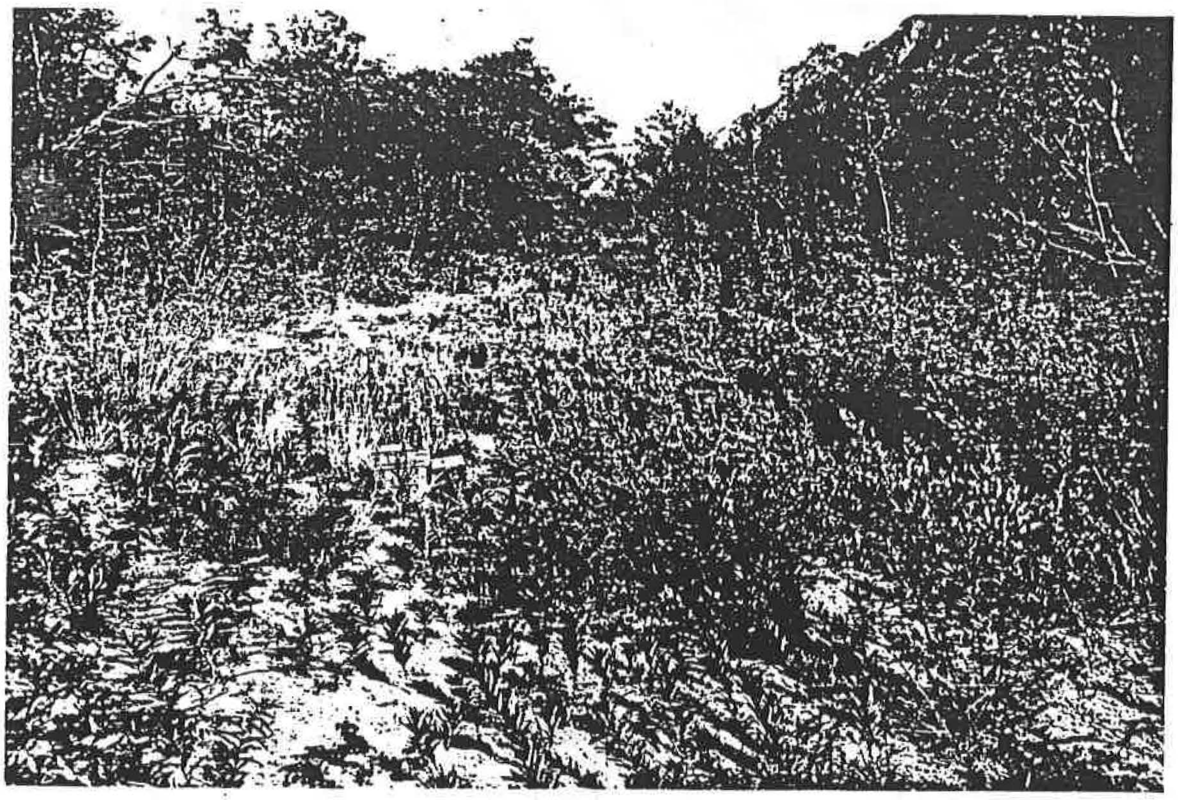

FIGURE 4 STATION 1, VENUS MINES PROPERTY. PARTIALLY REVEGETATED ACCESS ROAD 80 METRES SOUTH OF THE ABANDONED TAILINGS PONDS.

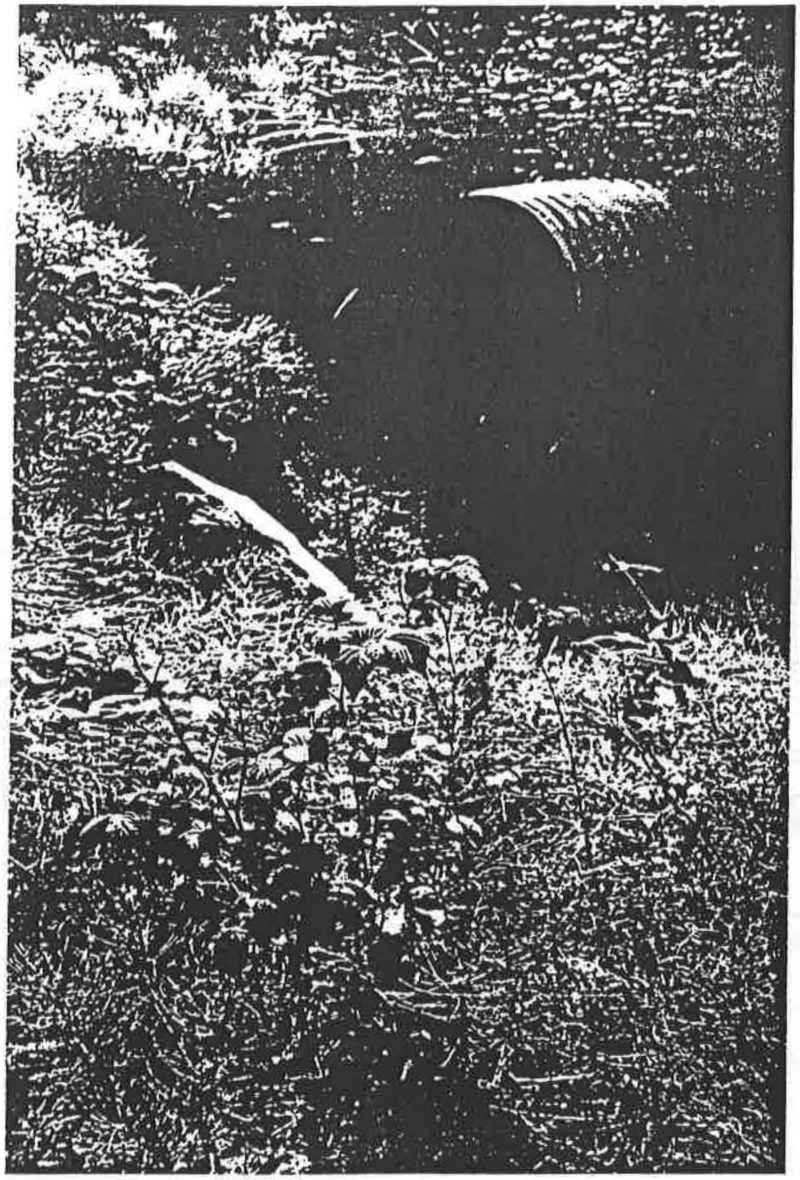

FIGURE 5 STATION 2, VENUS MINES PROPERTY. THE OUTLET OF A CULVERT USED TO DRAIN THE ABANDONED TAILINGS PONDS.

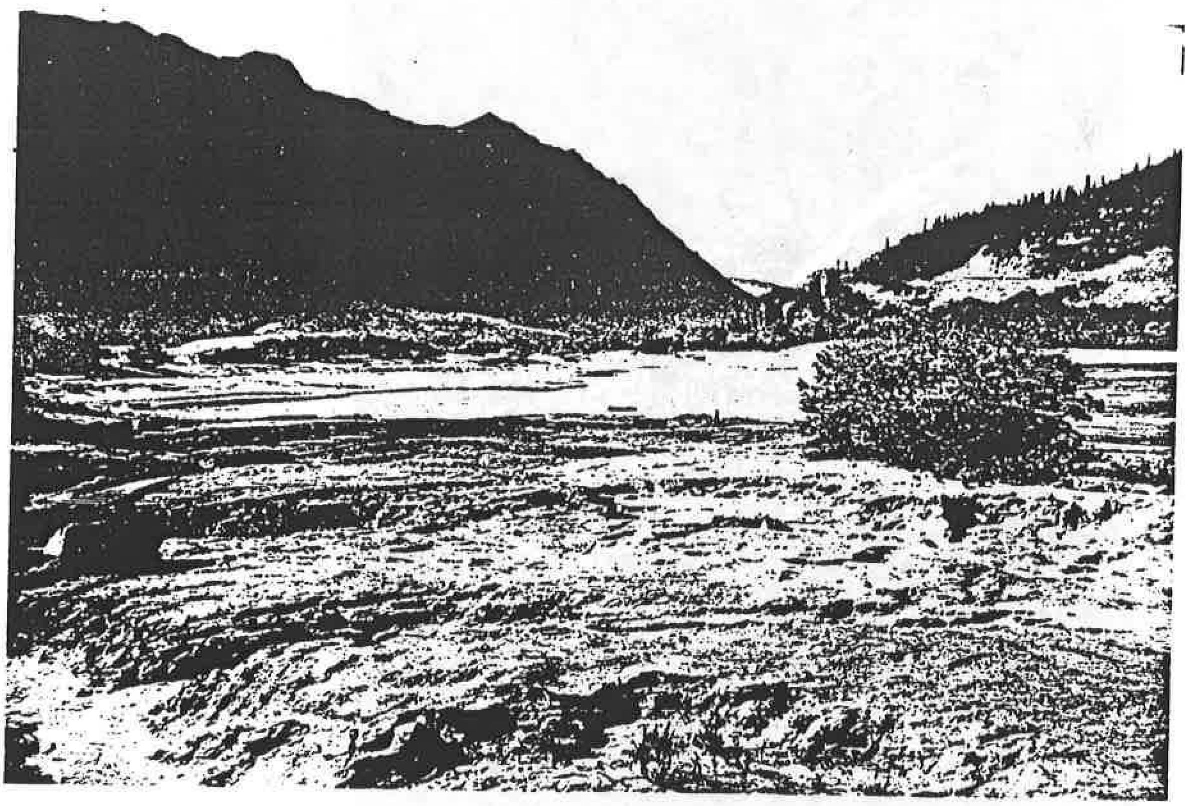

FIGURE 6 STATION 3, VENUS MINES PROPERTY. ABANDONED VENUS MINES TAILINGS POND CONTAINING THE FINE ARSENIC CONTAMINATED MINERAL MATERIAL.

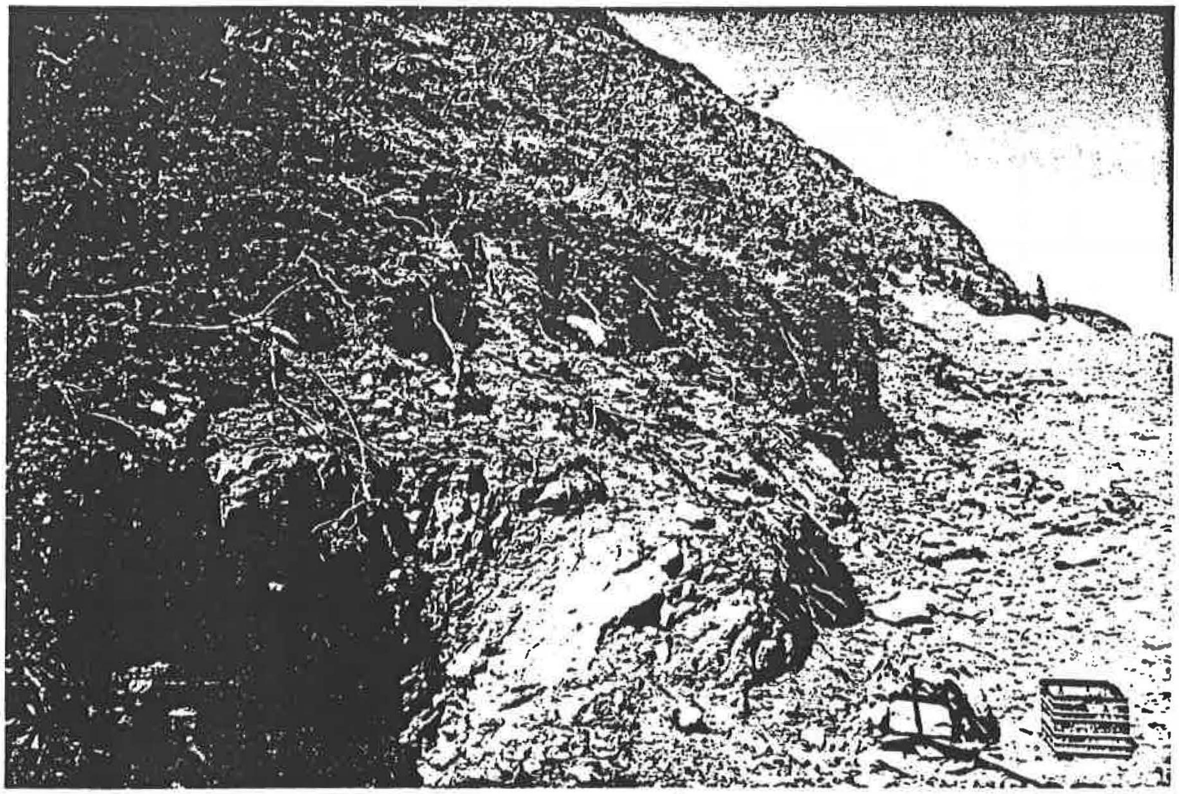

FIGURE 7 STATION 4, VENUS MINES PROPERTY. THE ABANDONED INCLINED ADIT ON THE MONTANA MOUNTAIN HILLSIDE ABOVE THE ABANDONED TAILINGS PONDS.

TABLE 1 DESCRIPTION OF SAMPLING STATIONS AT THE VENUS MINES AND MOUNT NANSEN PROPERTIES, 1984.

STATION	DATE SAMPLED	DESCRIPTION	SAMPLES TAKEN
1	84 08 21	Venus Mines Property. An open field area (10-50m) representing partially revegetated access road 80 metres south of the tailings pond. South wind blowing during sampling. Sunny and dry.	Raspberries, rosehips, goose berries, high bush cranberries. Soil.
2	84 08 21	Venus Mines Property. Southeast slope near the outlet of a culvert used to drain the abandoned tailings ponds. 20 metres from tailings ponds.	Raspberries, rosehips, goose berries. Soil.
	83 09 07	Sunny and Dry.	Water
3	84 08 22	Venus Mines Property. Open revegetation field at the north limit of the abandoned tailings pond down wind of exposed ponds.	Raspberries, rosehips, goose berries. Soil.
	83 09 07	Sunny and dry.	Water
4	84 08 22	Venus Mines Property. At the abandoned mine adit. Samples collected of vegetation growing on or uphill of the arsenopyrite vein. Sunny and dry.	Juniper berries, rosehips, raspberries. Soil.
5	83 09 07	Venus Mines Property. From the active mine adit. Samples collected from drainage crossing an arsenopyrite vein. Sunny and dry.	Water sample
6	84 09 05	Mount Nansen Property. From the slope 20 meters above to the west of the abandoned tailings pond. Rainy and cloudy.	Fireweed Soil.

TABLE 1 DESCRIPTION OF SAMPLING STATIONS AT THE VENUS MINES AND MOUNT NANSEN PROPERTIES, 1984. (Continued)

STATION	DATE SAMPLED	DESCRIPTION	SAMPLES TAKEN
7	84 09 05	Mount Nansen Property. Samples collected on the embankment of the dyke separating the abandoned tailings ponds. Rainy and cloudy.	Fireweed, water Soil
8	84 09 05	Mount Nansen Property. Samples were collected from a seepage site 5 meters below and to the east of the abandoned tailings pond. Rainy and cloudy.	Fireweed, water Soil
9	84 09 05	Mount Nansen Property. Sample site is 100m below abandoned tailings pond and to the east near Dome Creek. Rainy and cloudy	Alpine blueberries, Moss berries, water Soil
10	84 09 06	Mount Nansen Property. On Dome Creek 100m upstream of Station 8 in an area unaffected by the mine. Rainy and cloudy	Moss berries, water Soil
11	84 09 06	Mount Nansen Property. Samples collected were of the abandoned Lower Huestis Adit outflow. Rainy and cloudy	Water
12	84 09 06	Mount Nansen Property. Samples were collected from ponds between the abandoned Huestis Adit and tailings ponds. Rainy and cloudy.	Water
12a		Northern edge from seepage to the first settling pond.	Alga
12b		Sewpage from surface water pond.	Alga
12c		Surface water pond	Alga

The sample station arrangement at the Mount Nansen Property is depicted in Figure 3. Sample stations were selected to include an undisturbed area near the abandoned tailings ponds (Station 6, Figure 9), a station in the tailings ponds (Station 7, Figure 10), a station of water seepage from the ponds (Station 8, Figure 11) and a station on Dome Creek downstream of the ponds (Station 9). Station 10 (Figure 12) represents an undisturbed area on Dome Creek upstream of the mine's influence. Water samples from Station 11 were collected from a pipe draining the abandoned lower Huestis Adit. Station 12 (Figure 13) is a stagnant surface water pond, adjacent to the mill. The pond is formed by ground water seepage.

Sample site descriptions of the Mount Nansen Property are itemized in Table 1. Samples collected at each station are also listed in Table 1.

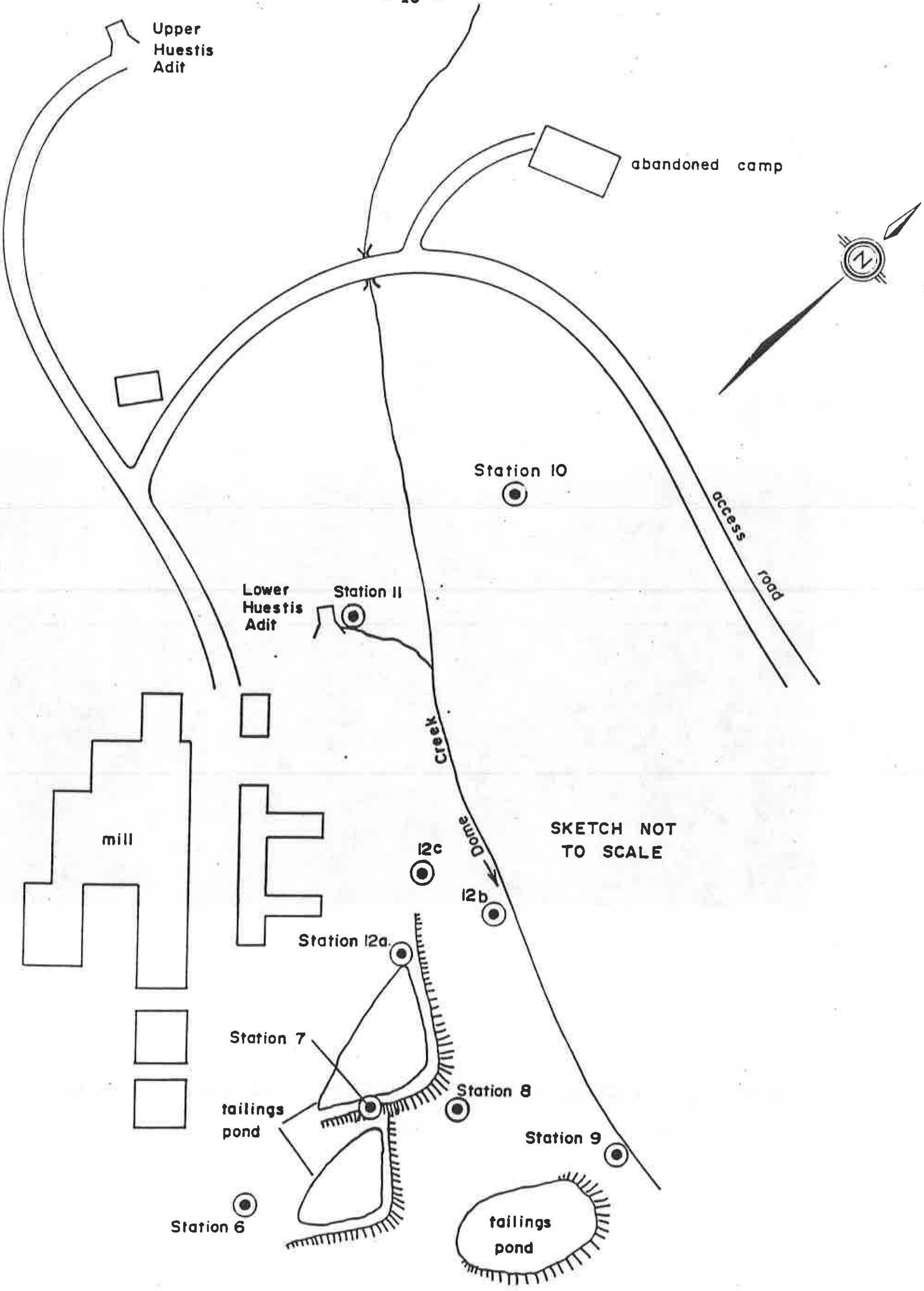

FIGURE 8: LOCATION OF SAMPLING STATIONS AT THE MOUNT NANSEN PROPERTY, YUKON

ETRES

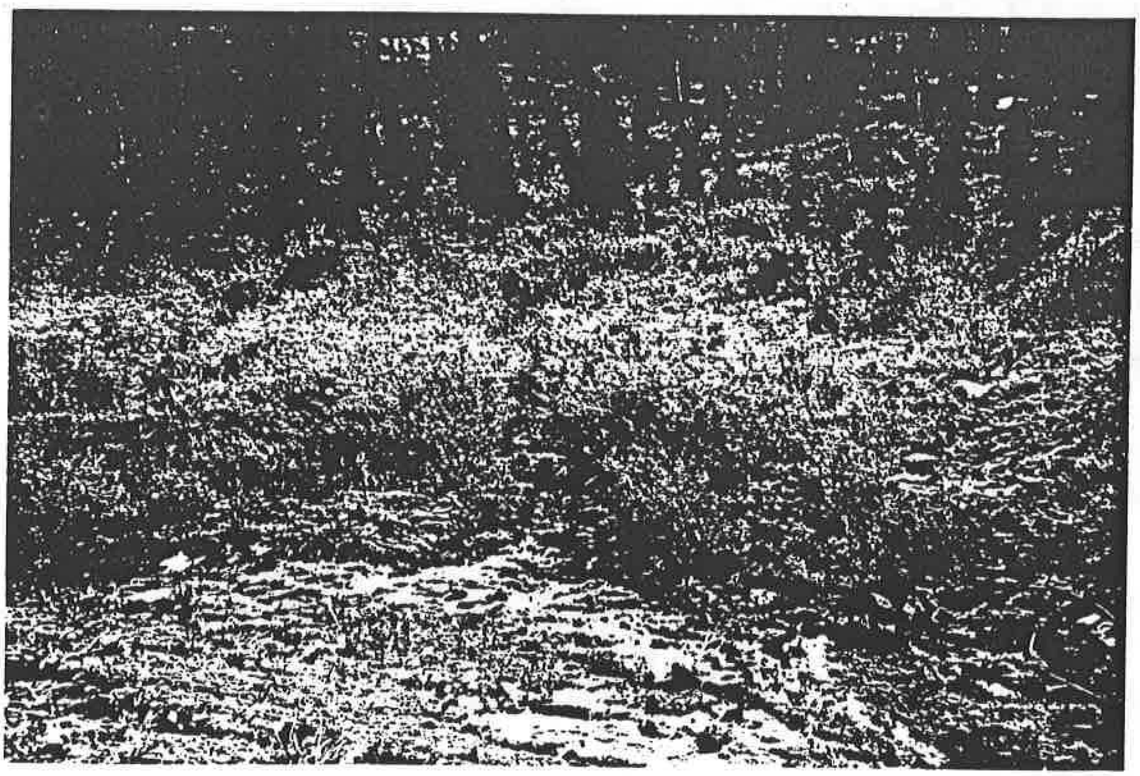

FIGURE 11 STATION 8 MOUNT NANSEN PROPERTY. SITE OF SEEPAGE FROM THE ABANDONED TAILINGS PONDS, AT THE TOE OF THE DYKE.

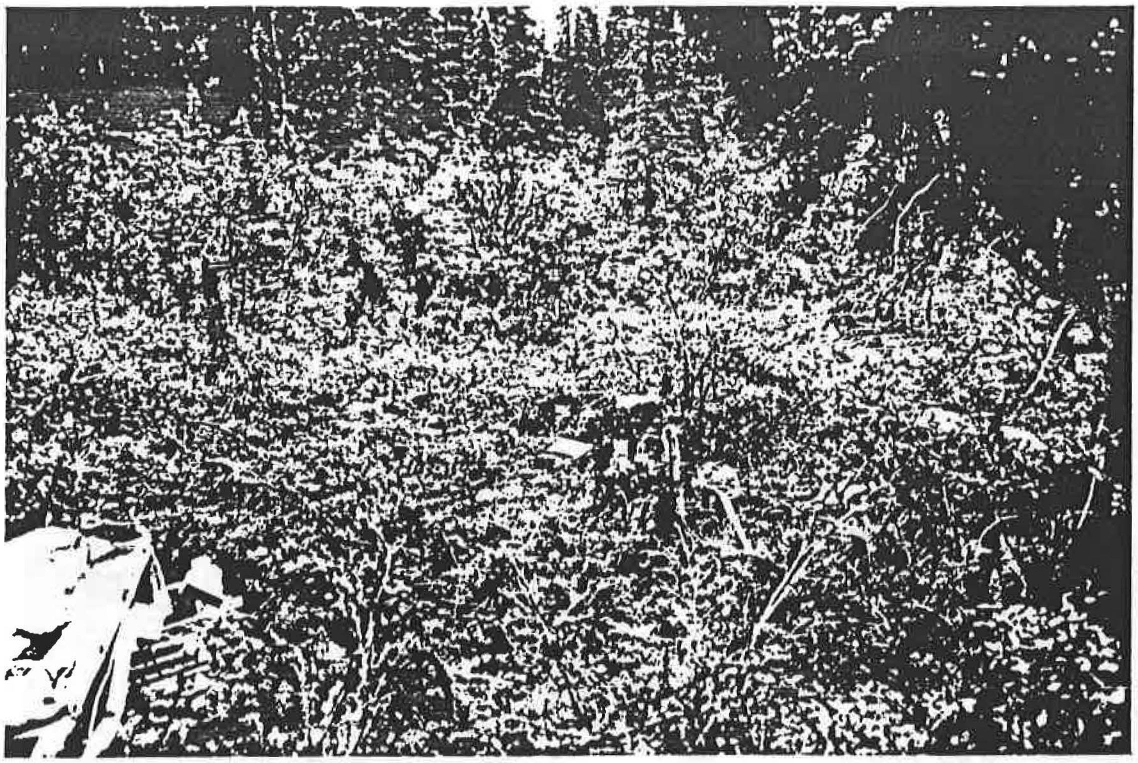

FIGURE 12 STATION 10, MOUNT NANSEN PROPERTY. UNDISTURBED DOME CREEK UPSTREAM OF STATION 9 AND ABOVE INFLUENCE OF ABANDONED MINE SITE.

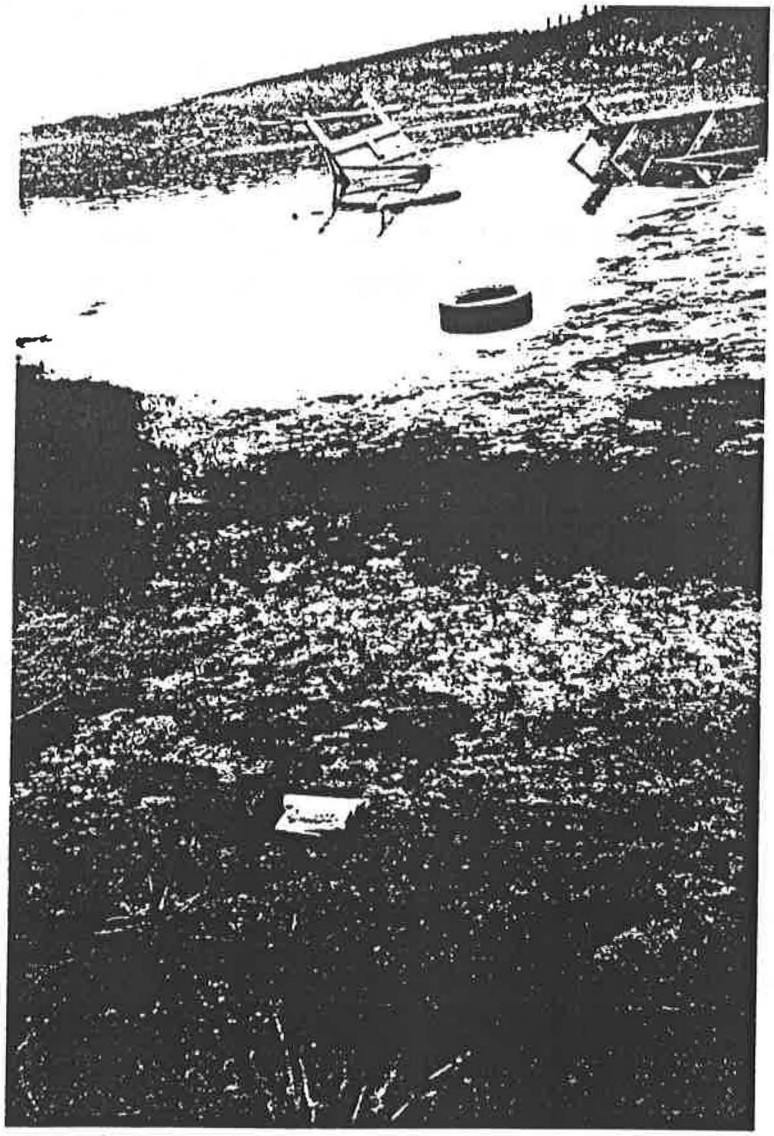

FIGURE 13 STATION 12a, MOUNT NANSEN PROPERTY. EDGE OF THE FIRST TAILINGS POND LOOKING SOUTH AT STATION 7 ON THE DYKE.

12b and 12c each had their own unique properties and all stations were separated by distances of up to 100 metres (Table 1 and Figure 8). Samples were kept frozen at -19°C until laboratory analyses were done. Algae samples were collected in triplicate and shipped to Laboratory Services, Environmental Protection Service, 4195 Marine Drive, West Vancouver, British Columbia, where they were analyzed for heavy metals.

4 RESULTS AND DISCUSSION

4.1 Water Quality

The water quality results are given in Table 2. The results of these water quality analyses are compared with recommended acceptable limits for raw drinking water supply and recommended limits for healthy aquatic life. Appendix II, Table 3 lists these water quality criteria and their references. The upper concentration limits for healthy aquatic life are usually lower than raw drinking water concentration limits because aquatic life may be more susceptible to harmful effects because of lower tolerance or biomagnification of the substance in the food chain.

Arsenic concentrations in Venus Mine sample station water taken in September 1983, exceeded the upper limit acceptable for drinking water (0.050 mg/l) and for healthy aquatic life (0.050 mg/l) in at least one of the replicates at Stations 2 (culvert), 3 (tailings pond) and 5 (mine adit). Station 3 (tailings pond) had the highest arsenic levels, with one of the replicates exceeding the acceptable limit by an order of magnitude of 10 times. The source of this as previously mentioned is the 10% arsenopyrite in Venus Mines ore and the previously processed arsenopyrite in the abandoned tailings.

Stations 7 (tailings pond), 8 (seepage), 9 (lower Dome Creek) and 11 (Huestis Adit) at the Mount Nansen property had arsenic concentrations in the water that exceeded recommended levels for drinking water and aquatic life. The samples from the tailings pond (Station 7), seepage (Station 8) and the adit (Station 11) were elevated 2 to 5 times acceptable limits confirming the existence of arsenopyrites at the Mount Nansen Property.

4.2 Soil Analyses

Arsenic is present naturally in all soils as a result of the parent rock material from which it is formed. Soils contain from 0.10 to 40 ppm (mg/kg) arsenic naturally with an average of 5-6 mg/kg but can vary significantly. Soils overlying sulfide- ore deposits contain arsenic at several hundred mg/kg and are present as the unweathered sulfide mineral or in an inorganic anion state. The most common sulfide is arsenopyrite (Fowler, 1983).

Soil analysis shows great variability and very high concentrations of arsenic at different strata in the ground (Table 3). The amount of arsenic in soils at the Venus Mine Property varies from lows of 30 mg/kg to highs of 83,000 mg/kg. Higher arsenic readings were obtained from surface samples at all stations with concentration levels decreasing proportionately with depth. As expected, the highest arsenic readings were obtained from soil samples taken from the abandoned tailings ponds.

The arsenic results from the Mount Nansen property were considerably lower (Table 3) and not as uniform in distribution. Concentrations varied between <5 mg/kg and 28,000 mg/kg. Undisturbed areas (Stations 8, 9 and 10) had low readings and as expected, soil samples from the tailings pond dykes had the highest readings.

To compliment the information on the availability of arsenic to the plants for systemic uptake, filamentous algae samples were collected at stations 12a, 12b and 12c. Algae are known to be able to bioaccumulate substantial quantities of trace metals such as arsenic in their tissues. These levels of arsenic in algae suggest the biological availability of these trace elements at their ambient concentrations over relatively long periods of time (Foster, 1982). The data in Table 4 shows elevated concentrations of arsenic in the wet weight analysis, mean average of 24.4 mg/kg and 876 mg/kg as the mean of the dry weight analysis.

4.3 Vegetation

Analysis of samples presented in this study demonstrate the presence of high arsenic concentration at the Venus Mines property and

TABLE 3 SOILS ANALYSIS - ARSENIC LEVELS AT VENUS MINES (AUGUST 21-22, 1984) AND MOUNT NANSEN (SEPTEMBER 5, 1984) STUDY AREAS - YUKON

STATION SAMPLE #	ORIGIN*	RESULTS (mg/kg)
1-1	Venus Mine abandoned access road	1500
1-2	Venus Mine abandoned access road	600
1-3	Venus Mine abandoned access road	70
1-4	Venus Mine abandoned access road	40
2-1	Venus Mine culvert	45000
2-2	Venus Mine culvert	800
2-3	Venus Mine culvert	40
2-4	Venus Mine culvert	30
3-1	Venus Mine tailings pond	83000
3-2	Venus Mine tailings pond	70000
3-3	Venus Mine tailings pond	27000
3-4	Venus Mine tailings pond	7000
4-1	Venus Mines - arsenic vein	10000
4-2	Venus Mines - mine adit	19000
4-3	Venus Mines - mine adit	1000
4-4	Venus Mines - mine adit	1000
4-5	Venus Mines - mine adit	1000
6-1	Mount Nansen Mine	300
6-2	Mount Nansen Mine	20
6-3	Mount Nansen Mine	50
7-1	Mount Nansen Mine - tailings pond	150
7-2	Mount Nansen Mine - tailings pond	40
7-3	Mount Nansen Mine - tailings pond	40
7-4	Mount Nansen Mine - tailings pond	28000
8-1	Seepage area	80
8-2	Seepage area	60
8-3	Seepage area	40
9-1	Mount Nansen Mine - Dome Creek	70
9-2	Mount Nansen Mine - Dome Creek	30
9-3	Mount Nansen Mine - Dome Creek	50
10-1	Mount Nansen Mine, (on the bank	<5
10-2	Mount Nansen Mine above the	180
10-3	Mount Nansen Mine Dome Creek)	10
11-1	Mount Nansen Mine, (in the flood	40
11-2	Mount Nansen Mine plain of the	110
11-3	Mount Nansen Mine Dome Creek)	50

* The first replicate is taken at the surface with subsequent samples being taken from increasing depths. Depths of soil samples are relative to each other at that station to a maximum depth of 0.5 metres.

TABLE 4 ALGAE ANALYSIS - ARSENIC LEVELS AT THE MOUNT NANSEN STUDY AREA, YUKON - SEPTEMBER 5, 1984

STATION	DATE	RESULTS (mg/kg)
12-a	84 09 05	38.2 Wet
12-b	84 09 05	11.0 weight
12-c	84 09 05	24.1
$\bar{x}$		24.4
12-a	84 09 05	1240 Dry
12-b	84 09 05	497 weight
12-c	84 09 05	892
$\bar{x}$		876

$\bar{x}$ = mean

relatively low levels at the the Mount Nansen property. The results of the berry and leaf arsenic analysis shows different concentrations between the two abandoned mining properties (Table 5 and 6).

Samples of berries and leaves collected at the Mount Nansen property have arsenic concentrations at or below the detection limit of 1.0 mg/kg (ppm) in most instances. Washing the biological samples with distilled water had little effect on results because of the low arsenic concentrations present prior to washing.

Concentrations of arsenic associated with vegetation samples collected at Venus Mines property ranged between a low of (1.0 mg/kg (ppm) and a high of 2800 mg/kg (ppm). Station 3, the abandoned tailings pond at the Venus Mines property, had elevated arsenic readings consistently above samples from other stations.

The Venus Mines berries and leaves show a constant difference between unwashed and washed samples, indicating some surface contamination is removed whenever washing occurs. The removal of all dust on the berries and leaves was difficult due to the pubescence of the surfaces which effectively retained fine particles of dust.

In terms of the uptake and effect of arsenicals on plants, there are several factors which appear to be important. Uptake of this element appears to occur primarily via the roots, and to some extent, on the foliage. The bio-availability of arsenic is generally greater to plants grown in sandy soils in comparison to silts or clays. Once absorbed, arsenic is generally more concentrated in roots, leaves and stems in comparison with fruits (Fowler, 1983). Results in this study reveal arsenic concentrations in leaf samples to be greater than the berry samples by an order of magnitude. Whether the arsenic in washed samples is on or in the leaves was not determined.

It has been shown that arsenic is more toxic to plants than animals (Demayo et al, 1979). Certain plant species however are more tolerant than others. Raspberries are known to be very tolerant to high levels of soluble arsenic in soil (Walsh, 1977). When arsenic poisoning does occur it is usually due to direct ingestion of surface contaminated berries or ingestion of spring water containing abnormally high levels of arsenic (Walsh, 1975).

TABLE 5 VEGETATION (BERRIES) ANALYSIS - ARSENIC LEVELS AT VENUS MINES (AUGUST 21-22, 1984) AND MOUNT NANSEN (SEPTEMBER 5, 1984) STUDY AREA, YUKON

STATION	FRUIT TYPE	WASHED/ UNWASHED	CONCENTRATION (mg/kg)
1-1	Raspberry	unwashed	1.0
1-2	Raspberry	unwashed	2.0
1-3	Raspberry	unwashed	1.0
$\bar{x}$			<1.3
1-4	Raspberry	washed	<1.0
1-5	Raspberry	washed	1.0
1-6	Raspberry	washed	<1.0
$\bar{x}$	Raspberry		<1.0
2-1	Raspberry	unwashed	65
2-2	Raspberry	unwashed	20
2-3	Raspberry	unwashed	25
$\bar{x}$			36.6
2-4	Raspberry	washed	6.0
2-5	Raspberry	washed	15
2-6	Raspberry	washed	8.0
$\bar{x}$	Raspberry		9.6
3-1	Raspberry	unwashed	110
3-2	Raspberry	unwashed	90
3-3	Raspberry	unwashed	80
$\bar{x}$			93.3
3-4	Raspberry	washed	50
3-5	Raspberry	washed	20
3-6	Raspberry	washed	30
$\bar{x}$	Raspberry		33.3
1-1	Rosehips	unwashed	<1.0
1-2	Rosehips	unwashed	1.0
$\bar{x}$			<1.0
1-4	Rosehips	washed	<1.0
1-5	Rosehips	washed	<1.0
$\bar{x}$	Rosehips		<1.0
2-1	Rosehips	unwashed	<1.0
2-2	Rosehips	unwashed	4.0
$\bar{x}$			<2.5
2-4	Rosehips	washed	1.0
2-5	Rosehips	washed	20
$\bar{x}$	Rosehips		10.5

$\bar{x}$ = mean

TABLE 5 VEGETATION (BERRIES) ANALYSIS - ARSENIC LEVELS AT VENUS MINES (AUGUST 21-22, 1984) AND MOUNT NANSEN (SEPTEMBER 5, 1984) STUDY AREA, YUKON (Continued)

STATION	FRUIT TYPE	WASHED/ UNWASHED	CONCENTRATION (mg/kg)
3-3	Rosehips	unwashed	1.0
3-4	Rosehips	washed	7.0
1-1	Goose berry	unwashed	1.0
1-2	Goose berry	unwashed	1.0
$\bar{x}$			1.0
2-1	Goose berry	unwashed	6.0
2-2	Goose berry	unwashed	2.0
$\bar{x}$			4.0
3-1	Goose berry	unwashed	1.0
3-2	Goose berry	unwashed	2.0
$\bar{x}$			1.5
3-4	Goose berry	washed	<1.0
3-5	Goose berry	washed	1.0
$\bar{x}$			<1.0
1-1	High bush cranberry	unwashed	<1.0
1-2	High bush cranberry	unwashed	<1.0
$\bar{x}$			<1.0
4-1	Juniper berry	unwashed	<1.0
4-2	Juniper berry	unwashed	<1.0
4-3	Juniper berry	unwashed	<1.0
$\bar{x}$			<1.0
4-4	Juniper berry	washed	<1.0
4-5	Juniper berry	washed	<1.0
4-6	Juniper berry	washed	<1.0
$\bar{x}$			<1.0

$\bar{x}$ = mean

TABLE 5 VEGETATION (BERRIES) ANALYSIS - ARSENIC LEVELS AT VENUS MINES (AUGUST 21-22, 1984) AND MOUNT NANSEN (SEPTEMBER 5, 1984) STUDY AREA, YUKON (Continued)

STATION	FRUIT TYPE	WASHED/ UNWASHED	CONCENTRATION (mg/kg)
9-2	Alpine blueberry	unwashed	<1.0
9-5	Alpine blueberry	washed	<1.0
9-1	Moss berry	unwashed	<1.0
9-2	Moss berry	unwashed	<1.0
9-3	Moss berry	unwashed	<1.0
$\bar{x}$			<1.0
9-4	Moss berry	washed	<1.0
9-5	Moss berry	washed	<1.0
9-6	Moss berry	washed	<1.0
$\bar{x}$			<1.0
10-1	Moss berry	unwashed	<1.0
10-2	Moss berry	unwashed	<1.0
10-3	Moss berry	unwashed	<1.0
$\bar{x}$			<1.0
10-4	Moss berry	washed	<1.0
10-5	Moss berry	washed	<1.0
10-6	Moss berry	washed	<1.0
$\bar{x}$			<1.0

$\bar{x}$ = mean

TABLE 6 VEGETATION (LEAVES) ANALYSIS - ARSENIC LEVELS AT VENUS MINES (AUGUST 21-22, 1984) AND MOUNT NANSEN STUDY AREA, YUKON

STATION	LEAF TYPE	WASHED/ UNWASHED	CONCENTRATION (mg/kg)
1-1	Raspberry	unwashed	75
1-2	Raspberry	unwashed	65
1-3	Raspberry	unwashed	60
$\bar{x}$			66.7
2-1	Raspberry	unwashed	450
2-2	Raspberry	unwashed	525
2-3	Raspberry	unwashed	650
2-4	Raspberry	unwashed	2800
$\bar{x}$			1106
3-1	Raspberry	unwashed	1600
3-2	Raspberry	unwashed	1800
3-3	Raspberry	unwashed	625
$\bar{x}$			1341
3-7	Raspberry	washed	1100
3-8	Raspberry	washed	1600
3-9	Raspberry	washed	500
$\bar{x}$			1066
4-1	Raspberry	unwashed	225
4-2	Raspberry	unwashed	60
$\bar{x}$			142.5
4-4	Raspberry	washed	40
4-5	Raspberry	washed	40
$\bar{x}$			40
3-3	Rose	unwashed	130
3-6	Rose	washed	90
4-1	Rose	unwashed	6.0
4-2	Rose	unwashed	15
$\bar{x}$			10.5
4-4	Rose	washed	4.0
4-5	Rose	washed	4.0
$\bar{x}$			4.0

$\bar{x}$ = mean

TABLE 6 VEGETATION (LEAVES) ANALYSIS - ARSENIC LEVELS AT VENUS MINES (AUGUST 21-22, 1984) AND MOUNT NANSEN STUDY AREA, YUKON (Continued)

STATION	TYPE	WASHED/ UNWASHED	CONCENTRATION (mg/kg)
3-1	Goose berry	unwashed	120
3-2	Goose berry	unwashed	60
$\bar{x}$			90
3-4	Goose berry	washed	40
3-5	Goose berry	washed	25
$\bar{x}$			32.5
4-1	Juniper berry	unwashed	1.0
4-2	Juniper berry	unwashed	1.0
4-3	Juniper berry	unwashed	4.0
$\bar{x}$			2.0
4-4	Juniper berry	washed	1.0
4-5	Juniper berry	washed	1.0
4-6	Juniper berry	washed	1.0
$\bar{x}$			1.0
6-1	Fireweed	unwashed	1.0
6-2	Fireweed	unwashed	<1.0
6-3	Fireweed	unwashed	<1.0
$\bar{x}$			<1.0
6-4	Fireweed	washed	1.0
6-5	Fireweed	washed	<1.0
6-6	Fireweed	washed	<1.0
$\bar{x}$			<1.0
7-1	Fireweed	unwashed	1.0
7-2	Fireweed	unwashed	1.0
7-3	Fireweed	unwashed	1.0
$\bar{x}$			1.0
7-4	Fireweed	washed	<1.0
7-5	Fireweed	washed	<1.0
7-6	Fireweed	washed	1.0
$\bar{x}$			<1.0
8-1	Fireweed	unwashed	<1.0
8-2	Fireweed	unwashed	<1.0
8-3	Fireweed	unwashed	<1.0
$\bar{x}$			<1.0
8-4	Fireweed	washed	<1.0
8-5	Fireweed	washed	<1.0
8-6	Fireweed	washed	<1.0
$\bar{x}$			<1.0

5 CONCLUSIONS AND RECOMMENDATIONS

The importance of information for safeguarding biota (including man) resides in the understanding that the toxic potential of arsenic (As) varies enormously, depending upon which chemical species are present (Fowler, 1983). Arsenic (As) concentrations in the waters sampled at the Venus Mines and Mount Nansen properties showed elevation over acceptable limits for drinking water and aquatic life in some of the replicates collected. The only water samples showing elevated arsenic (As) concentrations were from areas of confirmed arsenopyrite veins. The results of the replicate samples were not consistent, indicating arsenic (As) was probably mobilized into the water by natural erosion processes. The chemical species of arsenic (As) made available by these processes are suspected to be inorganic arsenic which has a lower absorption rate by the body than organic species of arsenic (Fowler, 1983). The clearance of arsenic from the body after exposure to inorganic species, is fairly rapid (Fowler, 1983).

Soils analysis showed great variability in arsenic levels and confirmed elevated concentrations at the sites sampled. The Venus Mines property results indicate that a high background level of arsenic does exist in the surface soil but decreases with depth indicating movement of surface material by natural processes such as wind. Arsenic at the Mount Nansen property is present but not in the same high concentrations and does not exhibit an obvious pattern with depth at the sites sampled.

The algae analysis also reveals elevated arsenic levels, confirming the availability of arsenic (As) to plants for systemic uptake and bioaccumulation in the tissues. The species of arsenic concentrated in the algae were not identified in this study and a literature research by Fowler (1983) could not shed further information on this topic.

The results of the vegetation (leaves and berries) analysis confirm the elevated arsenic levels originally suspected in the biota. The pubescent leaves had much higher levels than berries picked from from the respective sample sites. The vegetation from the Venus Mines property shows higher arsenic levels than the vegetation from the Mount Nansen property at the sites sampled. Arsenic levels of the vegetation from the vicinity of the Venus Mines settling ponds (Station 3) shows the highest concentration. The concentrations of arsenic in vegetation samples having elevated arsenic levels, markedly decreased in the portions of the samples washed with distilled water. This indicated the removal of some surface contamination of wind blown dust and dirt rather than systemic contamination. It is suspected that further washing would reduce the contamination.

Areas suspected of having naturally elevated arsenic levels should be considered to be environments that may reveal arsenic concentrations exceeding recommended levels for drinking water and aquatic life. In these situations measures should be implemented to increase the awareness of the potential health and environmental risks and protect the public health. For example, the public awareness signs presently being displayed in the vicinity of the Venus Mines property are an effective method and they should remain in place to warn the public of potential health risks.

A public awareness program to encourage the thorough surface washing of berries picked in areas that may be subject to surface contamination by arsenic containing dust particles is also an option. Since a major amount of the arsenic present in samples with high levels is due to surface contamination by wind blown dust, another option to reduce potential contamination would be to greatly reduce or eliminate wind transport of arsenic rich tailings. This could be achieved by covering arsenic rich tailings areas with soil material and re-vegetating the surface to reduce or eliminate wind transport.

ACKNOWLEDGEMENTS

The author would like to thank Mr. Dennis Prince (Chamber of Mines) and George Mackenzie-Grieve (Environment Protection Service Whitehorse, Yukon) for their technical reviews and inputs.

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APPENDIX I

EPS PROPOSAL

LABORATORY ANALYSIS
ARSENIC IN VEGETATION SAMPLES

APPENDIX I

EPS PROPOSAL

Laboratory Analysis - Arsenic in Vegetation Samples

Three locations, Venus, Mt. Nansen and Dublin Gulch are proposed as study areas because of the presence of abandoned tailings areas, rich in arsenic at these locations. The three locations vary in age, from recent to several decades since abandonment and will show varying degrees of natural revegetation and stability.

Two sampling options are possible with regard to the specific areas sampled. Sampling can be done at abandoned tailings area or in natural terrain across a naturally occuring vein rich in arsenopyrites. The former would likely have higher concentrations of arsenic in the soil and would represent the 'worst case'. The actual arsenic content of the soil will be cross referenced by taking soil samples for analysis for arsenic. We are planning to look at sampling vegetation near a tailings pond so that we will be looking at a worst case condition.

The vegetation sampling will be carried out along transects at each of three locations:

Minimum Samples

1 species per location (3)	- 3 (berries only)
3 replicates per site	- 3
	9 samples

Maximum Samples

3 species per location (3)	- 9
2 samples (leaf & berry) per site	- 2
9 samples per site	- 9
	162 samples

Additional sampling possible:

1. Duplicate above sampling at each location but along a transect which crosses arsenic bearing geological structure.

Minimum samples 9

Maximum samples 162

2. One soil sample at each site from each location:

   9 soil samples

Recommendations:

1. Maximum sampling intensity along a gradient at tailings ponds at each location for vegetation (berries and leaves) for three different species (if present). This would produce a maximum of <u>162 vegetation samples.</u>

2. Soil sample at each sample site at each location to be analyzed for arsenic content.
   <u>9 soil samples</u>

APPENDIX II

COLLECTION, PRESERVATION, ANALYSIS OR IDENTIFICATION METHODS AND WATER QUALITY CRITERIA

APPENDIX II TABLE 1 WATER SAMPLE COLLECTION, PRESERVATION AND ANALYSIS METHODS

PARAMETER	DETECTION LIMIT	COLLECTION AND PRESERVATION PROCEDURE[1]	ANALYTICAL PROCEDURE	METHOD SECTION[2]
Extractable Metals	mg/l	Single samples collected in 200 ml linear polyethylene bottles. Each bottle was rinsed 3 times with sample before filling. Preserved to a pH <1.5 using 1.0 ml concentrated HNO_3.	Inductively Coupled Argon Plasma (ICAP) combined with Optical Emission Spectrometer (OES)	201 592
As	0.050			

APPENDIX II TABLE 2 SEDIMENT COLLECTION, PREPARATION AND ANALYSIS METHODS

PARAMETER	COLLECTION/PREPARATION	ANALYSIS	METHOD CODE[1]
	Stations: Sediment samples were collected using an aluminum shovel to scoop sample into pre-labelled Kraft soil bags stored inside Whirl-Pak bags for shipping. Three samples were taken at each station. Samples were kept cool and were frozen (-19°C) as soon as possible.		
Metals (Leachable) mg/g As	Sample was freeze-dried for 48 hours to remove water. Sample was sieved through a size 100 mesh (0.15mm) stainless steel sieve. Sample was leached with HCl and HNO_3. The sample was heated for 3 hours.	Hydride Generation ICAP	EPS Lab

APPENDIX II TABLE 3 VEGETATION SAMPLE COLLECTION, PRESERVATION AND ANALYSIS

PARAMETER	DETECTION LIMIT	COLLECTION AND PRESERVATION PROCEDURE	ANALYTICAL PROCEDURE
Berries	1.0 mg/kg	Composite sample by species either unwashed or washed with distilled water collected in 100 ml polyethylene bottles, 7-10 berries (apprx. 5 grams). Kept frozen prior to analysis.	Graphite Furnace Atomic Absorption Spectrophotometry.
Leaves	1.0 mg/kg	Composite sample by species either unwashed or washed with distilled water; collected in Whirl-Pack™ bags. Kept frozen prior to analysis.	Colorimetric Analysis

APPENDIX II TABLE 4 ARSENIC CRITERIA FOR DRINKING WATER, FOOD INGESTION AND AQUATIC LIFE.

CRITERIA	RECOMMENDED MAXIMUM LEVEL	REFERENCE
Drinking Water	0.05 mg/l	2
Food Ingestion	1.4 mg/kg	1
Aquatic Life	0.05 mg/l (total)	3

Reference

1. Driesbach, R.G., Handbook of Poisoning. 11th Edition, Lange Medical Publications, Los Altos, California 1983.
2. Health and Welfare Canada, Guidelines for Canadian Drinking Water Quality 1978. Supply and Services, Canada 1979.
3. Inland Waters Directorate, Guidelines for Surface Water Quality. Volume 1, Inorganic Chemical Substances. Environment Canada, Ottawa, (1979, 1980).

APPENDIX II TABLE 5 BIOTA-(ALGAE)- COLLECTION, PRESERVATION AND IDENTIFICATION METHODS

FIELD COLLECTION, SAMPLING PROCEDURES AND PRESERVATION	LABORATORY PROCEDURES	ANALYSIS
The filamentous algae were collected by tearing the plant from the substrate near the attachment point. The algae was gently washed to remove inclusion of chironomids. The sample was put in a Whirl Pak™ bag and kept cool.	The samples in September were frozen and shipped to the EPS Lab in West Vancouver, B.C. for extractable metals analysis.	ICAP