ENVIRONMENT CANADA
CONSERVATION AND PROTECTION
ENVIRONMENTAL PROTECTION
PACIFIC & YUKON REGION

LEAD IN BRITISH COLUMBIA AND YUKON ENVIRONMENTS

- SUMMARY OF INDUSTRIAL DATA (1979 - 1986)

Regional Program Report 90 - 05

by

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ABSTRACT

This report has been prepared to provide an overview of the life cycle of lead in the industrial and commercial processes operating in British Columbia and the Yukon. The main objective was to document sources of lead from mineral extraction through concentration, refining to secondary and tertiary processing and miscellaneous uses. Loading estimates of lead releases to the environment were made where sufficient data was provided.

Over 40 lead mines were identified as either producing or under development, the three major ones being Cominco Ltd. (Sullivan) in Kimberly, B.C., United Keno Hill and Curraugh Resources in the Yukon. Several mines have lead contaminated effluent which was due to acid mine drainage.

Spills of lead concentrate, up to 48 metric tonnes, have occurred during the transport of lead and zinc concentrates in both B.C. and the Yukon. The year round road transport of concentrate from the Curraugh Resources mine in the Yukon is expected to increase the number of spills along the route from Faro, Yukon to Skagway Alaska.

Lead levels in the effluent at the Cominco concentrator in Kimberly are controlled by a treatment system. Data and loadings from the Cominco, Trail smelter were based on operations prior to the modernization of the main lead smelter which was initiated in September 1986. Lead discharges from smelting emissions and effluents appear to be declining as a result of plant modernization projects. The lead smelter modernization program is expected to significantly benefit the Trail region.

Ambient air lead concentrations have been decreasing in the Greater Vancouver area and may continue to decrease, when new regulations eliminating lead in automobile gasoline take effect, on December 1, 1990.

Other declines in lead pollution have occurred as a result of the banning of lead arsenate insecticides in agriculture, improved source control of industrial effluent discharges to sanitary sewer systems, and the restrictions on use of leaded paints.

RÉSUMÉ

Ce rapport a été préparé pour fournir une vue d'ensemble du cycle du plomb dans les procédés industriels et commerciaux en opération en Colombie-Britannique et les territoires du Yukon. Les principaux objectifs de ce rapport étaient de déterminer les sources de plomb dans l'environnement commençant avec les extractions minérales par concentration, raffinement avec procédés secondaires et tertiaires ainsi que les différents emplois produisant des rejets de plomb dans l'environnement. Les estimés de masse furent déterminés quand les données suffisantes furent fournies, lesquelles peuvent être reliées aux changements de procédé industriel ou législation affectant les produits chimiques contenant du plomb.

Plus de 40 mines furent identifiées comme des mines de plomb productrices ou potentielles, les trois majeures étant Cominco Sullivan à Kimberley, C.-B., United Keno Hill Mill et Curraugh Resources au Yukon. Plusieurs mines ont des effluents contaminés avec du plomb dû au ruissellement acide.

La contamination de l'effluent par le plomb est contrôlée par un système de traitement au concentrateur Cominco Kimberley. Des importants déversements jusqu'à 48 tonnes métriques de concentré de plomb se sont produits durant le transport de concentrés de plomb et de zinc en C.-B. et au Yukon. On peut prévoir que le transport par route de concentré à l'année longue de la mine Curraugh Resources dans le Yukon augmente le nombre de déversements le long de la route Whitepass.

Les données et les masses de Cominco à la fonderie de Trail furent basées sur les opérations avant la modernisation de la principale fonderie de plomb initiée en septembre 1986. Les décharges de plomb des émissions et des effluents de la fonte paraissent diminuer grâce à des projets antérieurs de modernisation de l'usine. On s'attend à ce que le programme de modernisation de la fonderie de plomb bénéficie significativement la région de Trail.

Les concentrations de plomb dans l'atmosphère ambient ont diminué dans la région du Grand Vancouver et peut continuer à diminuer quand les nouveaux règlements éliminant le plomb dans la gazoline des automobiles entrent en vigeur le 1 décembre, 1990.

D'autres diminutions de la pollution par le plomb se sont produites grâce à l'interdiction des insecticides d'arséniate de plomb dans l'agriculture, à l'amélioration du contrôle à la source des décharges d'effluent industriel dans les systèmes d'eaux usées sanitaires, et les restrictions de l'emploi des peintures à base de plomb.

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1.0 LEAD MINING AND CONCENTRATE PRODUCTION IN THE B.C. AND YUKON REGION

Canada is the third largest producer and second largest trader of primary lead, supplying 15% of all the primary lead consumed in the Western World. In 1979, lead production was estimated at 280 000 tonnes. Annual production in the B.C.-Yukon Region averages 102 000 to 116 000 tonnes/year. Development at the Faro Mine in the Yukon for lead and zinc will increase the supply of concentrate. Canadian domestic consumption of primary lead in 1984 was 65 614 tonnes of primary lead and 64 933 tonnes of secondary lead (216). Approximately 75% (79 300 tonnes) is used by the lead acid battery industry.

TABLE 1 LEAD PRODUCTION IN BRITISH COLUMBIA AND THE YUKON TERRITORIES 1970 - 1983 (7, 151, 215)

YEAR	BRITISH COLUMBIA		YUKON TERRITORIES	
	METRIC TONNES	DOLLAR VALUE	METRIC TONNES	DOLLAR VALUE
1970	97 654	$33,987,180	59 850	$20,830,000
1971	112 694	$33,469,737	98 789	$29,340,000
1972	88 704	$30,107,255	101 328	$34,392,000
1973				
1974				
1975				
1976	122 126		52 709	$ 8,990,000
1977	49 923		101 000	$26,900,000
1978	81 065	$24,773,464	125 000	$38,200,000
1979	87 653			
1980	71 501	$77,792,165	74 584	$71,558,000
1981	79 414		51 651	$50,706,000
1982	83 119		35 838	
1983				
1984	84 186		1 139	
1985	116 811		1 470	
1986	103 204		36 279	

* Total production till June 1983

1.1 The Effect of Lead Mining on the British Columbia and Yukon Environment

The major routes for contamination of the environment from lead mining are airborne and waterborne contamination. Dustfall originates from the mine sites, mills, concentrators, process operators, transport to the smelters and fumes from the spontaneous combustion of high sulfur ores (i.e. the Sullivan Mine at Kimberly, B.C.). Waterborne pollution can result from resuspension of dustfall by runoff, acid mine leachate or contaminated water from mine drainage, mill concentrate storage and shipping areas, holding or tailings settling ponds. Lead contamination can also occur during the mining of other ores which have trace amounts of the metal or from materials used such as explosives and lubricants.

1.2 Lead Used in Explosives and Lubricants for Mining Operations

Lead azide and lead styphnate in explosives and detonators are used extensively in the mining industry (19).

Lead powder is also used as a lubricant in heavy machines where finely ground powder is mixed in a carrier grease. The granules prevent the lubricant from being squeezed out and the soft lead will fill scratches and pits in the metal surfaces. Lead seal is used in piping as a 45-75% lead powder/lubricant mix. The resistance of lead to acidic corrosion makes it ideal for use in preventing metallic joints from corroding or seizing.

1.3 Acid Mine Water from Lead, Lead/Zinc Mines

Acid water discharge from mining operations can have severe deleterious effects on the aquatic environment (46, 5, 112). The low pH of acid mine water such as the pH = 3.2 ± 0.02 (106) reported at the Portal Mine in the Kootenay River Basin can largely be attributed to the oxidation of ores containing sulphur (99). Heavy metals such as lead, zinc, iron and aluminum readily dissolve in low pH water and can damage receiving waters to the point where fish cannot survive (112). A U.S. study (112) reported that fish are more sensitive to mine acid solutions than sulfuric acid of similar pH. This was indicated in the West Branch of the Susquehanna River in Pennsylvania which had a pH of 3.7 and caused a higher sensitivity in 1 year old Brook trout than 6 month old fish experienced in laboratory water at pH = 3.6. It was noted that the field study water was colder, of a higher pH and used older fish which should have increased tolerance.

1.4 Treatment of Acidic Mine Effluent

The Heath Steele Mine in New Brunswick is a 3,000 ton/day lead, zinc, copper mine. An acid drainage problem resulted from surface water contacting metal sulfides (5). Calcium (CA^{2+}) and lead (Pb^{2+}) precipitate rapidly out of solution at pH 5.3 and 6.0 respectively (46). First attempts at control were settling ponds with the addition of hydrated lime which resulted in a voluminous precipitate.

In 1969 stream requirements were made as follows:

1) No sulfur compounds other than sulphates were to be discharged below the mine property.
2) The pH range at the mouth of the Tomongus River is between pH 6-8 and no more than 18 ppb Cu and 108 ppb Zn.
3) The Mirimachi River downstream was to have no greater than 0.1*toxic units.

The problem was addressed by identifying and separating the contaminated water and directing it to a tailing disposal area. The water was mixed with tailings and hydrated lime which precipitated the dissolved metals. The capital cost was $2 500 000 with $220 000 operating cost per year which amounts to $0.20 per ton of ore. Average metal toxicity was reduced 80-90%.

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* The concentrations of 0.1 toxic unit defined as 3 ppb Cu, 30 ppb Zn with a combined hardness of 20.

1.5 Disposal of Mine Tailings in Marine Environments

Generally, heavy metals entering marine estuarine waters are rapidly precipitated in alkaline and saline environments (46). The rate and degree of accumulation by aquatic organisms depends on several factors including metal concentration, chemical form, organic content, pH of sediments, overlying water, sulfide levels and feeding habits of aquatic organisms. Shellfish and bottom dwellers tend to accumulate metals more than pelagic fish.

Choice of marine disposal of tailings over terrestrial disposal depends on factors such as potential damage to freshwater sources from acid leachate, or turbidity and destruction of bottom habitat by marine disposal. A study of the Amax Kitsault outfalls to Alice Arm recommended that the mine tailings outfall be extended from a depth of 50 m to 100 m and that abatement programs for lead, zinc and cadmium be implemented (35). It was calculated that 4% of the 10,000 to 12,000 tons/day of tailings discharged at the 50 m level would form a cloud in the surface receiving water. Discharge at 100 m would eliminate the shallow tailing cloud and reduce interference with small organisms and migrating fish. Further studies were recommended to determine background levels of metals in the fresh and salt water and sediment of the receiving environment. The environmental review panel found that with the possible exception of lead, zinc and cadmium that marine tailings disposal would not pose any deleterious effect (35).

The panel also found that the marine disposal was preferable to land surface disposal where the tailings contaminants would be expected to leach out and contaminate freshwater draining to the surface waters of Alice Arm (35).

Evidence presented at public hearings (sponsored by the B.C. Government) on waste disposal and pollution control in the mining industry concluded that such practice was detrimental to the marine community and that unconfined disposal should be avoided (123). Underwater disposal of tailings could under certain conditions improve the receiving environment if previous non-euphotic zones (areas beyond which light cannot penetrate) were made shallow enough for light to penetrate so that the opportunistic bottom dwellers were able to utilize the new habitat. This has occurred in Britain with the dumping of china clay into coastal waters (123).

Research and monitoring of lead in the sea has serious technical problems in obtaining reliable results. High background levels and interference in analytical techniques often results in analysis being too high. Exacting, clean room techniques are required for accurate analysis (86).

1.6 Concentrate Production

Lead and zinc are commonly co-existent elements in lead bearing ores. Production of one cannot be carried out without co-production of the other at least to the concentrate stage. Typically the ore is crushed and then ground to specific sizes and separated via selective flotation of the mineral fractions. Grinding and flotation may occur in several sequences to recover the various mineralized fractions. Tailings and effluents are a source of lead contamination particularly if the rock has acid generation potential (see Section 2.2).

1.7 Loading and Shipping of Metal Concentrates

Lead concentrates contain 56%-66% and zinc concentrates contain 2.5%-7.5% total lead. The concentrates are usually co-shipped and co-processed so that spills often contain equal amounts of each material. Concentrates are dry powders which are shipped primarily by rail in B.C. and by truck in the Yukon Territory. Concentrate loading at the major mines is from dust controlled sheds using covered conveyors to rail cars or trucks. Unloading is by conveyor, bottom dumping or rail car rotation.

The Cyprus Anvil Mine in the Yukon has re-opened under the ownership of Curragh Resources and is currently producing and shipping lead and zinc concentrates to offshore smelters. The concentrates are carried on double trailered trucks capable of holding 45 tonnes. Each trailer has a metal/fibreglass composite lid which prevents fugitive dust problems. The concentrate is shipped via the Whitepass-Carcross Highway to Skagway, Alaska. During 1977 and 1978 when production reached a peak there were twelve spills in the Yukon Territory totalling an estimated 465 tons of concentrate (105 tons of total lead). From 1979 through 1986 a total of 600 tons was spilled of which 300 tons were lead concentrate (180 tons total lead). The most recent spill occurred in August 1986 at 38 tonnes of lead concentrate. The new trucks are capable of carrying 48 metric tonnes as opposed to 45 tonnes in 1978. The Whitepass road has now been upgraded to all winter driving and shipment will continue year round.

In B.C., concentrate is shipped primarily by rail and there have been two major spills of 770 tons of Pb-Zn-Cu concentrate at Savonna, B.C. in 1979 and 400 tons of Zinc at Nelson, B.C. in 1981. The largest truck spill reported was 30 tons at Grande Forks, B.C. Cleanup involves reloading of uncontaminated concentrate by mechanical or manual methods and shipment to destination. Concentrate contaminated with dirt and gravel was returned for reprocessing (Table 2).

1.8 Lead Ore Deposits in British Columbia and the Yukon

The average background level of lead in Western Canadian soils is 10.6 ppm to 180 ppm (69). The most common form of lead bearing ore is a lead/zinc mixed ore. Other sources are primarily lead ores, copper ores and zinc ores. The percentage of lead produced from various ores is presented in Table 3.

The most heavily mined areas in British Columbia is the Kootenay Arc which is a geologic formation 15 to 20 miles wide with a curved trend to concave west (107) (see Figure 1). The area extends from south of the International border at Nelway, B.C. through the Salmo district, Kootenay Lake and Lardeau district 256 km north to Revelstoke. It is expected that the arc extends 400 km north of the international border (107). Figure 1 shows the relative location of lead producing mines in B.C. and the Yukon. The major concentration of mines is in the southeast corner of B.C. Other

TABLE 2 SPILLS OF LEAD AND ZINC CONCENTRATES IN THE PACIFIC AND YUKON REGION (1977-1986)

DATE	LOCATION AND TYPE OF CONCENTRATE			TONS OF CONCENTRATE	METRIC TONNES OF LEAD
77/03/08	Truck	Whitepass, Yukon	Pb-Zn	not recorded	21
77/05/24	Truck	Whitepass, Yukon	Zn	not recorded	1.0
77/05/31	Truck	Whitepass, Yukon	Pb-Zn	not recorded	21
77/09/21	Truck	Whitepass, Yukon	Zn	25 tons	1.0
77/09/20	Truck	Whitepass, Yukon	Pb-Zn		12.5
78	Six spills	Whitepass, Yukon	Zn	avg. 40 tons	12.0
78	One spill	Whitepass, Yukon	Pb	40 tons	36
79/01-86/08		Yukon Territory	Pb	300 tons	300 tons
79/01/02	Train	Savonna, B.C.	Cu-Pb-Zn	770 tons	unknown
80	None				
81	Train	Nelson, B.C.	Zn	400 tons	18.2
85/12/04	Truck	Vancouver Is., B.C.	Zn	unknown	
85/12/18	Truck	Trail, B.C.	Zn	<1.0	<0.05
86/01/30	Truck	Grande Forks, B.C.	Zn	30	1.4
	Truck	Whitepass, Yukon	Pb	38 tonnes	38

TABLE 3 PERCENTAGE OF LEAD FROM VARIOUS ORES (15)

% PRODUCED	TYPE OF ORE
62.9%	mixed lead/zinc
28.6%	lead ores
3.2%	copper ores
3.0%	zinc ores
2.3%	other ores

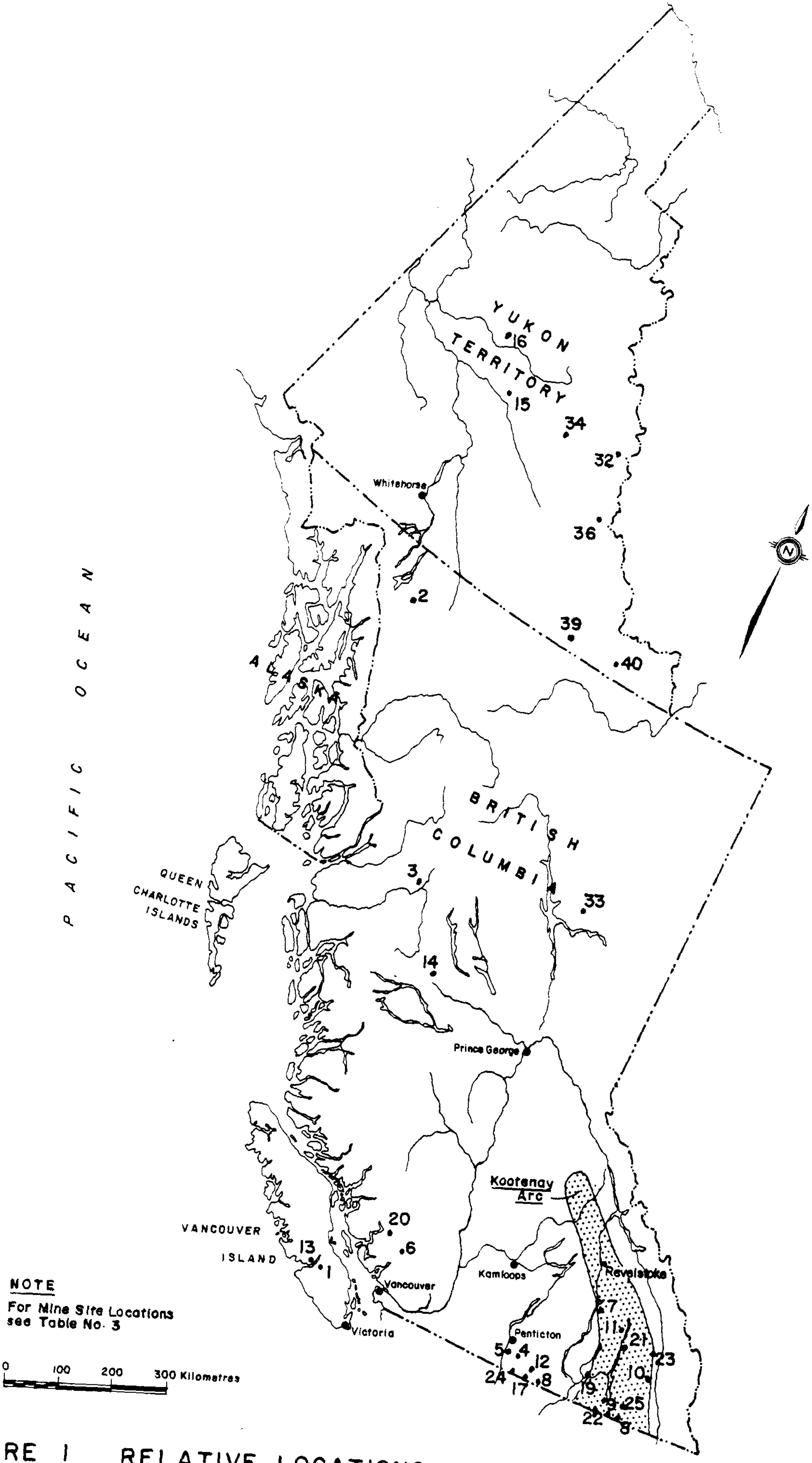

FIGURE I RELATIVE LOCATIONS OF LEAD PRODUCING MINES IN BRITISH COLUMBIA AND THE YUKON mines operating or having operated since 1976 are located in the Pemberton District north of Vancouver, Alberni District of Central Vancouver Island, White Sail District of Central B.C., Hazelton and Atlin District of North Western B.C. and Central Yukon.

The majority of the potential new development areas are located in the Yukon in areas near McMillan Pass, Hess region, Watson Lake, Coal River, Kwadacha River and Robb Lake totalling in excess of 92 000 000 tonnes of ore (Table 4). Many of these deposits show assays exceeding 7% lead up to 18% lead zinc complexes. The rate of development will depend on base metal prices which are currently depressed to levels of marginal profitability.

1.9 Major British Columbia and Yukon Lead Mines (13)

The major lead mines in B.C. in 1981 were:

1) Cominco Ltd., Sullivan Mine, Kimberly
2) Dickenson Mines Ltd., Silmonac Mine, Sandon
3) Northair Mines Ltd., Brandywine Falls, Brandywine
4) Tech Corporation, Beaverdell Mine, Beaverdell
5) Westmin Resources Ltd., Lynx and Myra Falls Mines, Buttle Lake

The major lead mines in the Yukon in 1981 were:

1) Cyprus Anvil Mining Corp. (now Curragh Resources), Faro Mine, Faro
2) United Keno Hill Mines Ltd., Elsa, Husky and No Cash Mine, Mayo District

Development in the Howards Pass area of the Yukon is expected to have a potential output of 100 000 tonnes per year in the mid 1980's (15). Data for the following text can be found in Appendices I-IV.

TABLE 4 HISTORICAL, PRODUCING AND POTENTIAL LEAD MINES IN THE PACIFIC REGION

MINE	LATITUDE	LONGITUDE
1) Lynx, Myra, Prince Mine - Alberni District	49° 34′ 00"	125° 35′ 00"
2) Atlin Rufiner Mine - Atlin District	59° 43′ 54"	133° 31′ 12"
3) Sunrise Mine - Hazelton District	55° 20′ 30"	127° 27′ 00"
4) Dusty Mal Mine - Penticton District	49° 21′ 00"	119° 33′ 00"
5) Horn Silver Mine - Penticton District	49° 03′ 24"	119° 41′ 00"
6) Warmen Mine - Pemberton District	50° 08′ 00"	123° 06′ 00"
7) Chaput Mine - Vernon District	50° 16′ 00"	118° 57′ 00"
8) Juval Denero Grand Mine - Penticton District	49° 09′ 30"	118° 37′ 00"
9) Reeves MacDonald Mines Ltd. (Annex Mine)	49° 03′ 00"	117° 20′ 00"
10) Cominco Ltd. (Sullivan Mine)	49° 43′ 00"	116° 01′ 00"
11) Dickenson Mines Ltd. (Silmonac Mine)	49° 58′ 43"	117° 14′ 06"
12) Teck Corporation (Beaverdell Mine)	49° 25′ 58"	119° 05′ 57"
13) Western Mines Ltd. (Myra Falls Mine)	49° 34′ 22"	125° 35′ 47"
14) Bradina Joint Venture (White Sail Mine)	53° 31′ 00"	127° 00′ 00"
15) Curragh Resources - Faro Mine (CAMC)	62° 20′ 00"	133° 30′ 00"
16) United Keno Hill Mines (Elso, Husky and No Cash Mines)	63° 55′ 00"	135° 40′ 00"
17) Riverside Mine - Penticton District	49° 06′ 42"	118° 58′ 12"
18) Gold Belt Mine - Vernon District	49° 09′ 30"	117° 07′ 24"
19) Scranton Mine - Nelson District	49° 47′	117° 07′ 24"
20) Northair Mines (Brandywine Falls Mine)	50° 30′ 15	123° 40′ 22"
21) United Keno Hill Mines (Venus Mine)	60° 01′ 00"	134° 35′ 00"
22) Silmonal Mine - Nelson District	49° 58′	117° 15′ 00"
23) Ruth Vermont Mine - Lardeau District	50° 57′	116° 59′ 00"
24) Highland Bell - Penticton District	49° 26′	119° 04′ 00"
25) Cominco Salmon (H.B. Mine)	49° 08′ 28"	117° 15′ 27"
26) Arlington Mine	49° 47′	117° 21′ 00"
27) Last Change Mine	49° 59.8′	117° 12′ 00"
28) Lucky Thought Mine	49° 56.3′	117° 24′ 00"
29) Ottawa Mine	49° 47.5′	117° 24′ 00"
30) Panama, Silver Glance Mine	50° 03.6′	117° 12′ 00"
31) Denero Grand Juvel Mine	49° 09.5′	118° 37′ 00"

TABLE 4 (Continued)

POTENTIAL BY MINABLE DEPOSITS

COMPANY	LOCATION	DEPOSIT SIZE TONS	ORE LOAD Pb Grade (%)
32) Aberford Resources Ltd.	MacMillan Pass, Yukon Territory	15 500 000	7.1%
33) Arrow Interamerican Corp.	Robb Lake	6 100 000	7.3%
34) Curragh Resources (C.A.M.C.)*	Hess Area, Yukon Territory	260 000	10.0%
35) Curragh Resources (C.A.M.C.)*	Kwadacha River	30 000 000	2.3%
36) Hudsons Bay Mining and Smelting	McMillan Pass, Yukon Territory	9 500 000	6.9%
37) Placer Development	Howard Pass, Yukon Territory	120 000 360 000	2.1% 7.0%
38) Placer/Kennco	Houston	394 000	2.7%
39) Regional Resources	Watson Lake, Yukon Territory	6 000 000	18% Pb/Zn
40) Sulpetro Minerals	Coal River, Yukon Territory	5 500 000	12%

* Cyprus Anvil Mining Corporation

1.10 Description of the Major Lead Producing Mines in the Pacific Region

The Metal Mining Liquid Effluent Regulations and Guidelines (MMLERG, 1977) (EPS 1-WP-77-1) provide the following limits for lead in liquid discharges. Total lead should not exceed 0.4 mg/l in a grab sample, 0.3 mg/l in an 8 hour composite sample, and 0.2 mg/l as an arithmetic monthly mean.

1.10.1 **The Lynx, Myra, HW and Price Mines.** Copper, zinc and lead concentration, as well as silver and gold values, are produced from the ore deposits near the southern tip of Buttle Lake on Vancouver Island (Figure 2). From 1975 to 1980 they produced an annual average of 6 284 tonnes of lead

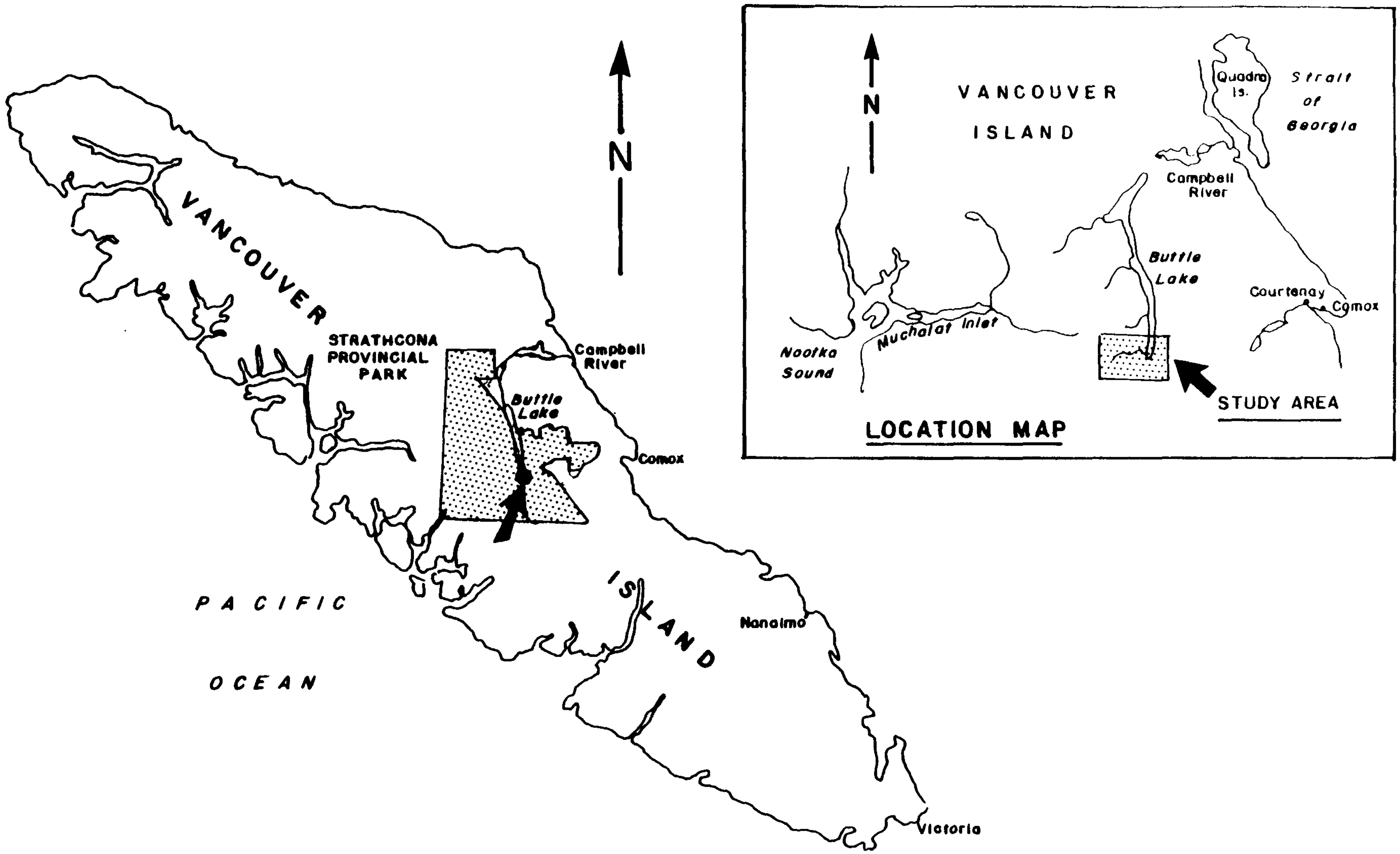

FIGURE 2 LOCATION OF WESTMIN RESOURCES LTD. MINING OPERATION (163)

concentrate containing 2 979 tonnes of lead. Production of lead averaged 2 556 tonnes from 1982 - 1984. Proven ore reserves are:

HW Mine	15 232 000 tons	0.30% Lead
Lynx Mine	512 600 tons	0.82% Lead
Myra Mine	14 300 tons	1.21% Lead
Price Mine	231 000 tons	1.07% Lead

Based on current production rates the mines will operate well into the next century.

Dissolved lead concentrations from sites in Myra Creek 30 m upstream and downstream of the Lynx Mine settling pond ranged from 0.0013 to 0.0044 mg/L. Average total lead values ranged from 0.003 to 0.44 mg/L with maximum grabs of 0.17 mg/L which is less than the Federal maximum monthly mean of 0.20 mg/L. Core samples of tailings solids taken from surface to depths of 92 feet averaged 1 067 ppm lead ranging from 600 ppm to 2 000 ppm. Tailing slimes discharged to Buttle Lake from 1975 to 1980 average 125 825 tonnes/year total lead (160). Freshwater monitoring of Buttle Lake north of Myra Creek is ongoing. Supernatant from the Price Mine settling pond average 0.02 mg/L dissolved lead from 1975 to 1982. Mill tailings discharged from a raft to Buttle Lake averaged 0.078 mg/L dissolved and 53.7 mg/L total lead from 1975 to 1983. Discharge to the lake was halted in 1982. To reduce metal loadings a surface tailings disposal site was located southeast of the Lynn Mine bordering Myra Creek. A portion of Myra Creek was diverted to move it further southeast out of the influence of the tailings disposal area (Figure 3).

The tailings slurry is sprayed in a sequence which allows drying before re-application. A collection system of wells intercepts groundwater and waste rock seepage from the waste dump and tailings area prior to its exfiltration to Myra Creek. A collection pump redirects the water to a sewage basin from which it is pumped to a treatment system where pH is increased by addition of lime to precipitate metals. The effluent is discharged via evaporation and as a supernatant to Myra Creek. In September

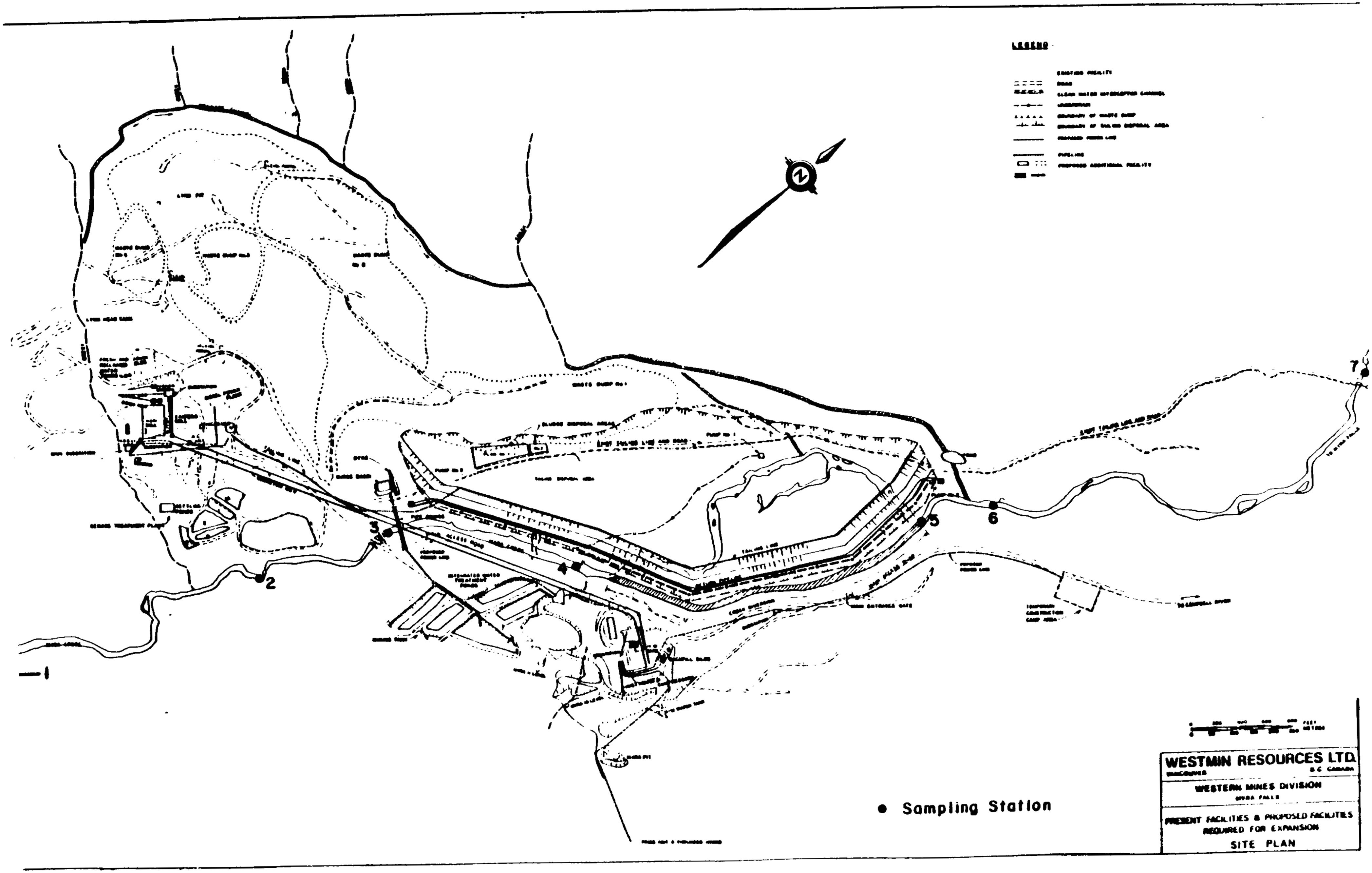

FIGURE 3 LOCATION OF THE TAILINGS FILL, WATER TREATMENT SYSTEM AND SAMPLE SITES OF THE LYNX MINE

1985 production was increased from 890 tonnes/day to 2 670 tonnes/day to process a new vein of copper/lead/zinc ore. The increase in production causes the mine to be subject to the Federal MMLERG, 1977.

1.10.2 **Northair Mines Brandywine Falls Lead/Zinc/Silver/Gold Mine**. Located 60 km north of Squamish, B.C. and 10 km north of Brandywine Falls (Figure 4). The mine has 5 portals and is permitted for intermittent discharge of up to 4 750 m^3/d of tailings pond supernatant. Effluent is treated by direction to a tailing pond with overflow to a settling pond and subsequent discharge to Anomaly Creek (Figure 4). A pipe follows a natural gully from the Belamy Lake Treatment Basin to "Water License" Creek. The highest effluent concentrations have been recorded in the 3 300 ft. and 2 800 ft. portal prior to discharge to the settling pond. Monitored concentrations of treated effluent reported to the EQUIS data system were well within Federal MMLERG, 1977. Ore was processed in a 300 ton/day mill beginning in 1976 and was suspended in June 1982 due to economic conditions. The mine is maintained on a standby basis.

1.10.3 **Dickenson Mines, Silvana Mines Ltd., New Denver, B.C.** This lead/zinc/silver mine is located near Sandon and New Denver in the Kootenay Arc (Figure 5). The maximum mine production rate is 135 tonnes/day with average production of 74 tonnes/day or 1 054 tonnes/year (150). Lime is added to a primary tailing pond for precipitation of a course fraction and slimes settle in a second pond prior to discharge to Tributary Creek (Figure 6). Mine water is contaminated with natural spring water that exceeds the WMB Permit requirement for zinc. This water may be treated by lime addition in a third pond. Average concentration was 0.075 ± 0.123 mg/L and average loading was 16.1 g/day which includes the natural spring water.

1.10.4 **Tech Corporation, Beaverdell Mine Near Kelowna**. Located in south eastern B.C. this silver/lead/zinc/gold mine has a 120 ton/day ore capacity (150). The mill and six treatment ponds are located between the C.P.R. right-of-way and the West Kettle River (Figure 7). Discharge is to a tailings pond with no positive discharge. Fluid loss is by exfiltration and evaporation. The limited number of monitoring results indicate that the

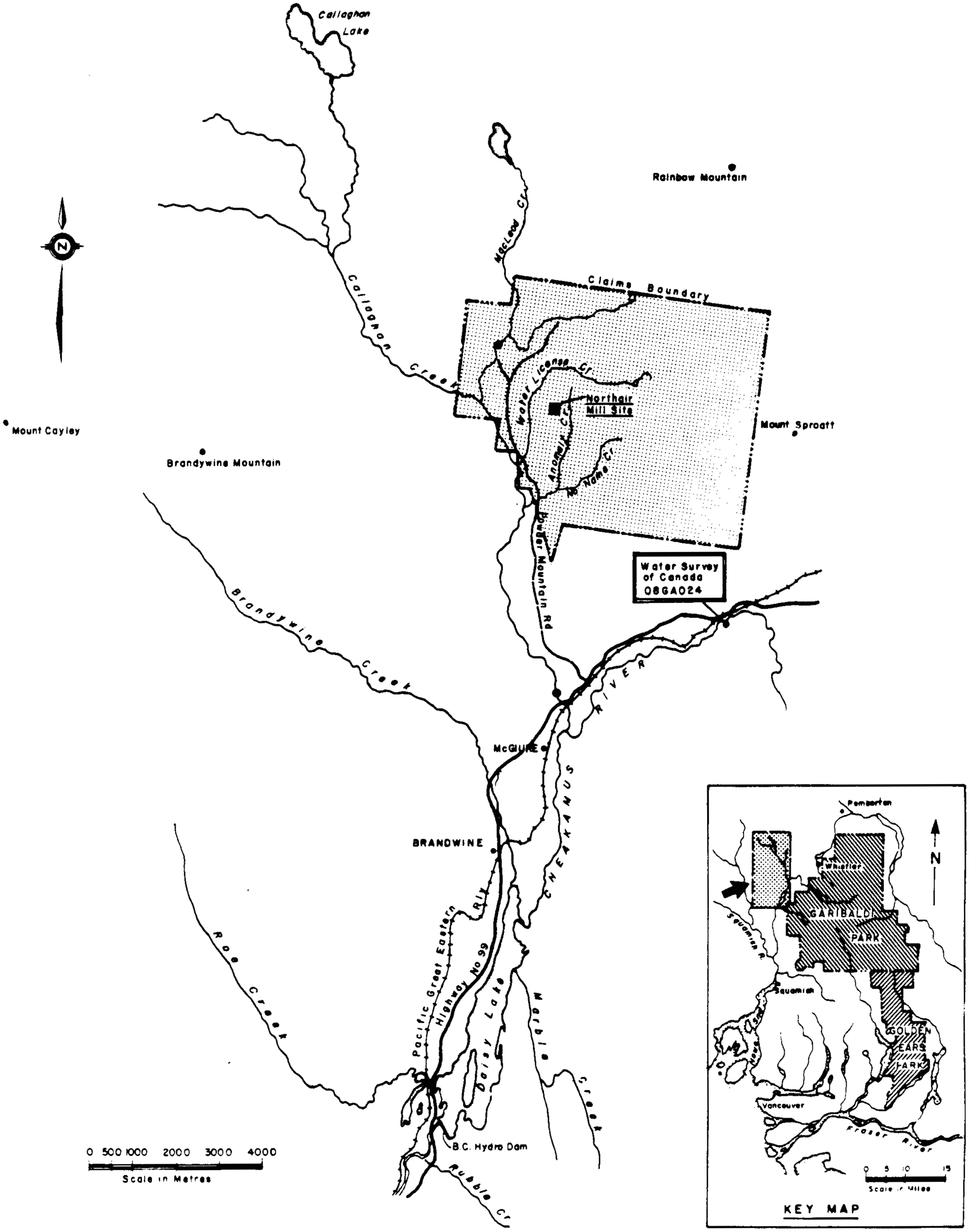

FIGURE 4 LOCATION MAP OF BRANDYWINE MINE

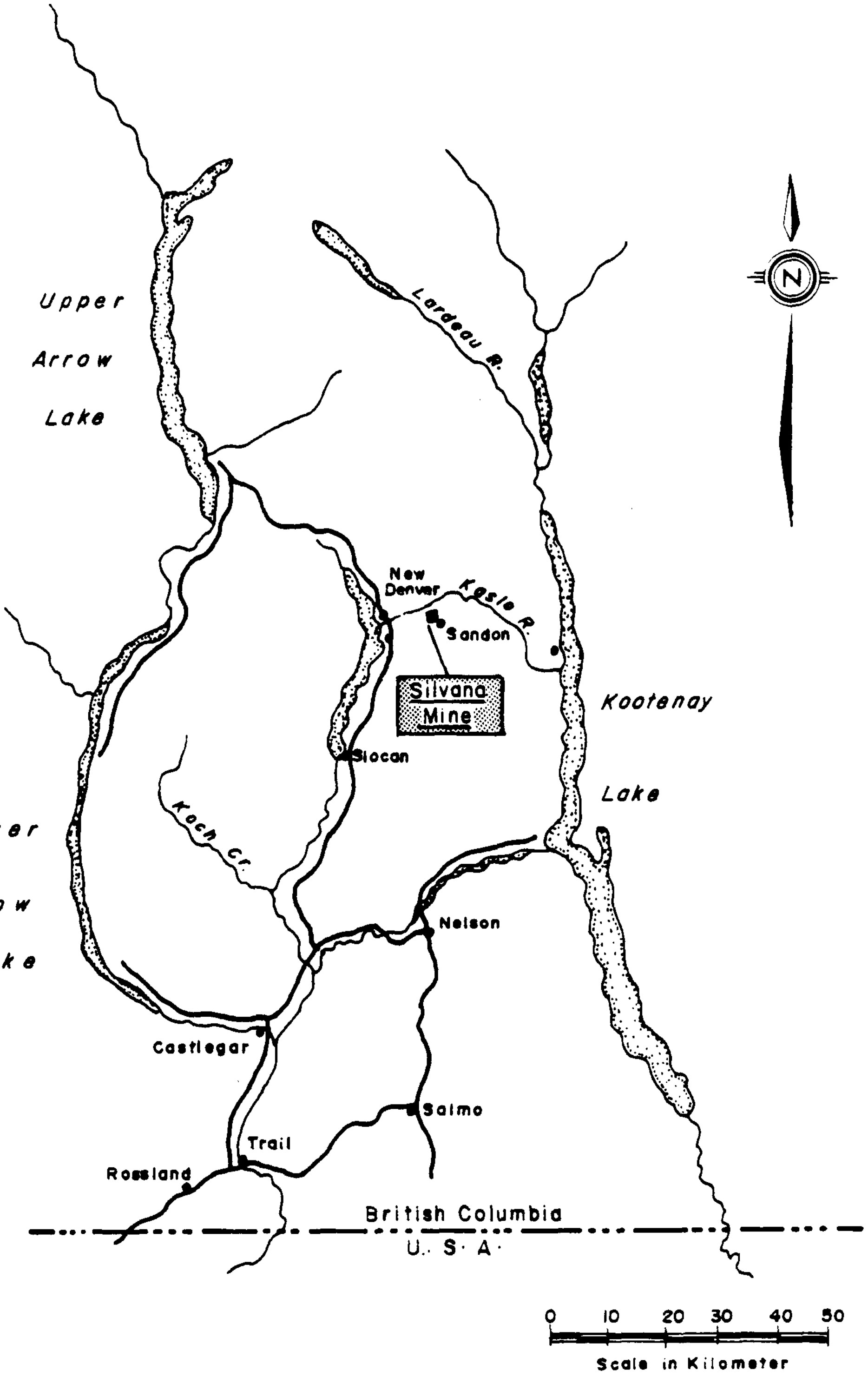

FIGURE 5 LOCATION OF SILVANA MINE SITE

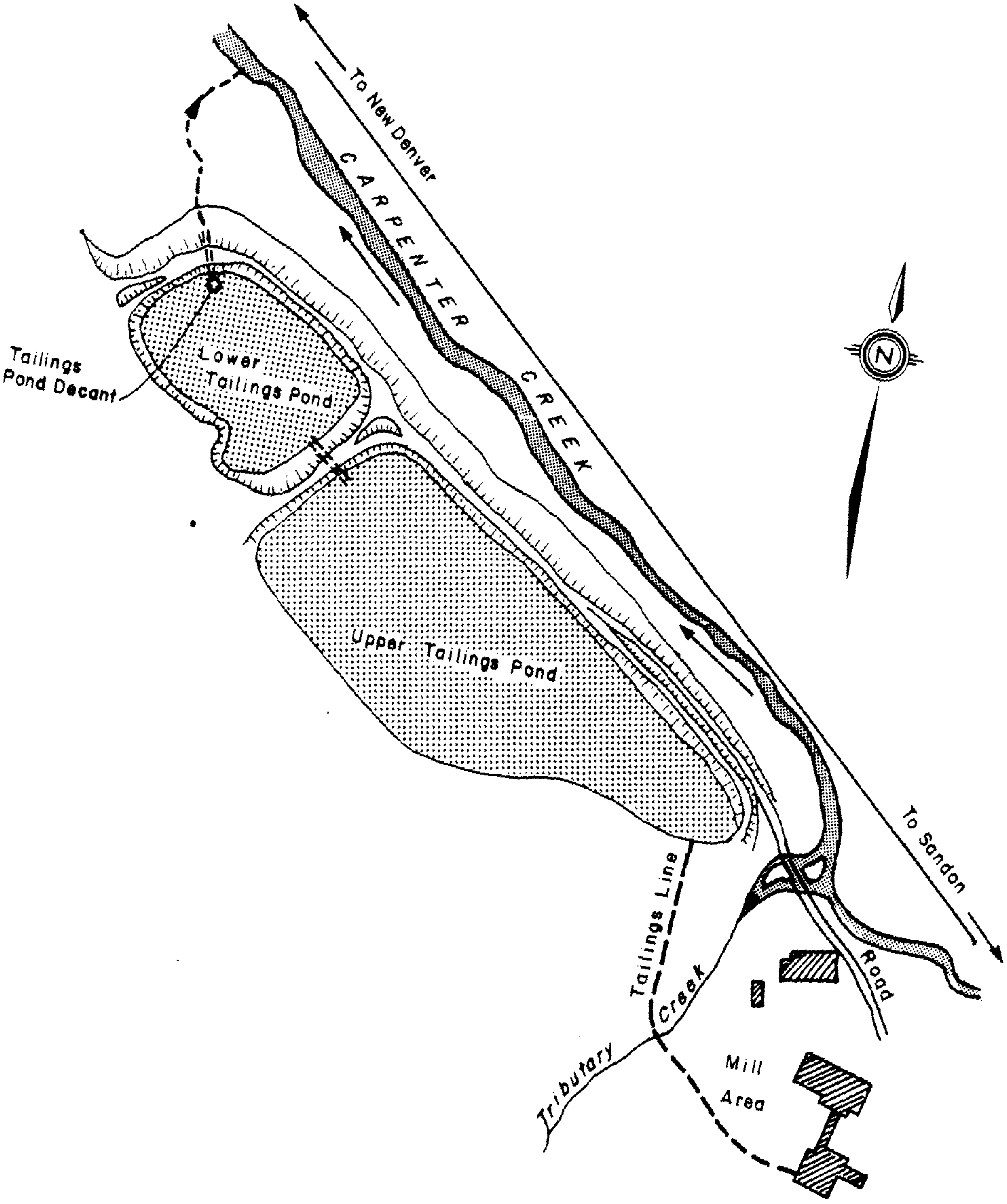

FIGURE 6 SILVANA MINES TAILINGS POND DISCHARGE TO CARPENTER CREEK

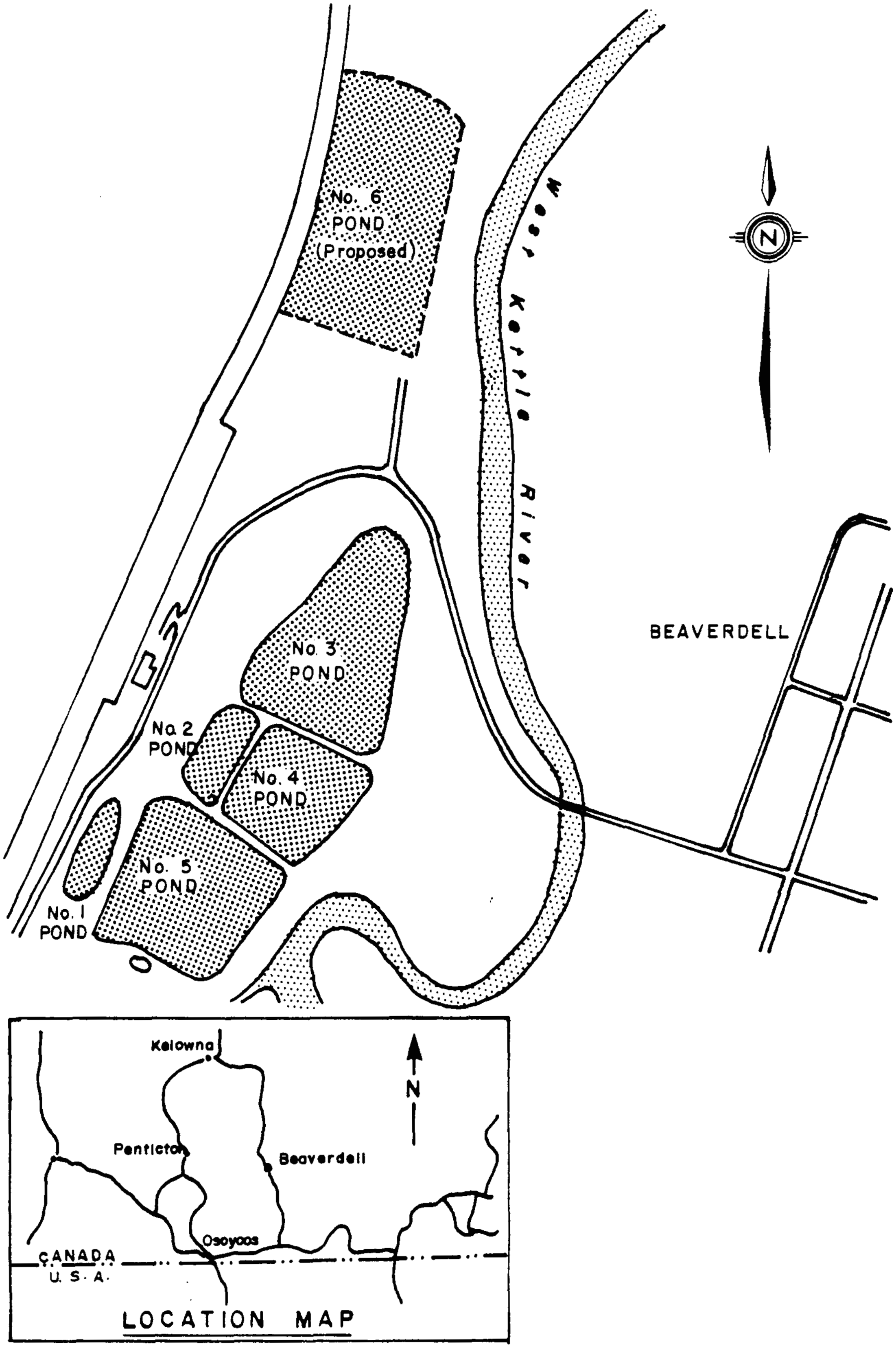

FIGURE 7 TECH CORPORATION, BEAVERDELL MINE

tailings pond supernatant lead concentrations are one to two orders of magnitude lower than the Federal MMLERG, 1977.

1.10.5 Cominco, Sullivan Mine, Kimberly. Cominco's Sullivan Mine is within the city limits of Kimberly B.C. It is one of the largest base metal deposits in the world approximately 9 000 m in diameter and 1 000 m deep at the center (151) (Figure 8). The ore body was discovered in 1892 and has been in production since 1908 (150). Production has averaged 2 465 000 tons/year from 1982 to 1984 grading an average of 4.9% lead. Lead concentrate production has averaged 168 067 ± 27 600 tons/year grading 61.7% Pb (150).

The underground mine workings are located on the southeast slopes of Sullivan Hill, approximately 3.2 km north of Kimberly. All crushing is done underground and conversion to mechanized mining which began in 1978 was completed in late 1984 (150).

A concentrator plant is located four miles southeast of the mine at the Chapman Hill subdivision of Kimberly. The original concentrator had a capacity of 2 500 tons/day and was upgraded to 10 000 tons/day by 1976 (152). The ore is crushed through several reduction stages in underground crushers and transported to the concentrator. Three separate flotation stages separate the lead, zinc and iron sulfides into high grade concentrates which are shipped to the Cominco smelter in Trail. There are various air emissions associated with the process as well as fumes created by spontaneous combustion of the ore in the mine which has been disturbed by blasting and extraction operations within the ore body. Air emissions are covered by Permit #PA-2443. Effluent discharges are allowed under Permit PE-189-01 to PE-189-08, Waste Management Branch, British Columbia Ministry of Environment and Parks (BCMOEP).

Lead emission data from the ore dressers, dryers and roasters stack has been recorded on the EQUIS data system from 1977-1982. All of the values from 1977 to 1981 were an order of magnitude lower than the range 0.16 to 0.27 mg/mole specified by the BCMOEP Control Objectives for Gaseous and Particulate Emissions. A single measurement of 1.65 mg/mole taken in April

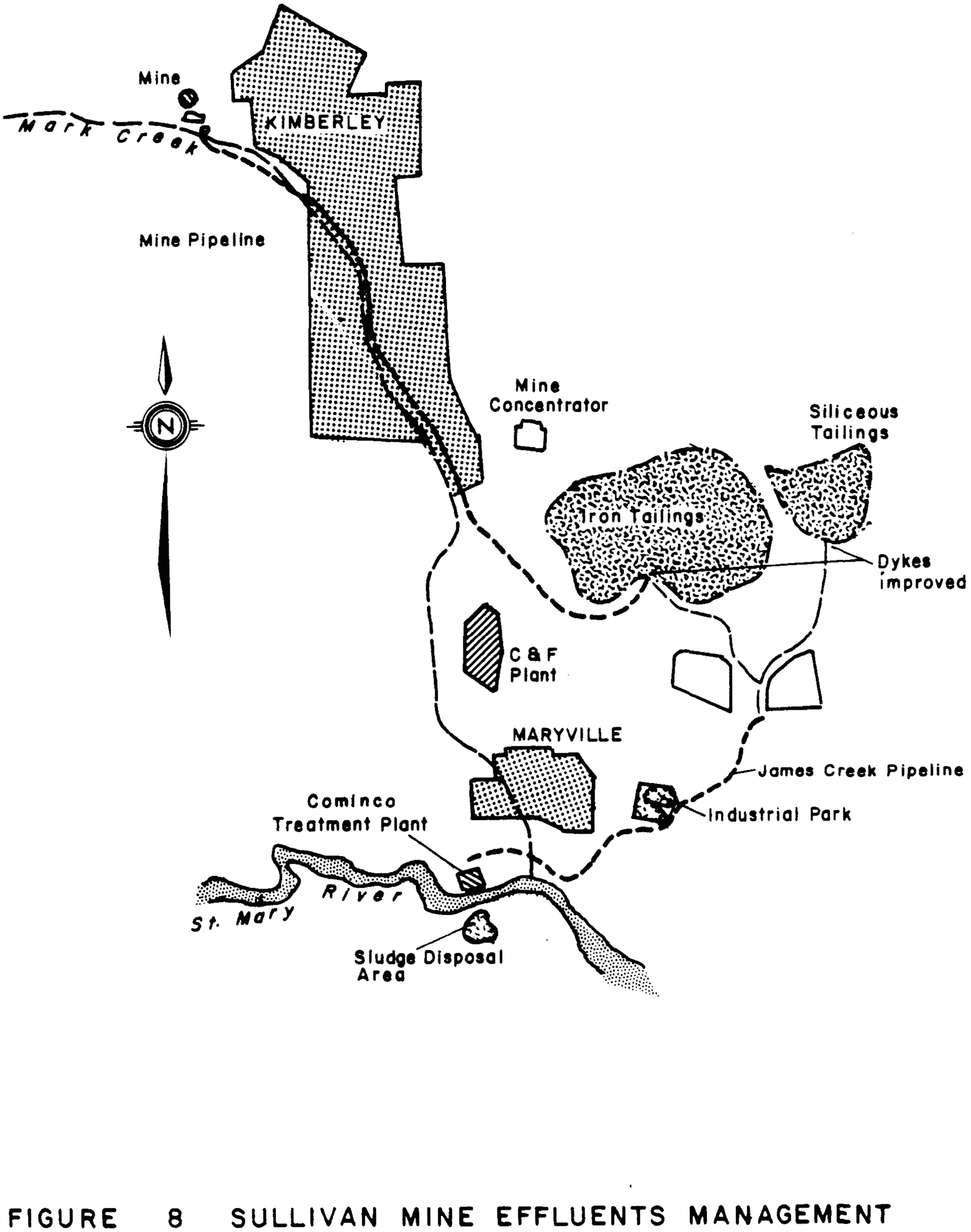

FIGURE 8 SULLIVAN MINE EFFLUENTS MANAGEMENT AND TREATMENT SYSTEM (164)

1984 exceeded this guideline. No further measurements were reported on the EQUIS data system.

Mine drainage from the 3 700 foot portal (Permit #PE00189-05) was considered to be of "fairly good quality" and within the range stipulated by the Pollution Control Objectives for the Mining, Smelting and Related Industries in B.C. (1979) (106).

Acidic mine drainage from the 3 900 foot portal contains high levels of heavy metals. Samples collected and analyzed by various agencies show an average concentration of 2.73 ± 0.59 mg/L dissolved and 6.38 ± 1.10 mg/L total lead which exceeds current guidelines. Prior to 1979 this effluent was discharged untreated to Mark Creek, a tributary of the St. Mary River, but is now combined with effluent from the iron and siliceous tailing ponds and directed to a treatment plant.

1.10.5.1. PE 00189-02 siliceous tailing pond overflow. Fine waste rock is discharged as a slurry from the concentrator to the siliceous tailing pond. Overflow was decanted to James Creek prior to 1979 after which it was routed to the waste treatment system. Concentrations and loadings showed a consistent decline during 1976 to 1979 from 998 g/d to 234 g/d total lead.

1.10.5.2. PE 00189-03 iron tailing pond overflow. Iron sulfide separated from the ore in the concentrator was used to produce sulphuric acid or discharged to the iron tailing pond. Composite and grab samples tested by various methods from 1976-1979 yielded an average of 1.70 ± 1.10 mg/L dissolved lead which exceeds the WMB guidelines. The trend in concentrations was increasing prior to the routing of this effluent to the treatment plant in 1979. Loadings were up to 22 366 g/d dissolved lead.

1.10.5.3. PE 00189-01 fertilizer complex sewer #32. The fertilizer plant discharges effluent to Mark Creek via sewer #32. The data from WMB monitoring shows lead concentrations vary up to two orders of magnitude depending on the analysis method for samples taken the same day. The range is between 0.001 to 0.85 mg/L and averages 0.104 ± 0.182 mg/L. The loading averages 3 969 ± 6 568 g/d. A detailed examination of the relation between the reported concentration and the method by which it was determined is not within the scope of this report except to note that the variability exists. It has been found that 53% of the measured lead concentrations and 61% of the pH measurements exceeded permit limits in water that discharged from overflows of the iron and siliceous tailing ponds to James Creek. Mean pH of the effluent was 3.2 ± 0.02 (105). Dissolved lead concentrations peaked during periods of low water when the receiving water provided the smallest dilution effect.

Total lead (includes dissolved and precipitated lead) was found to be consistently higher downstream of the site (144).

1.10.6 United Keno Hill Mines Limited, Elsa, Yukon Territory. The United Keno Hill Mines Limited operation, which includes several small mines, is centered at Elsa, in the Mayo District of the Yukon Territory, and lies approximately 44.8 km north of the community of Mayo on the Stewart River. Elsa is 456 km north of Whitehorse, the capital of the Yukon (Figure 9).

The discovery of silver-lead-zinc on Galena Hill in 1906 started the interest in this area, and some shipping grade ore was sent to the smelters commencing in 1914 (Figure 10). The discovery of rich veins of silver on Keno Hill Mining Company started production which continued until 1942, when all the mines shut down as all the known ore had been exhausted.

In 1946 the United Keno Hill Mines acquired the holdings of Treadwell Yukon and other properties and initiated a program of exploration, development and mining.

To the end of 1976 United Keno Hill Mines had produced over 126 million ounces of silver, more than 273 million kg of lead, and more than 149 million kg of zinc and an excess of 2.5 million kg of cadmium. In 1973 the Elsa mill averaged a throughout of 350 tons per working day.

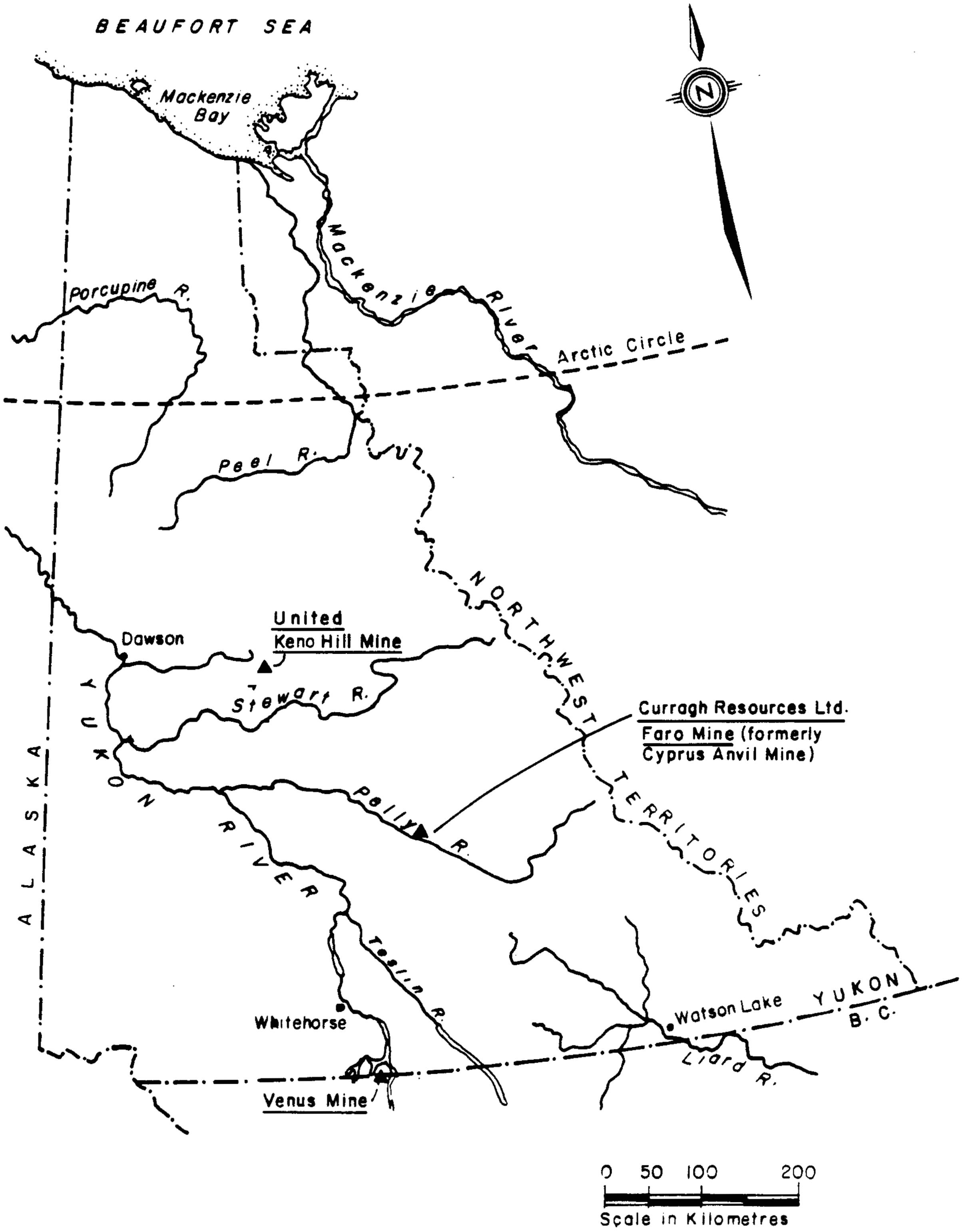

FIGURE 9 LOCATION MAP OF MAJOR YUKON LEAD MINE AND ORE DEPOSITS

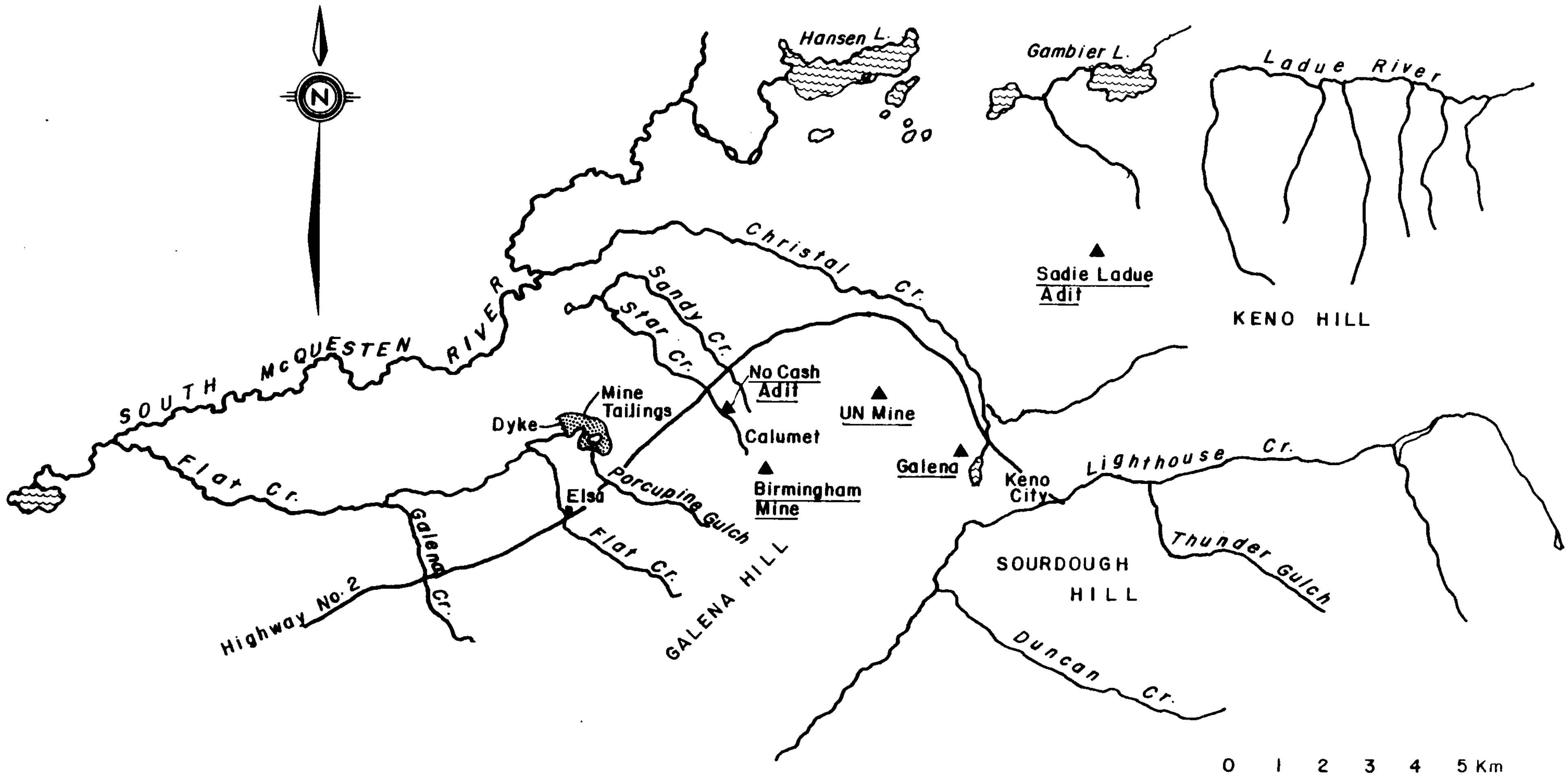

FIGURE 10 LOCATIONS OF THE UNITED KENO HILL MINES, ELSA, YUKON

In 1976 operations were set up to produce about 100,000 tons of ore per year from the Husky, No Cash, Elsa, Dixie and Keno Mines. In addition, an Exploration Office located in Whitehorse co-ordinated a field exploration program throughout the Yukon.

United Keno milled an average of 300 tons/day in the late 1970's and since September 1978 has used sodium cyanide for enhanced silver recovery from mill tailings when metal prices warranted. Environmental problems resulting from this mining operation results in frequent noncompliance with the Yukon Water Boards' licence requirement for copper, zinc, cyanide and toxicity in the final effluent.

Effluent production is estimated at 1 670 m^3/d with 1 213 m^3/d consisting of mine water, 327 m^3/d mill effluent and 129 m^3/d domestic effluent. Effluent treatment facilities consist of bi-level tailings impoundment with lime addition occurring between the levels and averaging 7 days retention. All discharges are through the tailings pond to Flat Creek which is a tributary of the McQueston River (Figure 11).

Upgrading of the pond treatment facilities was ongoing and compliance assessment was performed by the Environmental Protection Service in 1977. The mine tailings pond supernatant were monitored and found to be in compliance with all Federal guidelines on all three days of the study. The compliance status of the untreated mine water discharges were not assessed during the survey (153). In 1979 two fines were imposed for pollution, one as the result of an accident and the other for a water permit violation. The mines have gone through fluctuating production schedules due to falling metal prices for silver and lead during the 1982-1984 recessionary period. All operations were suspended in July 1982 and resumed in June 1983. The cyanide plant was closed in 1984. Mines production averaged 290 tons/day with lead production totalling 1 458 tonnes/year in 1984.

Operations have been continued at the Husky, Ruby, Silver King. Hector Fault, Husky SW, Calumet, Sagiyama, Sime 4 + 6 and Birmingham SW mines which are open pits. Ore reserves at the end of 1984 were estimated at

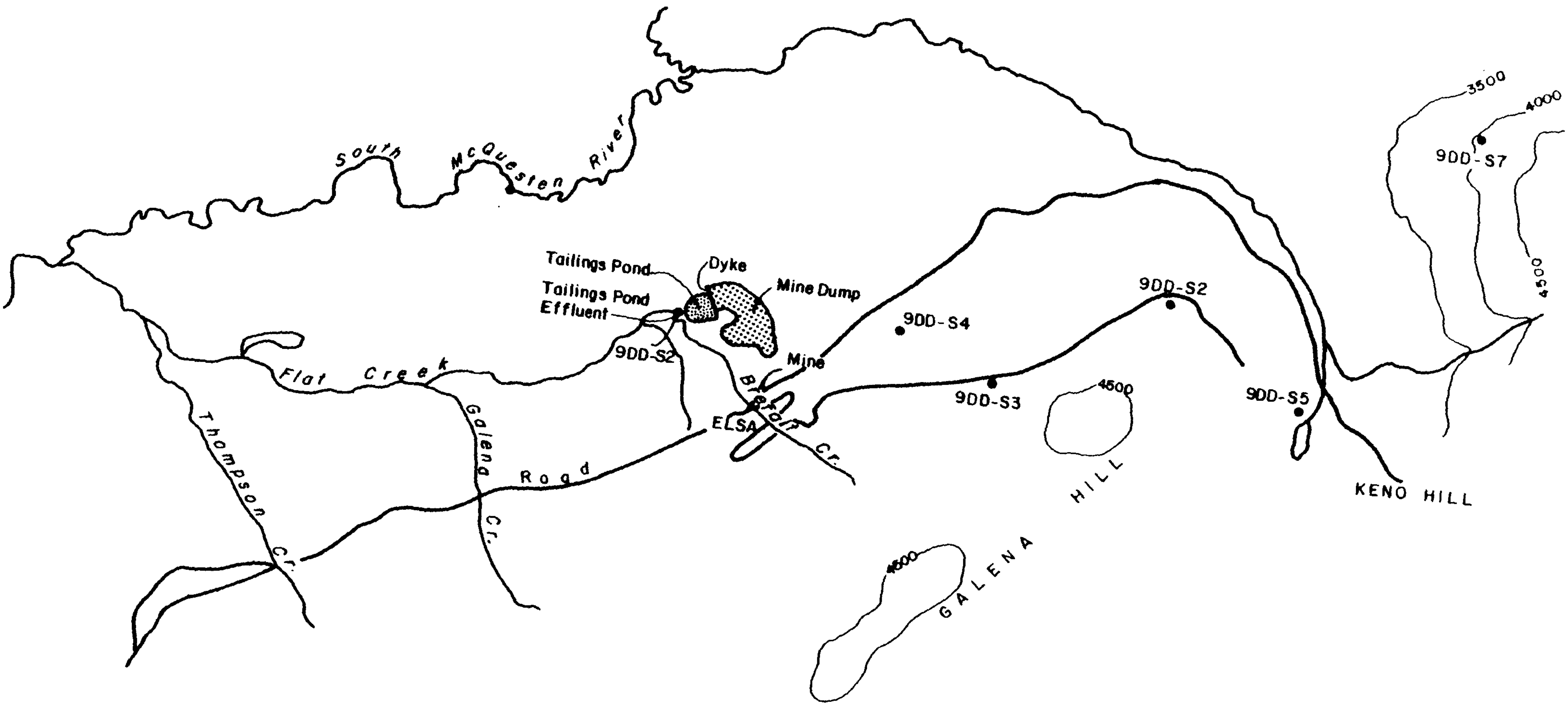

FIGURE 11 WATER QUALITY MONITORING SITES FOR UNITED KENO HILL MINES

234 800 tons and the 1984 milling rate was 72 409 tons (153). A reapplication for water licences was made in July 1985 and withdrawn in October 1985.

Monitoring Results for United Keno Hill Mines. For site locations see Figure 11.

Tailings Pond Effluent (#9DD-S1). Dates to 1983 indicates that effluent is in compliance with Federal Guidelines.

Water from UN-Mine (#9DD-S2). Data is limited but appears to be in compliance.

Birmingham Mines (#9DD-S3). Data is available to 1981 and appears to be in compliance.

Water from No-cash Adit (#9DD-S4). Data is available from 1976 to 1980. The annual averages for 1977 and 1980 were 0.273 and 0.275 mg/L which is higher than the maximum monthly mean of 0.20 mg/L specified by Federal Regulations.

Water from Balkeno 900 ft. Level (#9DD-S5). Appeared to be in compliance from 1976-1981, no further data was available.

Mine Water from the Klondike Keno Mine (#9DD-S6). Appeared to be in compliance from 1976-1981.

Water from Sadie Ladue Adit (#9DD-S7). Data is limited but appears to be in compliance.

1.10.7 United Keno Hill Mines Ltd., - Venus Mine, Windy Arm, Tagish Lake, Yukon Territories.

The following summary is taken from the Stage I Environmental Assessment by F.F. Slaney and Co. Ltd. (154).

"The Venus Mine is located on the west side of Windy Arm, Tagish Lake in the Yukon Territory, three kilometres north of the British Columbia boundary (Figure 12). The mine was established early in the century and operated until 1916. It was reopened in the 1960's and operated until 1971, when operation problems forced closure. United Keno Hill Mines Limited now desires to reopen the Venus Mine for production of gold, silver, lead and zinc.

The former processing plant was located 1.6 kilometres north of the mine. Tailings were disposed of in a pond adjacent to Windy Arm. This location is no longer suitable and it is proposed that a new mineral processing plant be located at a site in British Columbia, near the Carcross-Skagway Highway, nine kilometres south of the mine. The mill would be located about 100 metres east of the highway. Tailings disposal would be in a ravine east of the mill, about 300 metres from the highway" (Figure 13).

Ore reserves in the mine were estimated at 120 000 tons consisting of gold, silver, lead and zinc and the new mill was designed for 100 tons/day. Fifteen thousand tons of ore stored on site and existing reserves were to be processed for 2.1 years beginning in 1981. Further exploration was planned to discover new ore bodies and extend the operating life of the mine. A site visit in September 1984 by EPS personnel determined that mineral processing has not been carried out and the mill has been closed. Operations could begin a short time after resumption of mine activity at the Venus mine.

1.10.8 **Curragh Resources Ltd. Faro Yukon, Lead/Zinc Mine.** Curragh Resources Faro, lead/zinc mine is located 240 km northeast of Whitehorse, in the Yukon Territory (Figure 9). Production began in 1970 at 5 500 tons/day and was increased to 10 000 tons/day in 1974 (150). During peak operations the mine employed 700 workers and generated 25% of the Territory's gross income (158). Primary shareholder was Dome Petroleum Ltd. when operations were suspended in June 1982 due to falling metal prices. In may 1983 stripping of overburden was initiated and complete shutdown occurred in September 1984 (153, 155).

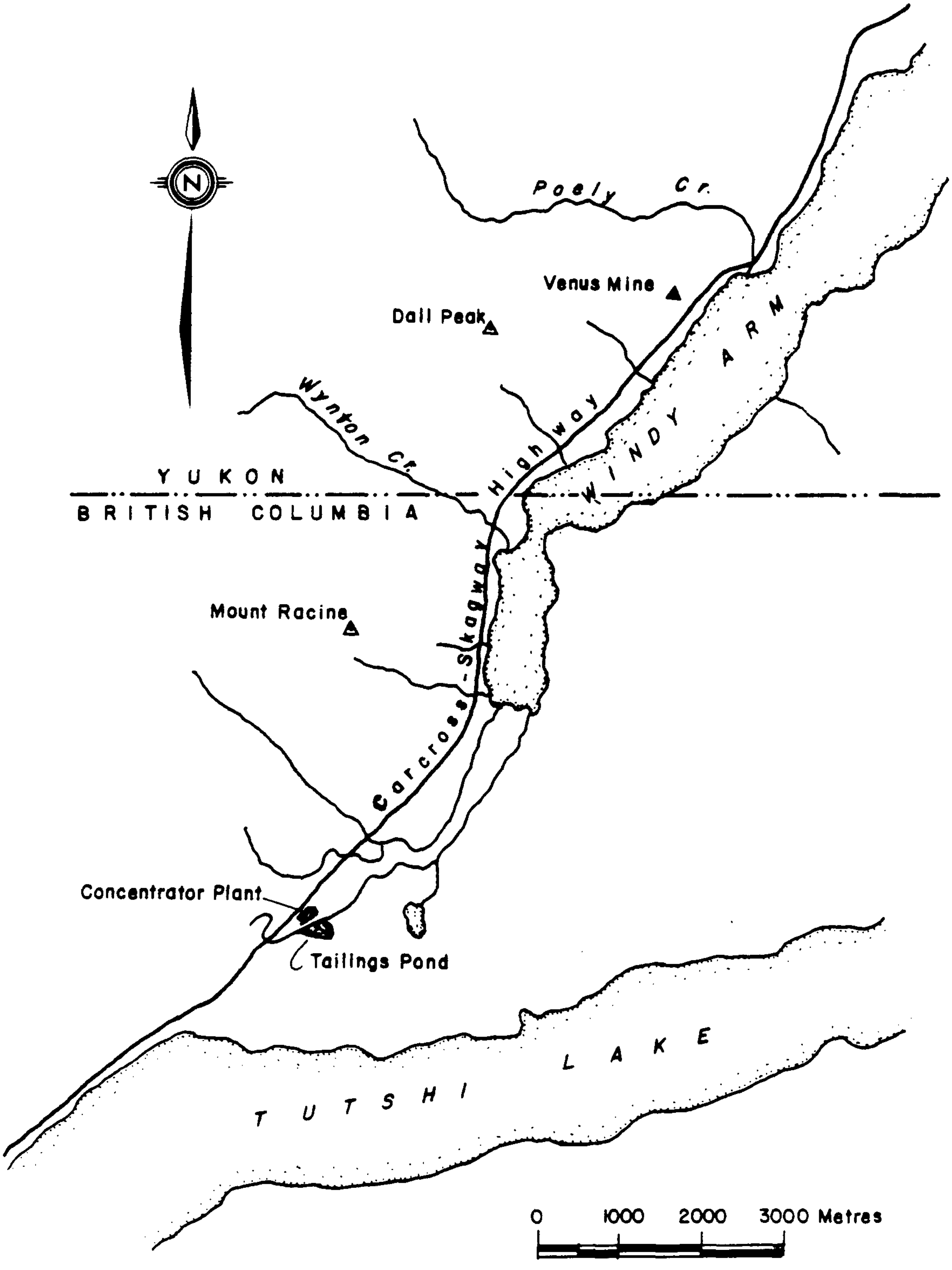

FIGURE 12 SITE LOCATION MAP OF THE UNITED KENO HILL VENUS MINE, YUKON TERRITORY

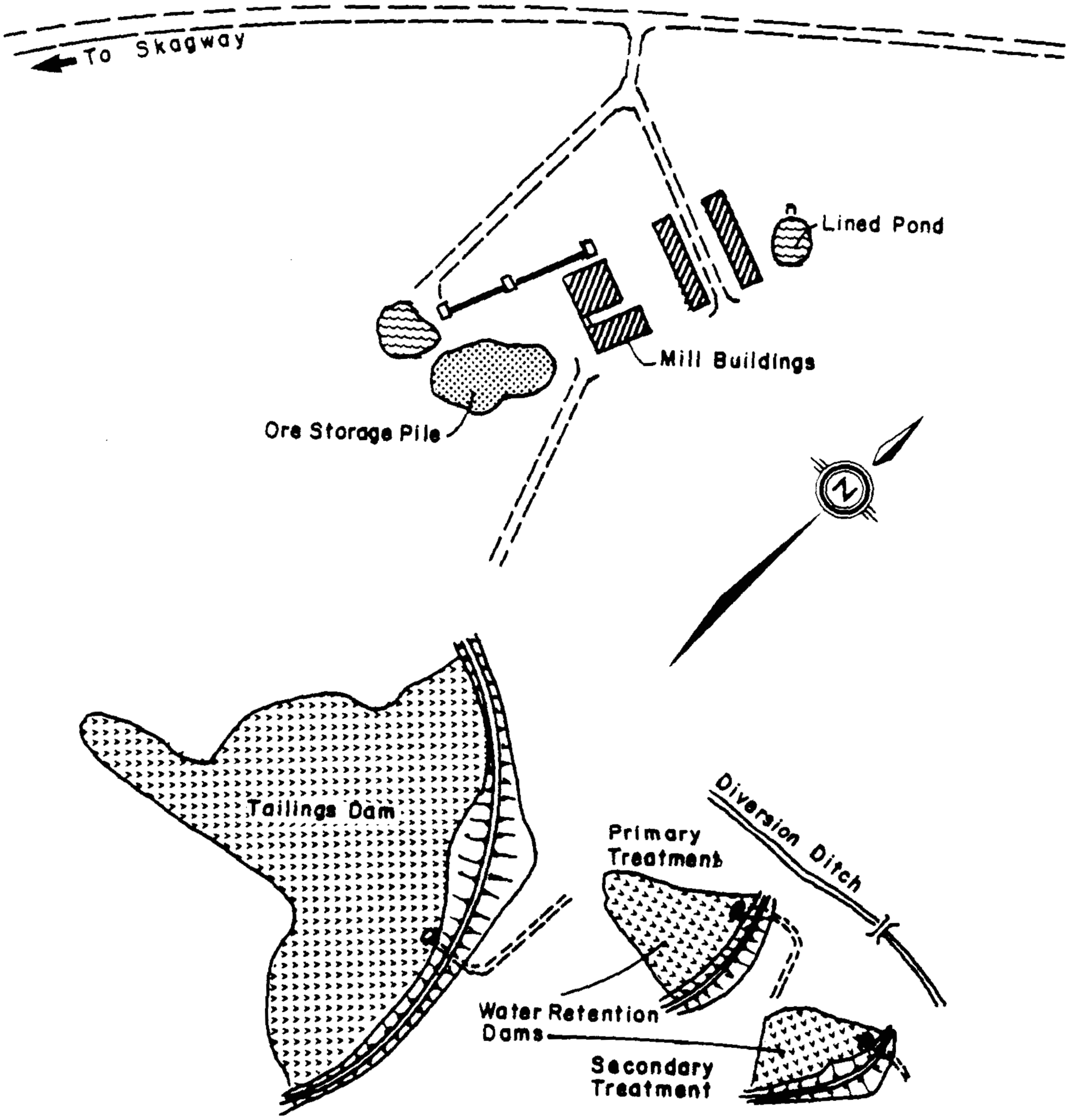

FIGURE 13 ORE PROCESSING PLANT SITE FOR UNITED KENO HILL VENUS MINE

On November 23, 1985 an offer to purchase the mine and assets was accepted from Curragh Resources Corp. of Whitehorse and restarting of the mine began almost immediately. Initial servicing of the main power units, utilities and accommodation began in December 1986 (155, 158). Removal of lower grade overburden was initiated prior to March 1986 and staffing for mill mechanical operations began the same month. Milling of new ore commenced in 1986. Peak production estimates are 175 000 tonnes of lead concentrate and 350 000 tonnes of zinc concentrate. The concentrates will be shipped by road to a port of Skagway Alaska for refining at overseas locations.

There are extensive deposits of lead/zinc/silver mineralizations near the Cyprus Anvil Mine which would maintain active mining for the next 25 years (150).

TABLE 5 ESTIMATED ORE RESERVES AND BASE METAL ASSAYS FOR - CURRAGH RESOURCES LTD. AS OF DECEMBER 31, 1984 (150)

DEPOSIT	ESTIMATED METAL ASSAY PER TON			TONS OF ORE
	LEAD	ZINC	SILVER	
Faro Deposit	2.9%	4.3%	36 g	26 700 000
Grum Deposit	3.0%	4.9%	50 g	28 000 000
Vangorda Deposit	3.0%	3.7%	43 g	7 600 000
Swim Deposit				
Dy Deposit	5.5%	6.7%	84 g	21 000 000
Cirque Deposit*	2.7%	9.0%	57 g	21 700 000
S Cirque Deposit*	2.7%	9.0%	57 g	10 000 000
TOTAL				115 000 000

* Located in north eastern B.C.

1.10.8.1 **Environmental concerns**. The Curragh Resources mine site consists of an open pit upgrade of the mill complex (Figure 14). A mine waterline connects with the mill to deliver tailings to the upper tailings pond which discharges to the lower pond that has a decant and a seepage outfall to Rose Creek.

The Faro ore reserves indicate 8 to 9 years of full production prior to abandonment. An abandonment plan previously approved by the Yukon Territory Water Board called for the construction of a flow through dam that would form an abandonment reservoir capable of covering the disposed tailings.

The tailings exhibit characteristics that make it capable of generating acid mine drainage with potential to leach heavy metals when exposed to the atmosphere. The construction of the dam and required works (estimated cost is $50,000,000) was considered too costly by the new proponent and a permit revision to allow a two year developmental study for an alternate dry abandonment plan is under consideration. The Cyprus Anvil Mine Site plan and environmental monitoring locations used by the EPS and CAMC are found in Figures 14 and 15. The water licence issued on October 4, 1985 indicates a maximum lead concentration "which shall not be exceeded in any waste discharge" as 0.20 mg/L extractable lead (159). Data from various sources indicated that the mine water at the road crossing exceeded this level in 1976, 1978, 1979 and 1980, however, this is not a discharge point.

The tailing line at the drophouse which is an intermediate sample point was consistently above the 0.20 mg/L extractable (E) for all years reported. Decant effluent from the first tailing pond averaged 0.288 mg/L (E) from 1976 to 1980. The lower tailing pond final effluent to Rose Creek averaged 0.102 mg/L (E) which was within the permit requirements. Reported concentrations from the tailing pond seepage were, on average within the permit limits.

The current mine start-up procedure required the recruitment of an entirely new staff for all facets of the mine and mill operation. It can be

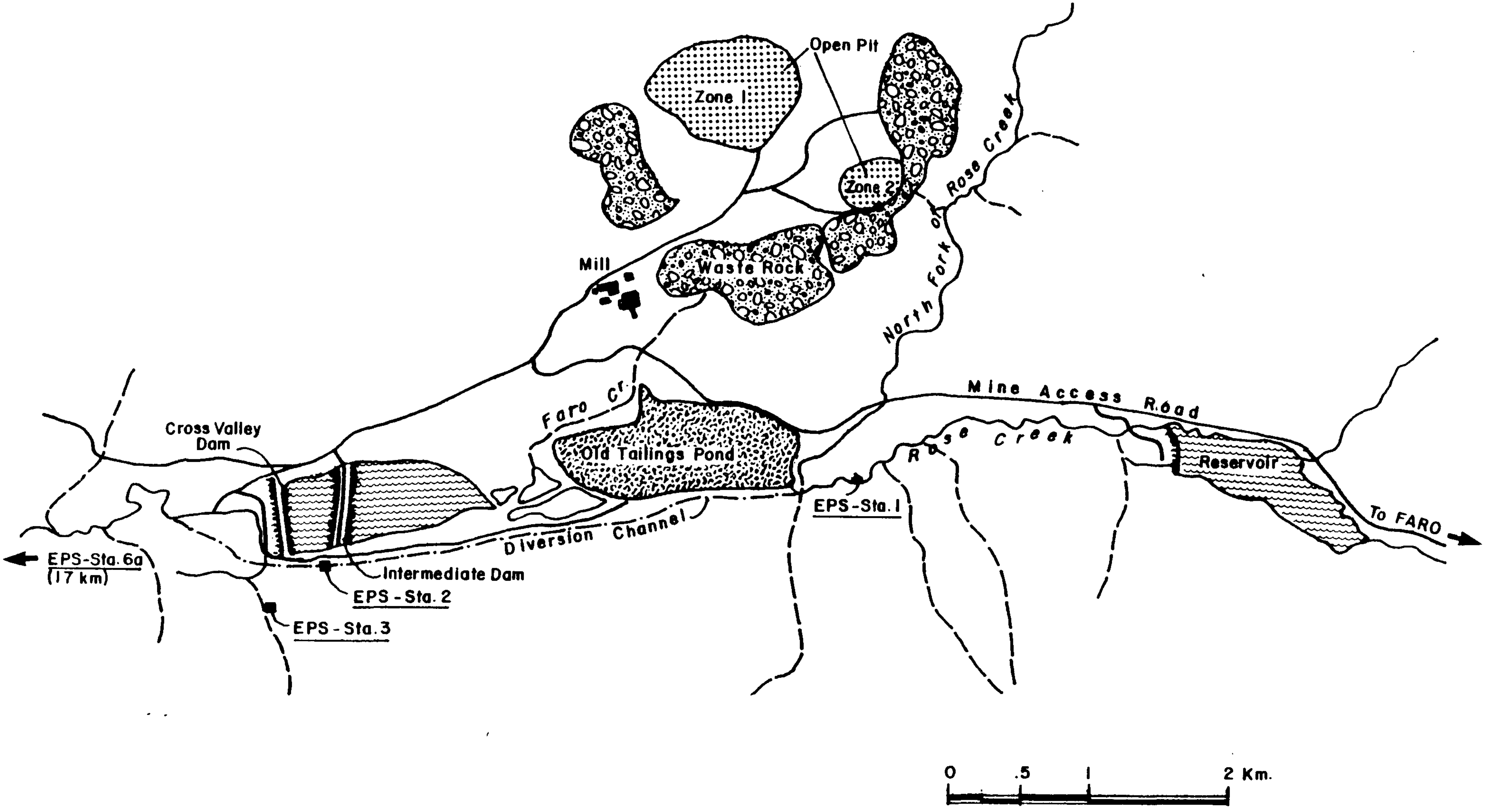

FIGURE 14 CURRAGH RESOURCES - FARO MINE (FORMERLY CYPRUS ANVIL MINE) - SITE PLAN SHOWING ENVIRONMENTAL PROTECTION-CONSERVATION AND PROTECTION WATER QUALITY STATIONS AND CAMC COMPLIANCE MONITORING STATIONS (160)

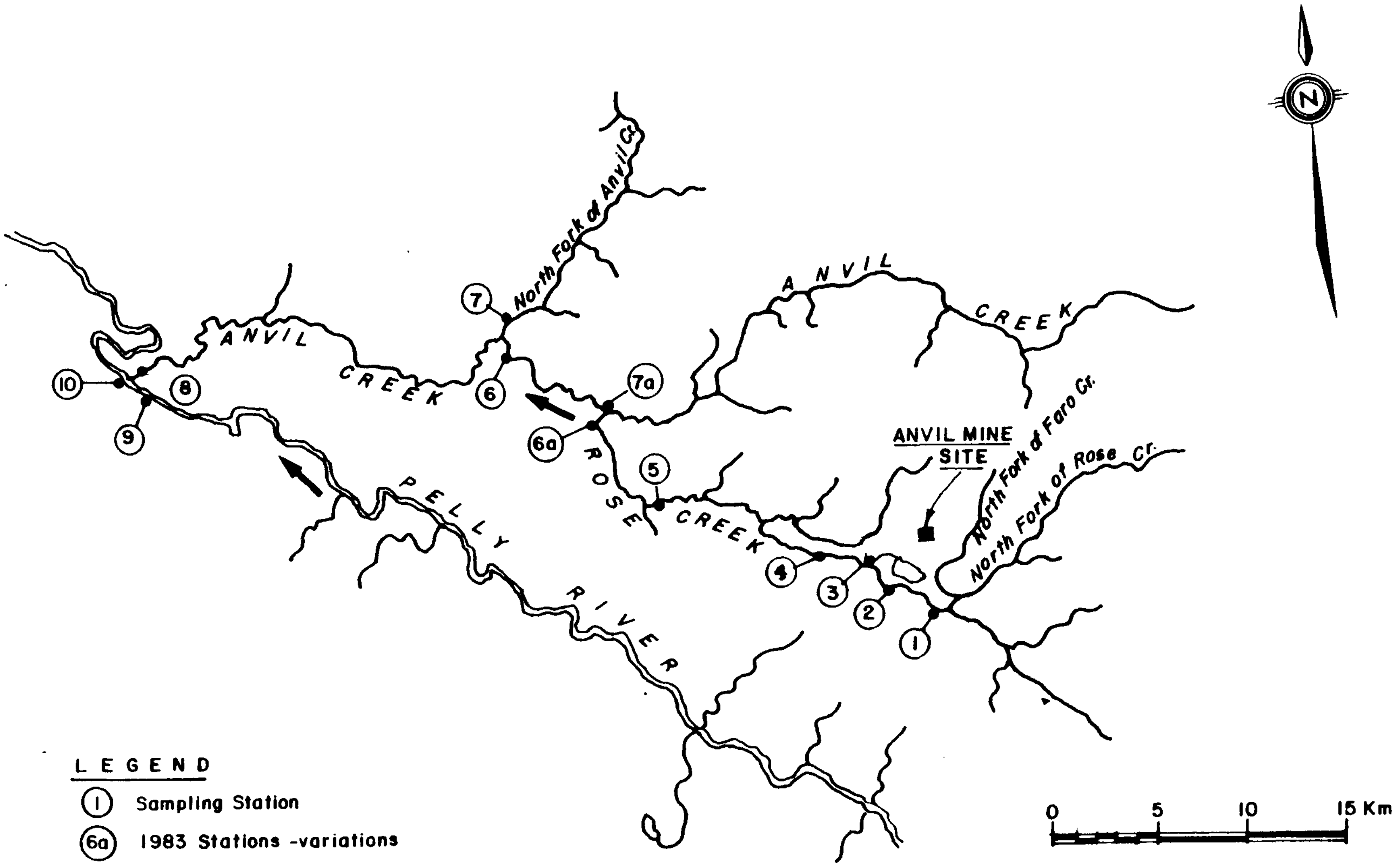

FIGURE 15 ENVIRONMENTAL QUALITY MONITORING SAMPLE LOCATIONS AT CURRAGH RESOURCES (THE CYPRUS ANVIL) MINE SITE (160)

expected that process control problems will occur due to unfamiliarity with the technical aspects of the mill machinery and operating parameters. The effect of restart and new operations on the receiving environment will be monitored on an ongoing basis with particular attention to the abandonment plans.

Environmental Protection, Conservation and Protection has monitored the biological communities, water quality and sediment characteristics of Rose and Anvil Creeks near the Cyprus Anvil Mine since 1973 (Hoos, 1973; Baker, 1979; Weagel, 1981)" (157). Godin and Osler have summarized the data base to 1983 and the following abstract describes the results.

ABSTRACT

> "An assessment of the water quality and biological conditions of Rose Creek, adjacent to Cyprus Anvil Mine, was carried out during the summer of 1983. The water quality, sediment and bottom fauna characteristics were documented at 10 environmental quality monitoring stations. Water quality information from Cyprus Anvil Mining Corporation's 21 Surveillance Network Stations was evaluated.
>
> Environmental quality monitoring program results have indicated an improvement in the water quality of Rose Creek since the CAMC; June 15, 1982 mine shutdown. Sediment analysis have revealed little change to previous studies. Benthic invertebrates have increased in abundance compared to previous studies and bioassays with Daphnia pulex showed no acute toxic effect from the tailings pond seepage. The surveillance network indicated incidents of non-compliance in 1982-83 with elevated levels of zinc at the tailings pond and in the winter months of 1983-84 at the north fork of Rose Creek" (157).

For detailed data presentation see reference 157.

1.11 Coal Mines as a Source of Lead

Lead is present as a trace element in most coast deposits ranging from sub-detectable levels to 3 000 μg/g. The lead can be released to the environment through acidic mine leachate, dust generation during processing, transport and in fly ash after combustion.

Coal deposits are being developed extensively in eleven major coal fields and exploration is being carried out in several deposits in B.C. and the Yukon (Figure 16).

These fields include:

1) The East Kootenay coal field of southeastern B.C.
2) The Merritt and Similkameen coal field of south central B.C.
3) The Wolf Mountain coal field of southeastern Vancouver Island
4) The Nanaimo field of central Vancouver Island
5) The Suquash deposits of northeastern Vancouver Island
6) The Graham Island Deposits of the Queen Charlottes
7) The Telkwa coal field of west central B.C.
8) The Groundhog deposits of northwestern B.C.
9) The Peace River coal field of northeastern B.C.
10) The Bowron River of east central B.C.
11) The Hat Creek deposits of the Southern Interior

In the Yukon Territories, coal is presently mined at Faro for use in power generation and drying of concentrate at the Cyprus Anvil lead-zinc-silver mine and concentrator. Exploration was being carried out at deposits near Ross river southeast of Faro and near Dawson in the northwest (20). Coal deposits being mined or explored for potential mine sites, are almost entirely destined for export, usually to foreign steel or power generation facilities.

TABLE 6 AVERAGE VALUES OF LEAD IN COAL AROUND THE WORLD

LOCATION	AVERAGE (ppm)	MAXIMUM (ppm)
Hat Creek, B.C.	2.6	4.0
Alberta	1.0	-
Nova Scotia	66.0	-
U.S.A*	6.0	14.0
U.S.A.	6.1	-
Germany	140.0	3 000.0
Denmark	54.0	

* Coal from the Illinois basin region contains lead as a trace element in the 10 to 100 ppm region (114)

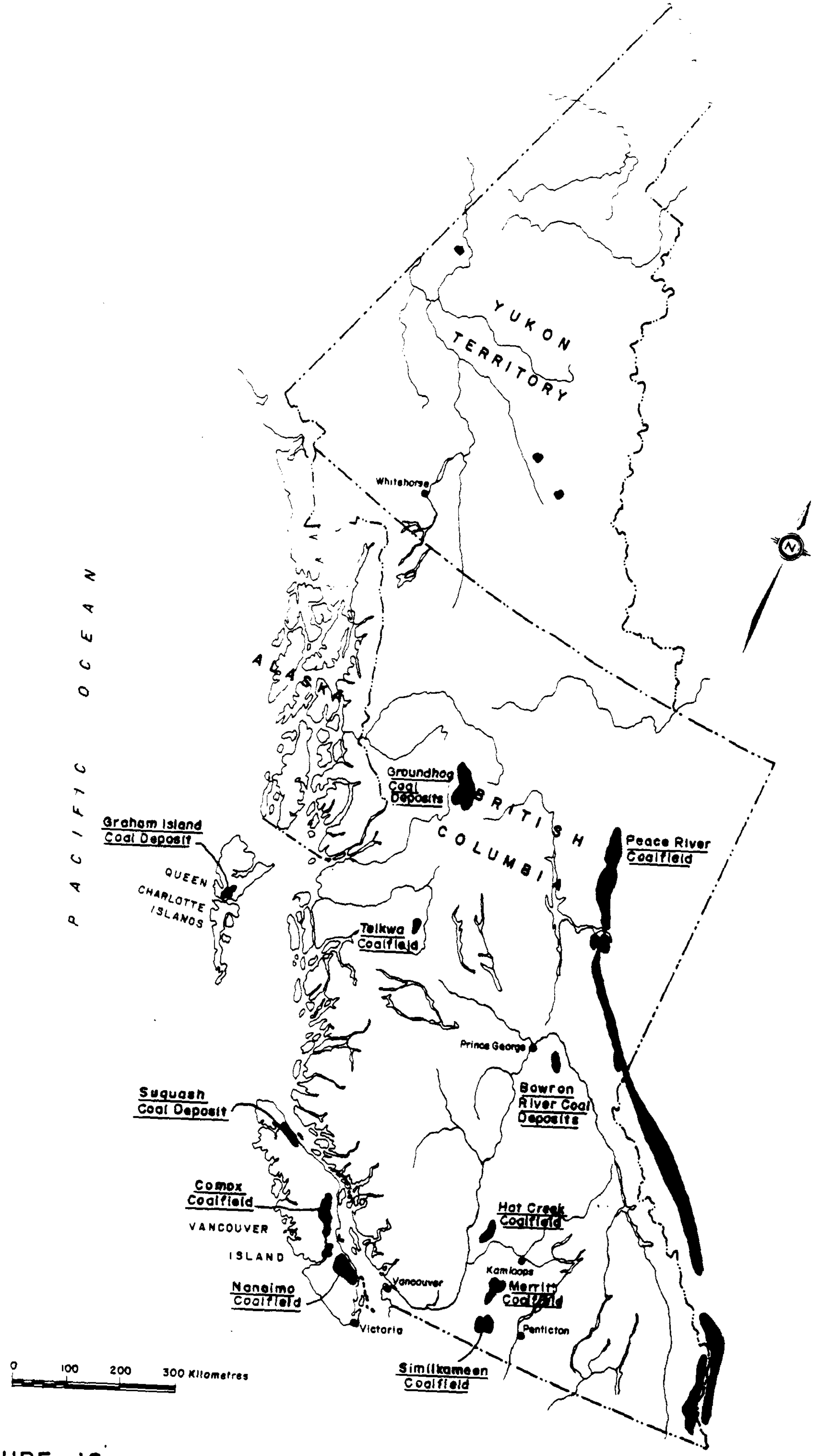

FIGURE 16 MAJOR COAL DEPOSITS IN BRITISH COLUMBIA AND THE YUKON TERRITORY

1.12 Lead in Coal Fly Ash

The knowledge of the distribution of heavy metals in coal fly ash is valuable in the assessment of environment impact and control of source emissions. When the elements and their structure within the particulate are known, it is possible to design uses for the large quantities of fly ash produced by coal combustion. It was found that more than 70% of As, Se, Mo, Zn, Cd, W, V, U, and Sb are associated with the surface material of fly ash and that Pb, Mn, Be, Cr, Cu, Co, Ga, and Ba are equally distributed in the matrix (53).

Coal is used for heat and power generation at the Cyprus Anvil Mine at Faro and had been proposed for a thermal generating station at Hat Creek in the B.C. Interior. (This station has not been constructed due to current economic factors). The fly ash from combusted samples of Hat Creek coal were analyzed for trace metals and of the 24 tests reported (26), 20 showed measurable levels ranging from 20 to 500 ppm lead. The average lead concentration was 74 ppm with a standard deviation of 160.6 ppm (26).

Disposal of the large amounts of fly ash (with it's relatively high metal content) produced by coal combustion can present a problem if alternate uses are found. Generating stations in the U.S. have used fly ash in the following applications (26):

1) Partial replacement of cement in - structural concrete
   - concrete products
   - dams and other massive use
2) Fill material
3) Manufacturing cement
4) Mixed to form cement clinker
5) Filler in asphalt mix
6) Anti skid winter roads
7) Light weight aggregate
8) Fertilizer filler
9) Mine fire control
10) Aluminum production (26, 36)

Until thermal electrical generating stations are developed in B.C., coal fly ash is not likely to be a source of lead pollution to the environment.

2.0 LEAD CONCENTRATION AND SMELTING CAPACITY IN THE PACIFIC AND YUKON REGION

The major concentration and smelting operations are carried out at the Worlds largest lead/zinc smelting complex owned by Cominco Ltd. at Trail, B.C. Some of the independent mines are large enough to have concentrators on site and ship the concentrate to Trail for processing. The Cyprus Anvil Mining Corp. is planning a feasibility study for a lead/zinc smelting plant at Faro for processing ore in the Yukon (15). The mine is presently owned by Curragh Resources and will produce only lead concentrate for the near future.

The basic smelting processes for lead ore include, crushing and grinding, separation from gangue materials (concentration), sintering, smelting, refining and alloy blending. Lead ore may be rich enough to smelt directly, however, it is generally separated from interstitial gangue materials before processing.

2.1 Ore Reduction

The mined ore is crushed to a uniform size by a variety of methods such as jaw crushers followed by ball or roll (bar) mills. In many cases the crushing is done underground before the ore is transported to the surface and shipped to the concentrator. The breaking of the rock structure via blasting and crushing exposes sulfides to air and moisture. This will lead to oxidation and the production of acidic mine water. The depressed pH of the water enhances the solution of metals including lead with produces effluents that can be toxic to aquatic life and degrade drinking water quality.

2.2 Concentrate Production

Initial crushing is followed by separation via flotation. Various additives are used in flotation depending on the ore constituents which need to be separated. They include:

1) Collectors - Xanthates* or long chain hydrocarbons to induce air avidity on mineral surfaces,
2) Depressors - e.g. Sodium Cyanide, used to prevent flotation of selective minerals,
3) Activators - e.g. Copper Sulfide to activate the reaction to zinc sulfide,
4) Froth Stabilizers - e.g. Pine oil, cresylic acid,
5) Conditioners - Sodium Carbonate or Calcium Oxide, used for pH stabilization.

The separation fluid will be high in metals and additives such as sodium cyanide and is recirculated with addition of fluid lost by withdrawal of the concentrate, spillage or evaporation. Discharged barren solutions are usually treated in the mills treatment system. The concentrates are dried to lower moisture levels of 8 to 10% by filters or kilns. Shipment is by rail or transport trucks to ports for foreign smelting or by rail to the primary lead zinc smelter complex at Trail, B.C. The loss of lead concentrate to the environment through bulk handling at, road, rail and shipping ports has not been documented in the region. Concentrates produced in the Yukon are shipped by road to a port at Skagway Alaska. Concentrate produced in British Columbia and at Pine Point in the Northwest Territories is shipped to the primary lead/zinc smelter complex at Trail, B.C.

2.3 Lead Pollution from Lead and Copper Smelting Operations in Other Regions

Lead pollution from smelters around the world has been reduced significantly by modern containment, however, large amounts have been released to the environment by earlier processes. These included uncontrolled heap roasting in the open air, low and high elevation stacks with no control equipment (78).

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* Xanthates are a combination of an alcohol and carbon disulfide in aqueous sodium hydroxide (to the general form of $RO-\overset{S}{C}-SNa$) and form viscous colloidal dispersions.

Analysis of lead, zinc and cadmium in soil and vegetation samples near a smelting complex in England showed levels of 5 000 ppm for lead. The concentration dropped to 200 ppm 10 to 15 km from the factory.

Studies in the United Kingdom have shown that 1-18% of the total dry matter intake of grazing cattle is soil that is accidentally ingested with grass. This is particularly important in grazing areas subject to contamination by nearby smelting operations (113). Exhaust fumes from the Anaconda copper smelter in Montana were contaminated with lead and found to be highly toxic to grazing animals. Horses downwind of the smelter suffered paralysis of a nerve in their necks which restricted breathing. Acute poisoning resulted in severe cholic, salivation, vomiting and uneasiness.

A study of emissions from copper smelters in Arizona found that a wide variety of elements including lead were present in flue gases and that concentrations varied significantly from plant to plant. The copper smelting process usually involves 4 steps, roasting, smelting, converting and casting of anodes. The roasting step eliminates most of the sulfur by converting to SO_2. Copper and iron are removed in the matte and the copper is transformed to blister copper. Lead concentrations in the various process steps for copper smelting were (47):

Ore = 50 ± 5 µg/g
Concentrate = 68 ± 7 µg/g
Electrostatic Precipitation Dust = 11 000 ± 1000 µg/g
Stack Plume = 3000 ± 300 ng/m^3

Elements such as Pb, Zn, Sb, In, Ce, As, Cd, W tend to be concentrated in the electrostatic precipitator dust and stack plume gases as they are volatilized in high temperature processes (1 500°C in the furnace) and condense on particulates after the precipitator (350°C) (47). It was concluded that variations in process steps and pollution control techniques played a significant role in quantities of pollution emissions released.

Copper is sometimes removed from molten lead by the addition of sawdust which forms a slag. The fumes generated were found to be "laden with lead". At temperatures below 700°C molten lead did not produce detectable concentrations of PbO but about 700°C a yellow oxide formed (113).

2.4 Smelting Sites in British Columbia

The only primary lead smelter in British Columbia is the Cominco Lead/Zinc/Fertilizer Complex at Trail, B.C. The only copper smelter is the Afton mine smelter located just outside of Kamloops (currently shutdown and only concentrate is produced). A second copper smelter was proposed for the Highland Valley area near Kamloops however it has not been developed to date. Data for the following text can be found in Appendices V-IX.

2.5 Cominco Trail Lead Smelting Process: Sources and Loading

Lead smelting began at Trail, B.C. in 1899 with major smelter process changes occurring in 1930 at the installation of the first slag fuming furnace and the addition of a second furnace in 1947. A sintering plant was commissioned in 1953. The original brick shaft furnaces were replaced with water jacketed shaft furnaces in 1940 and modernized in 1979.

The major portion of the recent mill modernization has occurred in the zinc production complex, the rerouting of sewers and construction of an effluent treatment plant.

Table 7 shows that the total average quantity of lead discharged from all sources over the period 1975 to 1985 was 1 043 kg/d. The trend since 1981 indicates decreasing discharges to a total of 790 kg/d from all sources in 1984. This total is expected to decrease as more of the metallurgical sewers are rerouted for treatment prior to discharge and the new smelting furnace becomes operational in the late 1980's. The major decrease in loading is expected to occur in the stack discharges from the lead smelter and elimination of the sinter sewer and stack. The feasibility study of the new lead smelting plant using the Kivcet Flash Smelting Process was completed in 1982 but not implemented. Various delays created by low metal prices and government funding arrangements allowed the examination of other technologies. After federal and provincial funding arrangements were completed in 1986, a decision was made to install a QSL process. Installation of the QSL process began in late 1986 and is expected to be complete in late 1989. Lead and zinc production is interrelated and the company plans to expand zinc production capacity from 270 000 tons/year to 300 000 tons/year and lead from 147 000 tons/year to 200 000 tons/year by late 1980's (146). It is not known how depressed metal prices will affect production goals.

TABLE 7 DISCHARGE OF LEAD TO THE ENVIRONMENT FROM COMINCO'S TRAIL OPERATIONS

SOURCE	AVERAGE FOR 10 YEARS (1975-1985) (kg/d)	AVERAGE FOR 1984 (kg/d)
Stack Emissions	517	440
Sewer (Dissolved Lead)	180	76
Sewer (Insoluble Lead)	346	274
Total from all Sources	1 043	790

Cominco has been actively pursuing the financial requirements to complete the modernization program estimated to cost $700,000,000. Expanded process descriptions, diagrams and process flow charts can be found in references 141, 142 and 143 whereas the following is a brief description of the single largest processor of lead in the Pacific Region.

2.6 Lead Smelter Feed Handling

The smelter feed consists of fresh concentrates from Cominco's Sullivan Mine and approximately 40 independent ore suppliers. These concentrates are mixed with silica and lime flux materials to produce blends with the proper metallurgical and slag characteristics. Coke breeze and by-products from the zinc and sinter processes are added to the blend prior to drying. The feed blend is dried in gas fired rotary driers to produce nodules less than 12 mm in diameter and containing a minimum of 5.5% water for dust suppression and proper combustion.

2.7 Lead Sintering (Prior to Modernization)

The sinter feed is transported by conveyor to the sinter machine. The speed of the conveyor is controlled to reduce dust generation. A treadmill conveyor moves the concentrate through the sinter furnace where a row of natural gas fired torches ignites the feed and a down draft of air supports combustion to bottom layers. Temperatures are maintained at 600°C. The heat generated decreases the sulfur content from 7% to 2% by oxidizing lead sulfide to solid lead oxide and evolving sulfur dioxide gas. Off gases from the lead and zinc processes are humidified and particulates are removed by electrostatic precipitators. The SO_2 fumes are scrubbed with an ammonium hydroxide and ammonium bisulfite solution before discharge through the 120 m high stack S1 (139, 140). The sintered nodules are screened with oversized particles recycled to the sinter feed and the balance fed to the smelter. The entire sinter process will be discontinued when the QSL smelting process becomes operational. The sinter sewer contains 45% of the lead discharged in effluents and the scrubbed gas from the sinter stacks contains approximately 30% of the lead discharged to the air (or 132 kg/d of the present 790 kg/d of total lead emissions).

2.8 Lead Smelting Furnace (Prior to Modernization)

Smelting reduces lead and other metals to the metallic state and gangue materials float to form a slag which is separated via decanting or skimming. Contaminants such as oxides, silicates and sulfides are removed by reagents that form stratified liquid phases. Copper is often an impurity which must be removed by chemical reaction to form a slag. Various other methods are used to refine the pig lead to the composition and purity required. At Cominco, sinter and coke are charged in a 9 to 1 ratio to the blast furnace. The two blast furnaces can operate at 460 t/d of bullion and 630 t/d of slag (142). Blast air is enriched to 24% oxygen. Lead bullion is continuously tapped to a drossing furnace. The skimmed dross furnace is cast into anodes, cooled and sent to the lead refinery. Slag from the furnace is rich in zinc which can be recovered by heating and removal as a fume. Gases from the furnace combustion products are cooled in a spray tower, filtered in a wheelabrator baghouse (containing 10 000 m^2 of cloth) and discharged through a 55 m stack (S32). Approximately 10% of the lead discharged by stacks is from the smelting process.

2.9 Proposed QSL Lead Smelter

The Queneau-Schumann-Lurgi (QSL) lead smelting process is a continuous feed/discharge system involving a refractory lined horizontal cylinder. The cylinder is approximately 40 meters in length and 3.74 m in diameter. Lead bullion is produced in an oxidation/reduction section from which it will flow into a continuous drossing and bullion cooling furnace (217).

2.10 Lead Refinery

The lead anodes cast in the drossing process are mounted in refinery cells with circulating electrolytic solutions containing 70 g/L dissolved lead (142) which provides electrical contact with the pure lead starting cathodes. A black slime containing silver, gold, bismuth, antimony and arsenic is removed from the anodes for refining and the depleted anodes are recycled to the smelter for reprocessing. The electrically refined lead cathodes are melted and flash treated with caustic soda to remove traces of antimony, arsenic and tin before final casting and transport to market.

2.11 Cominco, Trail, Metallurgical Sewers

In 1979 the Cominco discharges from smelting, refining and fertilizer complex averaged 296 000 m^3/d of effluent to the Columbia River at Trail (144). The effluent was collected in 12 main sewers and discharged through 9 submerged outfalls to the Columbia River and two outfalls to Stoney Creek, 600 m upstream of its confluence with the Columbia River (144) (Figure 17). The sewers contained lead from all the process in the form of concentrate dust, slag and dissolved metal ions. The calculated annual average of daily dissolved lead loadings supplied by Cominco show a progressive decline from 254 kg/d in 1977 to 64 kg/d in 1984 (Table 8, Figure 18). The total for the first 9 months of 1985 was reported at 65 kg/d (143). The dissolved and total lead loadings from each sewer were calculated for comparison with the Cominco values using data on the Waste Management Branch, EQUIS data base and other sources. The EQUIS data is based on 24 hour monthly composite samples and the Cominco data is based on daily grab samples. The data from both sources correlates in the same order of magnitude averaging 209.6 ± 79 kg/d dissolved lead from 1977 to 1982. The average loading based on EQUIS data based is 213.5 ± 113 kg/d. From 1982 to 1985 both data bases correlate well with the EQUIS data averaging 33 kg/d higher than the Cominco data and showing the same declining trend in daily loading.

TABLE 8 ANNUAL, DAILY AVERAGE DISSOLVED AND TOTAL LEAD LOADING TO THE COLUMBIA RIVER FROM COMINCO, TRAIL, METALLURGICAL SEWERS, 1972-1985

YEAR	COMINCO DISSOLVED (kg/d)	EQUIS DISSOLVED (kg/d)	EQUIS TOTAL (kg/d)
1975		187.2	305.3
1976		195.3	408.1
1977	254	100.7	803.8
1978	221	137.7	51.4
1979	210 — x = 209.6	163 — x = 213.5	
1980	204	364.3	
1981	159	301.9	741.6
1982	163	192.6	
1983	105	148.6	555.6
1984	64	87.9	326.8
1985 (9 mo.)	65	102.8	377

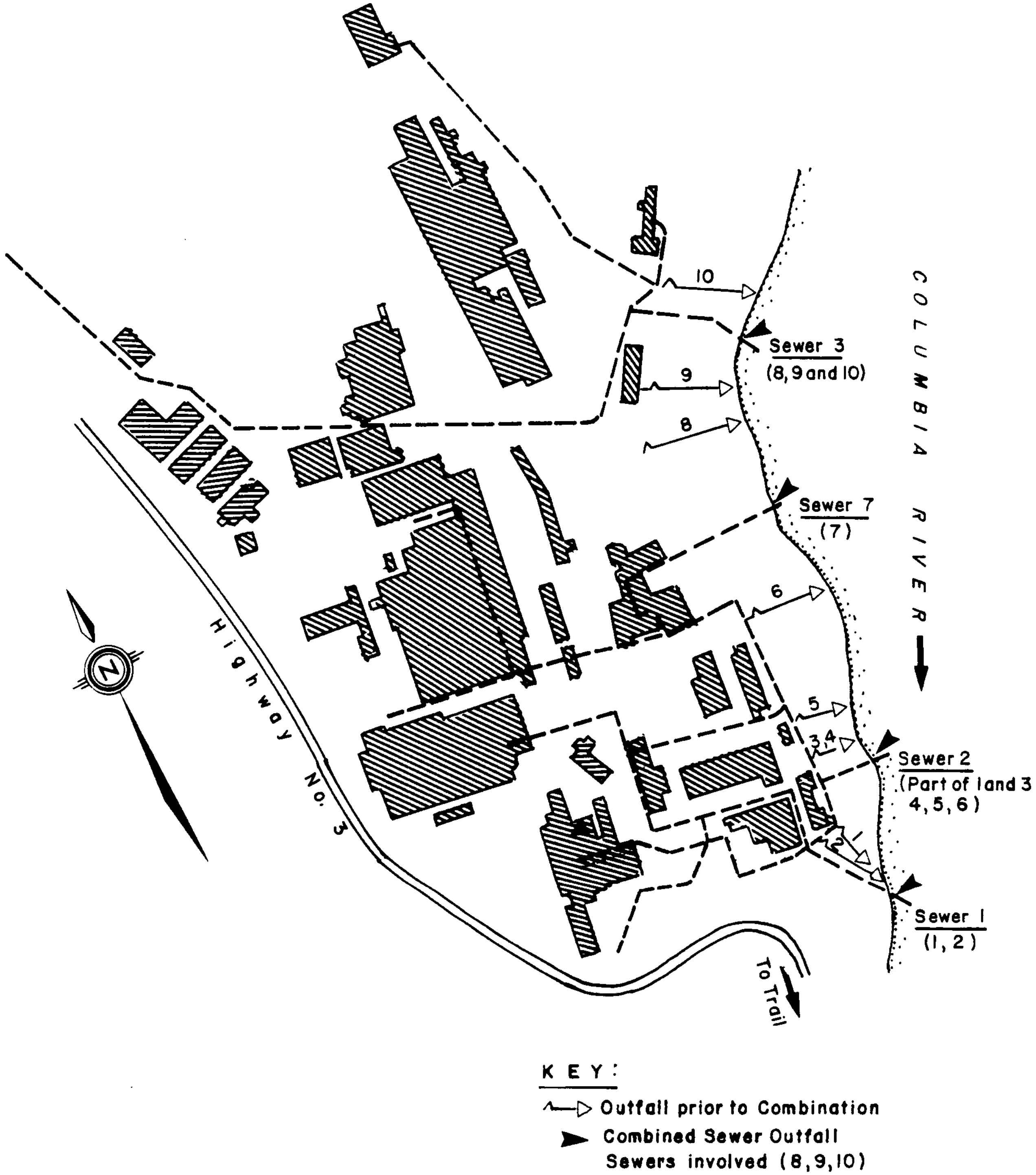

FIGURE 17 SITE DIAGRAM OF COMINCO, TRAIL - COMBINED SEWER DISCHARGES TO THE COLUMBIA RIVER

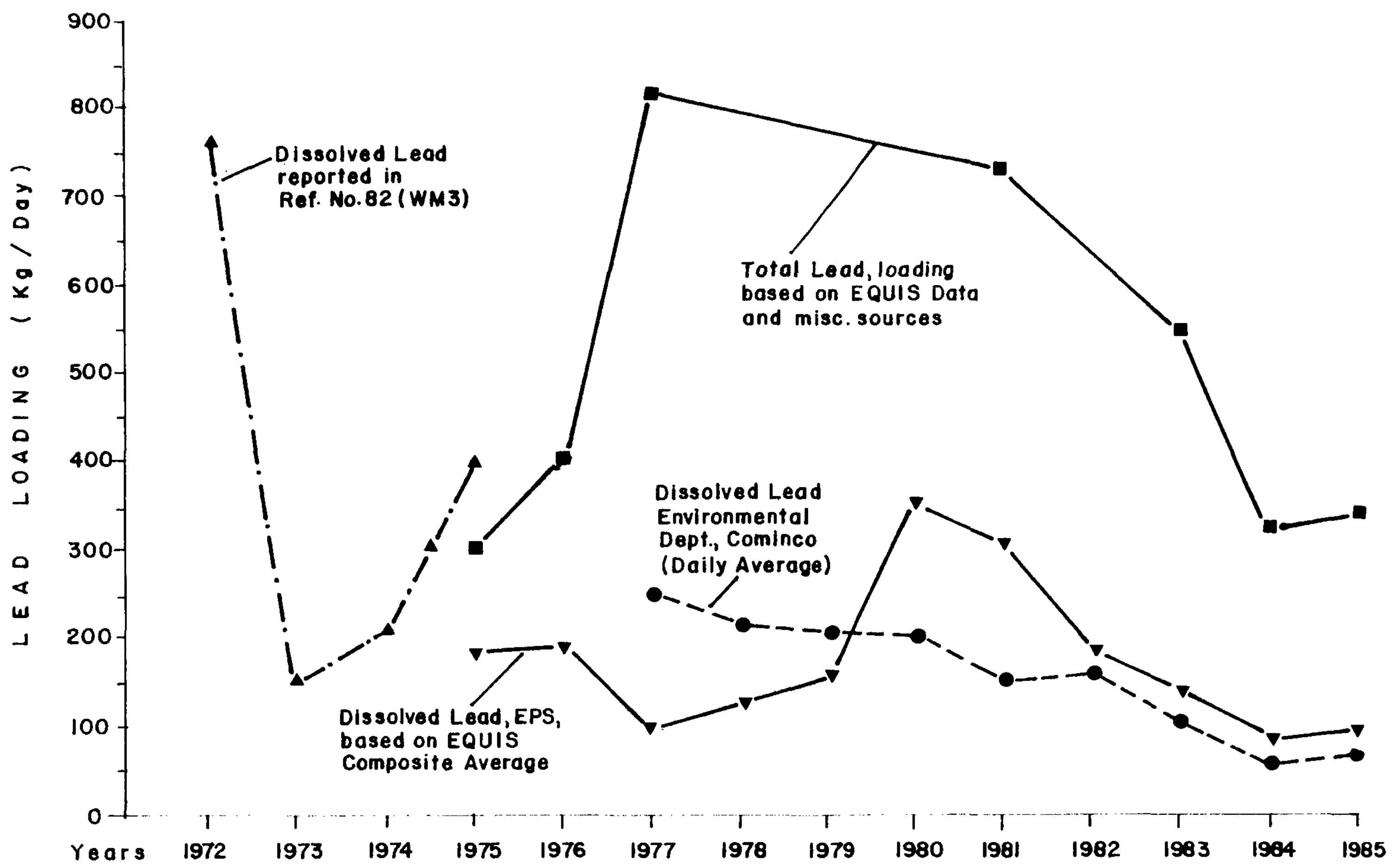

FIGURE 18 GRAPH OF DAILY AVERAGE DISSOLVED AND TOTAL LEAD LOADING TO THE COLUMBIA RIVER FROM COMINCO, TRAIL, METALLURGICAL SEWERS, 1972-1985

The discharge characteristics are constantly changing as modernized process and environmental control facilities are brought on stream. The significant decline in dissolved metal loss beginning in 1980 and continuing through the present coincides with the start-up of the new effluent treatment plant. The 1984 and 1985 loadings are approximately three times the 19 kg/d (dissolved) lead loading required by the Waste Management Branch Permit and seven times the objective of 9.1 kg/d (dissolved Pb) (142) of the environmental engineering department at Cominco. The current levels of 64 kg/d dissolved lead are not expected to decline significantly until the new QSL smelter process becomes functional. When the furnace comes on stream the improved control of the smelting process and the elimination of the antiquated material handling and sintering stage will significantly affect loadings. The plant is presently under a permit variance order with reviews scheduled May 1, 1985 and February 1, 1988. Compliance with the permit requirements depends largely on completion of the lead smelter modernization program. Funding and construction schedules are under active negotiation at the present time.

In order to relate loading changes to process changes at the Cominco Trail lead/zinc smelting and refining complex, the following review of the sewer system is presented. Prior to 1980 the following conditions existed in the sewer system (Figure 17). (Note most of the analysis is for dissolved lead, therefore, it is not always possible to calculate total loading.

2.11.1 **Sewer #1.** The total flow is approximately 23 000 m^3/d of cooling water from the shops and south end of the lead smelter and 8 000 m^3/d of overflow from the lead blast furnace slag pond. From 1975 to 1980 the annual mean concentration of dissolved lead appeared to increase from 0.07 mg/L to 0.30 mg/L. "In 1977, it contained an average of 4 percent of the lead discharged by Cominco (147)."

2.11.2 **Sewer #2.** The effluent consists of 10 000 m^3/d of cooling water from the lead blast furnace jacket and intermittent flow of 30 000 m^3/d of slag slurry (averaging 460 t/d of relatively inert slag) from the lead fuming furnace (144). Very little data exists for this sewer, and a combined result with sewer #3 shows a decline in annual mean concentration from 0.841 mg/L to 0.58 mg/L from 1980 to 1985.

2.11.3 **Sewers #3 and #4**. Average flow is 7 000 m^3/d of fuming furnace cooling water with minor contamination of cooling water (147). Mean annual dissolved lead concentrations range from 0.17 to 0.23 mg/L.

2.11.4 **Sewer #5**. Average flow of 26 000 m^3/d consists mainly of effluent from the scrubbing rotary drier exhaust gases in the lead sintering plant, cooling water from the sintering machines, floor washings and humidifier condensate from the sinter machine. The effluent contained 2% of the lead discharged from the Cominco complex (144). Data reported from 1975 to 1979 shows fluctuating values from 0.18 mg/L to 0.571 mg/L dissolved lead.

2.11.5 **Sewer #6**. Average flow of 24 000 m^3/d originates as cooling water from acid pachuca tanks and electrolytic cells in the zinc plant, effluent from scrubbing zinc melting furnace exhaust gases and washdown from the zinc sulfide leaching plant and its roof and drains. The effluent contained an average of 4% of the lead discharged from the plant in 1977 (144). Concentrations fluctuated from 0.06 mg/L to 0.40 mg/L dissolved lead.

2.11.6 **Sewer #7**. Average flow of 31 000 m^3/d consists of cooling water from the absorption plant and water from the lead sinter gas cooling tower in the SO_2 recovery process. In 1977 it contained an average of 45% of the lead discharged from the plant making it one of the major discharges. Annual mean dissolved lead concentrations appeared to decline from 0.75 mg/L in 1977 to 0.482 mg/L in 1980.

2.11.7 **Sewer #8**. Average flow of 59 000 m^3/d consists of stripped electrolyte from zinc electrolysis, scrub water from zinc waste gases, wash water from electrostatic precipitators that have been clarified, and cooling water from various cadmium processes. The effluent was highly acidic from two thirds of the H_2SO_4 discharge by metallurgical plants. It contains 23% of the lead discharged by the complex. Concentrations were high with annual means fluctuation between 0.74 mg/L and 2.04 mg/L. Values up to 16.0 mg/L dissolved lead were recorded.

2.11.8 **Sewers #9 and #10**. Average flow is 1 000 m^3/d and 3 000 m^3/d respectively coming from the slag reduction furnace of the lead refinery and specialty metal processes. They contain 6% of the lead discharged by the complex. Annual mean dissolved lead concentrations fluctuated from 0.23 mg/L to 1.70 mg/L during 1975 to 1977.

2.11.9 **Sewers #11 and #12**. Average flow of 62 000 m^3/d and 20 000 m^3/d respectively contain flow from the ammonium sulphate crystalizer and gas scrubbers from phosphate rock reactors. These flows discharge 4% of the total quantity of lead discharged to the Columbia River via Stoney Creek.

In June 1980 ten sewers were combined into four discharges under Waste Management Branch Permit numbers PE-2753 as follows (Figure 17):

PE 2753-01 - Metallurgical Plant Sewer I replaces Sewers T-1 and T-2. The maximum flow = 10 x 10^4 m^3/d. There was a definite trend in decreasing concentrations of dissolved lead in this combined sewer from 1980 to 1983. Except for a series of composite samples taken in 1983 the values appear to have stabilized at an annual mean concentration of 0.15 mg/L.

PE 2753-02 - Metallurgical Plant Sewer II replaces Sewers T-3, T-4, T-5 and T-6. The maximum flow = 9.6 x 10^4 m^3/d. Dissolved lead concentrations fluctuated from 1980 to 1983 and show a general decline from 0.53 mg/L in 1983 to 0.191 mg/L in 1985 (composite samples).

PE 2753-03 - Metallurgical Plant Sewer III replaces Sewers T-8a, T-8B, T-9 and T-10. The maximum flow = 8.6 x 10^4 m^3/d. Annual mean dissolved lead concentrations showed an order of magnitude decrease of 1.40 to 0.17 mg/L from 1980 to 1983 for grab samples and a fluctuation between 0.65 and 0.89 mg/L for 24 hour composite samples from 1983 to 1985.

PE 2753-04 - Metallurgical Plant Sewer IV (previously T-7) remains the same and the maximum permitted flow is 3.7×10^4 m^3/d. Annual mean dissolved lead concentrations declined from 0.75 mg/L in 1977 to fluctuate between 0.45 mg/L and 0.55 mg/L from 1979 to the present date.

2.12 Cominco, Trail Fertilizer Plant Sewers

Lead present in the fertilizer plant sewers likely has its origins in the sinter process of the lead refinery. In the sintering process lead contaminated SO_2 gases are scrubbed and converted to sulfuric acid for use as acid or in conversion to ammonium bisulfite and ammonium sulphate crystals which are marketed as fertilizer (140). Dissolved lead loadings were calculated as 7.7 kg/d in 1982 and 15.6 kg/d in 1983 based on limited data.

2.13 Cominco, Trail Effluent Treatment Plant

In December 1984, effluents from the Lead Refinery, Antimony Plant, Silver Refinery and Metal Products fabrication building were removed from Combined Sewer III and directed to the effluent treatment plant. The sanitary sewer discharges, previously flowing untreated to the Columbia River, are now treated in the effluent treatment plant (142).

The effluent plant treats 36 400 m^3/d of process water from 20 areas in the metallurgical plant complex prior to discharge to the Columbia River through Sewer III. The acidic influent is neutralized with lime solution in reaction tanks to precipitate heavy metals in a slurry form.

The slurry is flocculated prior to discharge to a clarifier from which decanted effluent discharges to Sewer III and solids are pumped to the lead smelter to recover lead, zinc and cadmium (146).

2.14 Cominco, Trail: Lead Emissions from the Major Lead and Zinc Refinery Stacks

The Waste Management Branch (WMB) Air Emissions Permit for Cominco Trail lists 52 stacks and vents associated with lead smelting, 15 with the refining of lead and other metals plus miscellaneous vents. The zinc refining permit lists 34 stacks associated with that process prior to modernization of the zinc process. There are more than eight miscellaneous sources in the Indium Plant plus non-permitted sources in the salvage yard. Of the 108 potential sources, the data for 48 have been summarized in the Appendices and atmospheric loadings have been estimated for 16 of the major emission points (Table 9). Figure 19 shows the loading trends from the stacks from 1972 to 1984.

TABLE 9 ESTIMATED LEAD LOADINGS FROM 16 OF THE MAJOR PROCESS STACKS AT COMINCO'S TRAIL LEAD/ZINC REFINERY

YEAR	4 MAJOR STACKS (kg/day) A	12 MINOR STACKS (kg/day) B	TOTAL ESTIMATED LOADING (kg/day) A + B
1972	564.0	114.8	678.8
1973	544.6	150.9	695.5
1974	520.4	250.9	771.3
1975	289.8	138.8	428.7*
1976	282.7	138.8	421.6*
1977	226.2	48.1	274.3
1978	269.4	74.9	344.3
1979	306.9	138.8	445.8*
1980	306.9	138.8	445.8*
1981	407.8	138.8	546.7*
1982	573.4	138.8	676.3*
1983	414.6	138.8	553.5*
1984	302.7	138.8	441.6*

* These values are estimates that include known data on the four major stacks plus an additional 138.8 kg/d lead averaged from the 12 minor stacks for the years 1972, 1973, 1974, 1976 and 1977.

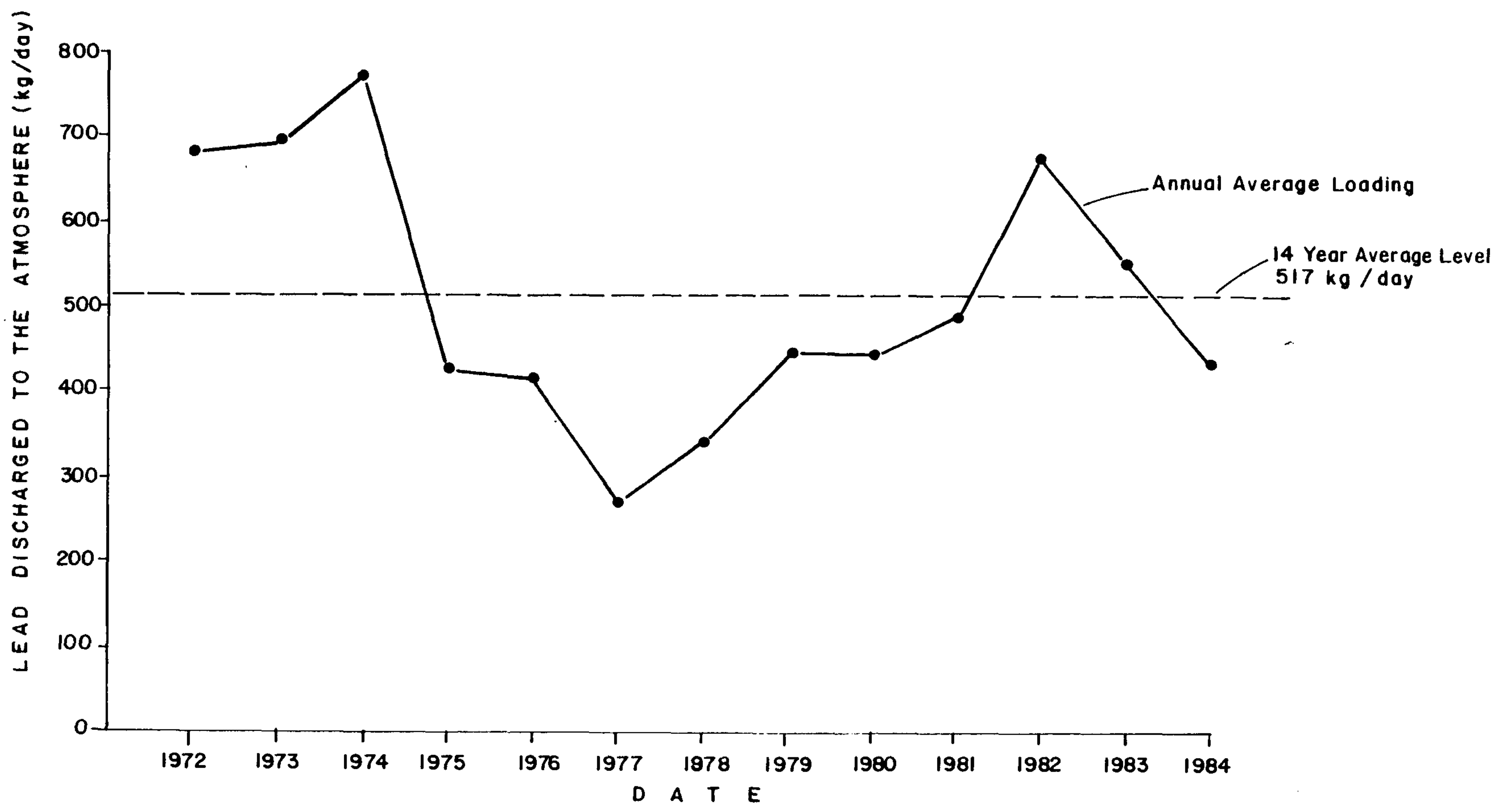

FIGURE 19 GRAPH SHOWING ESTIMATED DAILY MEAN COMBINED ATMOSPHERIC LEAD LOADINGS FROM THE COMINCO LEAD-ZINC SMELTER AT TRAIL, B.C., 1972-1984

The loading data was relatively complete for the years 1972 - 1974 and 1976 - 1978. Data from the main smelting stacks S1, S8, S32 and S40 has been recorded from 1972 through 1984. A combined average emission rate of 138.8 kg/d lead from the minor stacks S46, R1 to R11 and Z51 was calculated from data collected for the years 1972, 1973, 1974, 1976, averaged and added to the total for 1975, 1979 - 1984 for which values were not recorded. Based on this data the average daily emission of lead to the atmosphere from 1972 to 1974 is 517.2 kg/d in 1974 down to 274.3 kg/d in 1977.

Two peaks occurred in 1974 and in 1982 and the current trend is declining (Figure 19). (Note: All numbers are calculated based on average monitoring concentrations and the geometric mean of the flow rates for the stated period. They do not represent a rigorous statistical study under measured operating conditions).

2.14.1 Summary of the Major Process Stacks.

Stack S1: is a 122 m high stack with a rated flow of 5 709 m^3/min. (140). The lead concentration has averaged 0.430 mg/mol since 1978 and loading is estimated at 0.430 kg Pb/tonne of lead produced. (Based on a production of 368 tones of bullion per full operating day). The Provincial Waste Management objectives for gaseous and particulate emissions for specific processes in 0.50 kg/tonne of lead produced (147).

Stack S8: from the sintering plant driers is a 216 m high stack (143) with a rated flow of 1 870 m^3/min. (142). The lead concentration has averaged 1.175 mg/mol from 1981 to 1984.

Stack S32: from the lead blast furnaces is a 86.9 m high stack (140) with a rated flow of 7 840 m^3/min. (142). The lead concentration has averaged 0.096 mg/mol from 1981 to 1984.

Stack S40: from the slag fuming furnace is 30.5 m high (140) with a rated flow of 3 553 m^3/min. The lead concentration has averaged <0.100 mg/mol from 1981 to 1984.

Stack S46: is an 18.3 m high stack from the drossing furnace with a rated flow of 124 m^3/min.

Stack Z-1: is a 122 m high stack discharging from the absorption plant with a flow rate of 36 576 m^3/min.

Stack Z-48: is from the Indium plant and discharges at a rate of 112.8 m^3/min. and contains lead particulate (143).

Stack Z-51: is from the reduction furnace tap hole vent of the Indium plant (143). Flow is rated at 307 m^3/min.

2.15 Afton Mines Ltd. Copper Smelter

The Afton Mine Copper smelting complex near Kamloops, B.C. began operating in 1977 producing blister copper. The mine site consisted of the mine, primary crusher, coarse ore stock pile, concentrator, assay lab, smelter, accommodation and support shops (Figure 20). Treatment works included a bag filter on crushing operations, scrubbers for sulfur dioxide and mercury removal. Liquid effluents were treated in aeration and evaporation lagoons and a tailings pond. Operation of the smelter suffered repeated interruptions and was shutdown in July 1983 for an indeterminate period. Mine operation has restarted for the production of copper concentrate for export.

Scrubbing liquids are principally used for mercury removal. No records of stack tests of lead were located. Pieziometric measurements of the ground water at various sites showed that average annual total lead concentrations were low at 0.039 ± 0.029 mg/L. Total lead was an order of magnitude below the maximum monthly mean of 0.20 mg/L specified by the MMLER, 1977 for a grab sample from mining effluent (149). The maximum authorized concentration of 0.40 mg/L total lead in grab sample of mine effluent as specified in the MMLER, 1977 was exceeded only once at 0.413 mg/L. On February 19, 1982, 1 362 m^3 of mercury scrubber water spilled from a storage tank into the water treatment system. In addition to this

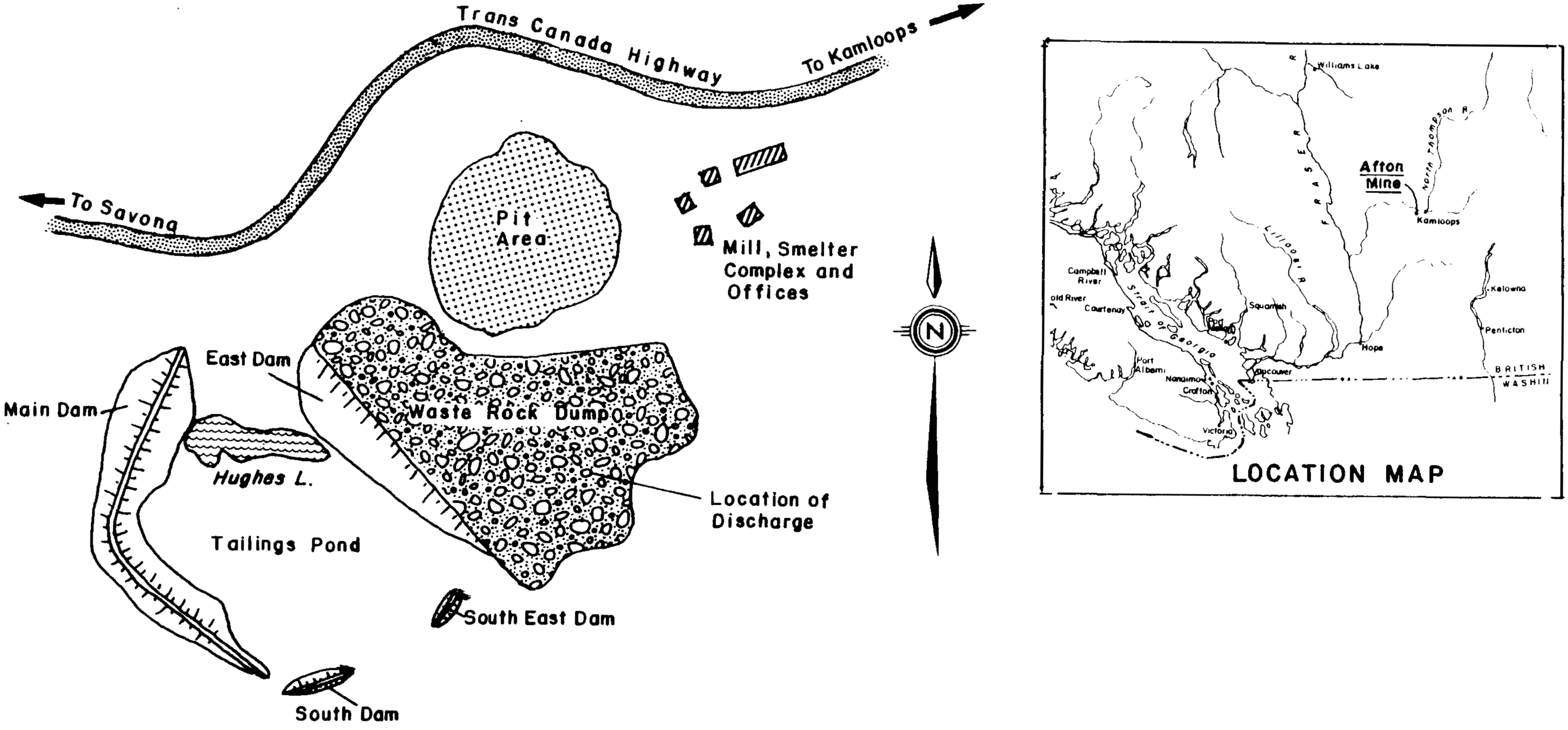

FIGURE 20 SITE DIAGRAM OF THE AFTON MINES, COPPER MINE AND SMELTER COMPLEX

flow, abnormally high volumes of surface runoff caused the containment system to overflow a dam to a slough. There was no discharge from the slough except by infiltration. The site was considered secure and the low lead concentrations were diluted by runoff.

Ambient air particulate studies conducted under the National Air Pollution Surveillance program (NAPS) show statistically high levels of lead for the Kamloops City area. These levels have persisted after shutdown of the smelter and are not believed to be associated with it. Other sources may be the use or misfueling of leaded fuels or undetermined atmospheric variables used in the mathematical model.

2.16 Alcan Aluminum Smelter, Kitimat, B.C.

No significant data regarding lead discharges from the Alcan Aluminum smelter at Kitimat, B.C. was found.

3.0 SECONDARY LEAD SMELTING

In 1976 the Air Programs group of the Pacific Region identified 28 facilities to which the Federal Secondary Lead Smelter Air Regulations applied. All plants were screened and nine located in the Greater Vancouver Regional District were found to come under the regulations. All nine were found in compliance and only four were considered significant. Emission testing on these four plants indicated they were an order of magnitude lower than the limits set by the regulations. Only one plant is required to conduct annual tests as part of its permit requirements.

The products for which lead is reprocessed include antimonial lead alloys and lead oxide for lead acid battery manufacturing and lead soldering. Industrial consumption of lead is for products in the assembly of lead acid batteries, pipe, sheet lead and solder, soldering during can manufacturing, and lead weights for fishing.

Smelting equipment used includes one reverberatory furnace, melting kettles, melting crucibles and solder baths. Quantities of lead processed range from <1.0 - 250 tons per month per facility. Fiberglass or cotton baghouses are used for emission controls with the maximum emission at any of the plants estimated <2 kg/week. Table 10 shows the emission limits set by the various environmental agencies (Appendix X).

TABLE 10 EMISSION LIMIT REQUIREMENTS FROM THE FEDERAL REGULATIONS, THE B.C. CONTROL OBJECTIVES AND THE GREATER VANCOUVER REGIONAL DISTRICT (GVRD) REQUIREMENTS

	SUSPENDED PARTICULATES EMISSION (mg/m^3)		LEAD EMISSION (mg/m^3)	
	Blast Furnace Cupolas	Kettles Lead Oxide Production	Blast Furnace Cupolas	Kettles Lead Oxide Production
Federal	46	23	28	14
B.C.	46 - 343	46 - 343	7 - 11	7 - 11
G.V.R.D.	50	50	1.2	1.2

G.V.R.D. lead emission limits meet or exceed the Federal regulations

TABLE 11 PACIFIC REGION SUMMARY OF SECONDARY LEAD SMELTERS SUBJECT TO FEDERAL REGULATIONS (151)

FACILITY	LOCATION	EMISSION TEST DATE	RESULTS (mg/m^3)		FURNACE TYPE AND OTHER SOURCES	PARTICULATE CONTROL
			PARTICULATE	LEAD		
Metalex Products	Richmond	May/77	10	0.2	Reverb Melting Kettles	Baghouse
Canadian Battery	Richmond	June/77	<2.0	<2.0	Kettle Crucibles	Baghouse
Canada Metal	Vancouver	Jan/80	0.1	<0.1	Kettle Crucibles	None
Varta Batteries	Richmond	June/80	1.0	<1.0	Kettles	Baghouse
American Can	Vancouver	N.R.	-	-	Solder Baths	None
C & B Batteries	Delta	Apr/86	0.9	0.9	Crucible	None
Metal Distributors	New West	N.R.	-	-	Crucible	None

N.R. = Emission tests not required due to limited lead production

The 1984 Federal Status report on compliance with the secondary lead smelter regulations indicates that the regulations have been administered by the Greater Vancouver Regional District with the regional office of Environmental Protection - Conservation and Protection (EP, C&P) auditing the progress and status of compliance. The report states that "Seven plants are subject to the regulations, and are considered by the Greater Vancouver Regional District to be in full compliance" (148). Table 11 lists the performance of facilities under regulation. The highest levels of soil contamination were detected in soils near a battery smelter in Richmond in 1971.

4.0 INDUSTRIAL AND COMMERCIAL USES OF LEAD

Table 12 is an alphabetical listing of the tertiary commercial and industrial uses of lead in 1944 as compiled by the research department at Cominco's Trail Refinery (19). Many of these applications persist today and several additional applications have been included from other sources. Some of the flexible film applications such as bottle caps and cable sheathing have been replaced by plastic or alternate materials. The use of tetraethyl lead as a fuel antiknock additive is also rapidly declining. Many of the uses of lead present little or no environmental hazard once they are applied, as they are not subject to corrosion or erosion, i.e. in lead crystal, glass lenses and building vibration dampers. Other uses such as lead shot or leaded gasoline can affect the environment. The following chapters will deal with the major uses of lead in the Pacific Region and the associated discharges to the environment.

TABLE 12 ALPHABETICAL LIST OF THE USES OF LEAD (21)

Acid Concentrators	Tanks
Agitators	For acidic process reactions
Air Conditioning Equipment	Lead coated fans, ducts, etc.
Aircraft	Storage batteries, bearings, solder, control wire protection, lubricant
Aluminum, Lead Plated	Connecting storage battery terminals
Ammunition	Bullets and shot
Anodes	Plating, and in electrolytic production of zinc
Antivibration Mats	Building, foundations machinery (such as printing presses, rubber mills)
Artificial Leather	In rubber, oil cloth, enamel etc.

TABLE 12 (CONTINUED)

Artists Materials	Collapsible paint tubes, pigments
Assaying	Litharge and test lead
Automatic Signals, Railway	Storage batteries
Automobiles	Storage batteries, solder, bearings, paint
Babbitt Metal	Bearings
Bearing Bronzes	Bearings
Boiler Tubes	Coatings
Bolts and Washers	Expansion bolts and lead washers
Boots and Shoes	Blocks on which leather is cut
Bottles	To contain acid
Bottle Caps	For milk bottles, of lead, tin-coated
Bridge Construction	To reduce vibration (lead sheet)
Building	Paint, plumbing, roofing, ornamental work, pressure relieving joints, anti-vibration mats, stair treads, putty sheets under bathroom tiling, leaders, gutters, sash weights, flashings, caulking spandrels, lead-headed nails
Cable	Sheathing
Canning	Solder
Capping	On wood piles to prevent rotting
Cars, Railroad and Street	Bearings, batteries, paint, solder noise reducers, safety trends
Caskets	Lead and lead-lined, trim
Cast Iron Pipe	Coating, lining, caulking

TABLE 12 (CONTINUED)

Caulking	As molten lead or lead wool plumbing, anchoring bolts in stone or cement walls
Cement	Litharge with glycerine
Ceramics	Litharge, lead antimonates and bisilicates
Chemical Laboratories	Equipment, table tops
China	Glaze
Cinch Bolt	To fasten articles in concrete or stone
Clocks	Clock weights
Clothing	Dress weights
Coatings, Metallized	Spraying, electroplating, hot-dipping
Collapsible Tubes	For glue, lubricating grease, paint, colours shoe polish
Condensors	Corrosive vapours
Copper and Iron Sheets	Lead coatings
Corrosion Resistant Lead	For acid storage or mixing tanks
Die Castings	
Digestors	Distillation columns
Divers	Lead shoes and belts
Doors, Skylights, Windows Drums	Cames (slender grooved lead strips to hold glass in lattice windows), puttyless frames, sash weights, putty, lead covered glazing bars, expansion joints
Ducts, Lead	Exhaust for fumes from laboratories (or for any gases containing S02 or S03)

TABLE 12 (CONTINUED)

Dyeing	Dye Fixer (lead acetate as mordant)
Electrical	Storage batteries, cable sheaths, fuses, bearings, light bulbs, insulator glaze, solder, lead-covered conductor cable in heating hot beds and underneath sidewalks to melt snow. Cell liners
Enameling	Iron ware, etc.
Explosives	Lead sulphocyanate, lead azide, lead nitrate, lead peroxide
Extractors	
Filter Grids	
Fire Sprinklers, Automatic	Low melting alloys to keep valves closed
Fireworks	Lead nitrate
Fishing	Sinkers, net weights
Flooring	Explosive plants, chemical plants, laboratory
Flower Boxes	Lead lined
Flues	Ventilation
Foil	Tea, tobacco, electrical condensors, electrical fuses, bottlecaps, covering for stems or cut flowers
Fusible Alloys	Electric fuses, automatic sprinkler systems, boiler plugs, surgical casts
Gaskets	Machinery
Gasoline	Antiknock compounds (tetraethyl lead)

TABLE 12 (CONTINUED)

Glass	Litharge and red lead in high grade glass, imitation jewelry, optical goods, neon tubes, photographic apparatus (as lenses)
Glue	Collapsible tubes
Hammer	For removing dents in sheet metal
Heat Exchangers	
Homogeneous Lead Linings	Chemical plant equipment
Ink, Printing	Pigments (orange mineral)
Insecticides	Lead arsenate
Jewelry	Lead glass for imitation gems
Lab Apparatus	
Leadleaf	Metallic lead pigment for primary coat on steel, and seal coat on concrete
Lead Compounds	Lead acetate - manufacture of other lead salts, mordant in dyes, drier in paints, lead coating steel Lead antimonate - pigment in paint, ceramics, crockery, glass industries Lead arsenate - insecticide Lead azide - primer in explosives with nitroglycerine Lead borate - drier in paints, glazes, enamels Lead chromates - colour pigments Lead cyanamide - pigment Lead dithiofurate - accelerator in manufacture of rubber Lead fluoborate - electrolytic refining of lead Lead fluosilicate - electroplating with lead Lead thiosulphate - accelerator in vulcanizing rubber, to deposits lead mirrors Lead linoleate - drier in paint and varnish Lead nitrate - manufacture of other lead salts, matches, fireworks, insecticides

TABLE 12 (CONTINUED)

Lead Compounds (continued)	Lead oleate - drier in varnish, rubber and lubricants Lead peroxide - strong oxidizing agent Lead resinate - drier in paints Lead silicate - glazing, enamelling, fire-proofing fabrics Lead stearate - drier in varnish and laquer Lead sulphide - source of lead, "doctor" in oil refining Lead sulphocyanate - primer in explosives Lead tetraethyl - anti-knock ingredient of motor fuels Sodium plumbite - oil refining as "doctor solution"
Lighting Fixtures, Ornamental	
Lightning Rods	Lead coated copper
Linoleum	Drier and pigment (litharge)
Litharge	Storage batteries, insecticides (as lead arsenate), ceramics, chrome pigments, oil refining (as sodium plumbite), varnish, rubber linoleum, special glasses, glue (cement), assaying
Locomotives	Bearings, coating for boiler tubes, paint
Lubricants	In drawing steel wire through dies
Lubricating Grease	Collapsible tubes, lead oleate (as a constituent), powdered lead
Machinery	Bearings, noise reducers, grouting gaskets and washers, metallic packaging, anti-vibration pads
Marble and Stone Work	Lead wedges
Markers	Hide and furs

TABLE 12 (CONTINUED)

Matches	Red lead and lead thiosulphate, lead nitrate
Mirrors	Lead thiocyanate
Motion Pictures	Lead glass lenses
Motor Boats	Solder, paint, bearings
Musical Instruments	Organ pipes, player piano keys, piano key counterweights, bending band instruments by pouring lead into the tubing
Nails	Lead-headed
Navigation	Sounding lead
Optical Goods	Lead glass
Orange Mineral	Printer's ink, vermilion colour pigment
Packing	Metallic
Paints and Varnishes, Pigment and Drier	White lead, basic lead sulphate, leaded zinc oxide, lead titanate, litharge, red lead, orange mineral, metallic lead ("Leadleaf"), lead cyanamide, lead chromates
Paper	Litharge cement, lead-lined equipment
Petroleum Refining	Litharge (sodium plumbite), lead and lead-lined equipment, sodium sulphide
Photographic Apparatus	Lead glass lenses, photographic development tanks (X-ray films)
Plumbing	Pipe, solder, bonds, traps, ferrules, caulking lead, sheet lead, lead wood, fittings
Pneumatic Tubes	For conveying mail in post offices
Pottery	Glazing (as litharge)

TABLE 12 (CONTINUED)

Printing	Type metals, printer's ink
Pumps	Lead-cast and lead-lined for handling corrosives, lead wool packing
Putty	Litharge and red lead, for steel sash
Radio	Tube caps, solder
Radium	Lead lines cases, rooms, equipment
Railway Tank Cars	
Red Lead	Storage batteries, paints, ceramics, high grade glassware, pottery, enamels, varnish
Regalia, Badges, Emblems	Die cast lead medallions, etc.
Rivets	Lead, fastening linings to steel shells of vessels in petroleum refining
Roofing	Sheet lead roofing, and lead coated terneplate. Metals as pure, hard or special leads
Rubber	Litharge (as an accelerator and toughener), lead thiosulphate, white lead, basic lead sulphate
Rubber Hose	Moulded in lead
Scales and Balances	Lead weights
Scrubbers	
Shipbuilding	Paint, bearings, shaft sleeves, storage batteries, piping, keel weights, solder
Shot	Ammunition, weights for dresses, suites, draperies, curtains, display fixtures

TABLE 12 (CONTINUED)

Solder	Soldering automobile radiators, smoothing dents and welded joints in automobiles, soldering tin cans, copper and steel tubing, "Wiping" solder for lead pipe and cable joints, zinc and galvanized ironwork, dipping baths, electrical joints, general purposes
Sound Proofing	Doors (with sheet lead)
Sporting and Athletic Goods	Weights in decoys, bats, golf clubs, sinkers, ammunition, tennis court markers
Statuary and Art Goods	Statues, garden figures, spandrels, roof crestings, tablets, etc.
Steel Barrels, Kegs, Drums	Lead linings
Steel, Lead-bearing	For screw stock "Ledloy"
Steel Treating	Hardening and tempering
Storage Batteries	Battery grid alloys, active material paste for grids, lead plated aluminum for connecting battery terminals
Structure and Ornamental Iron Work	Painting (with red lead)
Sulphuric and Mixed Acids Telephone	Lead on lead-lined equipment. Storage batteries, lead covered cable, solder
Terneplate	Lead and tin coating on steel plate for roofing, gasoline tanks
Tin Cans	Soldering
Tin-Coated Lead	Bottle caps(replacing aluminum milk bottle caps)
Tin Foil	Lead-coated
Tobacco	Foil wrapping on cigars, cigarettes, tobacco

TABLE 12 (CONTINUED)

Toys	Cast
Trucks, Industrial	Storage batteries, bearings
Type Metal	Printing (monotype, linotype, intertype, stereotype, electrotype)
Valves	
White Lead	Prints, component of lubricant for heavy machinery
Wire	Metal spraying, heating element buried underground, sculpting, pattern making, decorative work
X-Ray	Lead as protection against and director for rays

5.0 LEAD IN INTERNAL COMBUSTION ENGINE FUELS

Tetraethyllead (TEL) is used to increase the octane rating of fuels and provide lubrication for value seats in internal combustion engines. The release of this lead to the environment can occur at any of the five major stages in its life cycle of use:

1) Manufacture of tetraethyllead (TEL)
2) Transport of TEL to refineries
3) Use of TEL at the refineries for fuel blending
4) Distribution to and from fuelling stations
5) Combustion of the fuels

Data for the following text can be found in Appendix XII.

5.1 Manufacture and Transport of TEL

All TEL used in the Pacific Region is manufactured elsewhere and imported by rail/tanker. To date there have not been significant reported environmental releases associated with manufacturing or use of TEL in this region.

There have been no reported incidents of spills of TEL during transport to the oil refineries. Misblending has occurred which results in product recall (163).

5.2 Use of Tetra Ethyl Lead at Refineries

There are seven crude oil refineries, one waste oil refinery and one blending terminal in the Pacific Region and all are located in British Columbia. They include:

1) Chevron Oil - Burnaby
2) Shell Oil (Shellburn) - Burnaby
3) Gulf/Petrocan Oil - Burnaby
4) Imperial Oil - IOCO
5) Imperial Oil - Kamloops (Blending only)
6) Gulf/Petrocan - Kamloops
7) Husky Oil - Prince George
8) Mohawk Oil - North Vancouver
9) Petrocan - Taylor

A major bulk storage terminal is also located on Burnaby Mountain, Burnaby, B.C. Secure storage and handling facilities of TEL are used at the refinery sites due to the high cost and high toxicity of TEL. All refineries file quarterly reports with Environmental Protection - Conservation and Protection on the quantities of TEL used. Regulations in the Clean Air Act apply to the concentration of TEL at the dispensing pump stations and at the refineries. There have been no major studies of refinery effluent discharges. Data that is available comes from permit applications and monitoring on a site specific basis.

5.2.1 **Chevron Canada, Burnaby Refinery**. Effluent measurements for lead from refinery process area #1 and #2 during 1982 to 1985 were less than 0.20 mg/L. A high value of 2.5 mg/L was recorded at the effluent discharge to Burrard Inlet in 1976.

5.2.2 **Shell Canada (Shellburn), Burnaby**. The Shell Canada refinery discharges to the Greater Vancouver Regional Drainage District Sewer and must meet the requirements for industrial discharge. Monitoring results are few with only one value (of 0.30 mg/L) reported in 1983 that exceeded the 0.20 mg/L level. All other values were one to two orders of magnitude lower.

5.2.3 **Gulf/Petrocan Oil Refinery, Burnaby and Kamloops, B.C.**. No data was located for effluents from the Burnaby refinery. The refinery operations were discontinued at the Kamloops refinery in 1983 and the site is currently used as a bulk terminal. TEL is blended into fuels at this facility. Prior to shutdown of the refinery operations in Kamloops in 1982, effluent monitoring was carried out at the west lagoon, east lagoon, discharge to lagoon #2 and a groundwater wet well. None of the annual averages at the lagoons exceeded 0.20 mg/L. Some single grab samples exceeded this level in 1982, however the majority of tests were an order of magnitude lower than the 0.20 mg/L standard.

5.2.4 **Imperial Oil, IOCO Refinery.** Site monitoring data reported on the EQUIS data system did not record any values greater than 0.20 mg/L. Most values were reported as less than 0.20 mg/L. Test methods with greater sensitivity gave results at 0.001 to 0.006 mg/L.

5.2.5 **Husky Oil, Prince George.** Permit monitoring data for the Huskey Refinery effluent discharge from the aeration lagoon to the exfiltration lagoon had a maximum reading of 0.035 mg/L (in 1978). Data from Environmental Protection - Conservation and Protection monitoring at the bio-oxidation pond outlet was 0.20 mg/L or less except for one reading of 2.40 mg/L in 1982.

5.2.6 **Mohawk Oil, Waste Oil Refinery, North Vancouver, B.C.** A waste oil refinery producing lubricating oil by a filtration procedure produces 22 740 litres per day of waste water which is discharged to sewer and 3 750 kg of filter solids which are disposed to landfill. There is no monitoring data available and the pilot tests indicate that the effluent concentration would be <0.020 mg/L and solids would be 6.4% lead. Leachate tests performed on the sludge produced concentrations of <0.10 mg/L. There were no monitoring results of stormwater effluent for any of the sites.

5.3 Motor Gasoline Production and Tetraethyllead Consumption

Lead particulate carried in the atmosphere is eventually deposited on the surface of the earth (94). One method of monitoring increases in atmospheric lead is by sampling deposits in ice and snow in Greenland which show that lead has increased from 0.001 ug Pb/kg snow dated from 800 B.C. to well over 0.200 ug Pb/kg snow in 1950 (51) (Figure 21). This increase corresponded with the industrialization of the Western World and showed the sharpest increase with the introduction of leaded fuel for use in the automobile.

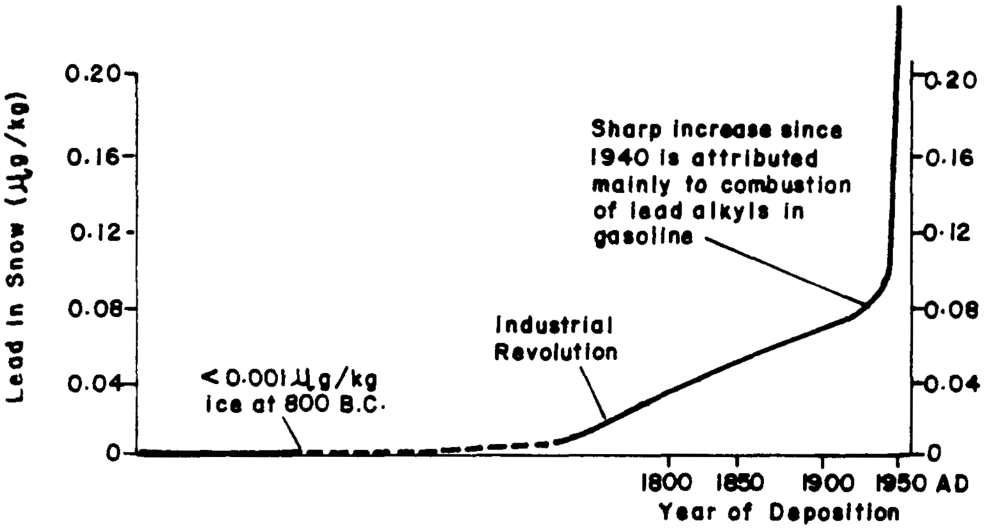

FIGURE 21 LEAD CONTENT OF GREENLAND SNOW TO 1950AD
Source: Chemistry in Britain, 7, 55, 1971

Leaded automobile exhausts are considered to be the major source of lead emissions in Canada (34, 12) accounting for 60 to 68% of the total of 14 360 tonnes in 1973 (174).

Tetra ethyl lead as an octane booster in motor fuels was first introduced to the public in 1923 in the United States. Sales of TEL increased steadily and in 1940, 75% of all fuel sold was leaded. In 1940 consumption of TEL in Canada was 1 091 tonnes which increased to 15 818 tonnes in 1975 (89). The introduction of lead free fuels decreased TEL consumption to 7 278 tonnes by 1982. Consumption is expected to decrease to 2 500 tonnes by 1990 (174). In 1983 leaded gasoline accounted for 53% of gasoline sales in Canada and lead additives consumed 15% to 18% of the primary lead produced in Canada (37).

5.3.1. Concentrations of Lead in Motor Fuels. Table 13 shows that unleaded fuel production has increased significantly from 5.7 in 1975 to 36.6 in 1980 (89).

TABLE 13 CANADIAN PRODUCTION VOLUMES OF PREMIUM LEADED, REGULAR LEADED, AND REGULAR LEAD FREE GASOLINES (BILLIONS OF LITRES)

GASOLINE TYPE	1975 (89)	1980 (89)	1986 (218)
Premium Leaded	4.994	0.454	N/A
Regular Leaded	28.15	23.6	14.9
Regular Lead Free	1.816	14.07	14.64

The maximum allowable concentration of lead in Canadian leaded fuel is 0.29 g/L, which is equivalent to the value in the United States. The United States adopted the 0.29 g/L standard for leaded fuel in 1982, and the current British standard is 0.15 g Pb/L. The Canadian and British governments plan a complete phase out of leaded fuel by 1990 (34).

The maximum allowable lead in 14 European countries ranges from 0.15 g/L for regular gasoline to 0.40 g/L for premium. In Australia 0.84 g/L is allowed for commercial use, 0.3 to 0.4 g/L for metropolitan uses. Spain uses 0.48 g/L for 90 RON (Research Octane Number), 0.60 g/L for 96 RON (Canadian fuels are generally 89 to 92 RON). New Zealand and South Africa allow 0.84 g/L (60).

5.3.2 Enforcement of Lead Concentrations in Automotive Fuels

Refineries must report on a quarterly basis the quantity of gasoline produced and imported and total amount of lead used (89). Enforcement sampling is done by collecting samples from retail outlets, marketing depots and refinery storage tanks. If the product is found to contain lead in excess of the regulated limit, it is seized and ordered replaced or diluted to meet regulations (89). Violations of the unleaded gasoline regulations began to be enforced in 1974 with a national non-compliance rate of 3.2%. The failure rate dropped to 1.8% in 1975 and rose steadily to 5.9% by 1980. Highest failure rates were in Newfoundland and New Brunswick followed by British Columbia and Nova Scotia.

Of the 1 141 samples collected from refineries in 1981 no violations occurred indicating that transportation and fuel transfer operations are the source of contamination. Cross transfer and improper flushing of tankers are suspected sources of contamination.

There are approximately 2 800 retail outlets in British Columbia and 90 in the Yukon and Northwest Territories. In 1980, 140 (5.0%) B.C. outlets and 13 (14.4%) of the Yukon/NWT outlets were sampled. 4.1% of the B.C. outlets and 15.4% of the Yukon/NWT outlets sold leaded gasoline which contained lead in excess of the regulated limits (89). Adequate sampling programs have been implemented in British Columbia, however, in remote areas of the Yukon adequate monitoring and sampling programs have not been initiated (89).

5.3.3. Lead Consumption of Gasoline Additives in British Columbia and the Yukon, 1982 to 1983.

Table 14 lists motor gasoline production in British Columbia and sales in the Yukon in 1982 and 1983. Gasoline is rated as:

Premium/Regular Leaded*	Maximum lead = 0.77	g/L
Premium Non-Leaded	Maximum lead = 0.0132	g/L
Regular Non-Leaded	Maximum lead = 0.0132	g/L
Aviation 80 octane*	Maximum lead = 0.14	g/L
Aviation 100 octane*	Maximum lead = 1.28	g/L

* Federal regulations allow 0.29 g/l lead in leaded gas effective January 1, 1987. There are no Federal limits for lead in aviation fuel (125)

The volume of gasoline produced in B.C. has been relatively stable from 1982 through 1986 however the quantity of lead consumed has declined from 1 418 tonnes to 874 tonnes over the same period.

An average lead concentration of 1.00 g/L is typical for 100 octane aviation fuel (65). A breakdown of volumes for 80 and 100 octane fuels is not available however an estimation using an average lead concentration of 0.71 g/L would indicate an approximate lead consumption of 2.6 tonnes in the Yukon in 1983.

TABLE 14 PRODUCTION OF MOTOR GASOLINE IN BRITISH COLUMBIA (219) AND ESTIMATED SALES IN YUKON (111) 1979 TO 1986

YEAR	LEADED VOLUME (m3)	LEAD-FREE VOLUME (m3)	LEADED + LEAD-FREE VOLUME (m3)	LEADED Pb (kg)	LEADED Conc. (g/L)
British Columbia:					
1979	3,077,723	869,579	3,947,302	1,274,997	0.323
1980	3,011,584	1,048,182	4,059,766	1,330,787	0.300
1981	2,921,067	1,179,304	4,100,371	1,428,491	0.348
1982	2,802,666	1,114,426	3,917,092	1,418,666	0.362
1983	2,543,556	1,094,751	3,638,307	1,209,675	0.332
1984	2,407,172	1,234,745	3,641,917	1,094,456	0.301
1985	2,225,505	1,472,419	3,697,924	938,129	0.254
1986	2,154,101	1,553,561	3,707,662	874,278	0.236

GASOLINE TYPE	1982 GASOLINE TOTAL m3	1982 LEAD ADDED TONNES	1983 GASOLINE TOTAL m3	1983 LEAD ADDED TONNES
YUKON: (Sales)				
Premium (Leaded/Lead-free)	2 116	0.028*	20	---*
Regular (Lead-free)	8 449	0.112*	7 737	0.102*
Regular (Other)	36 193	27.9*	37 906	0.50**
Aviation Gas (Leaded)	4 348	3.1***	3 699	2.60***

* Estimated using a maximum allowable lead content of 0.132 g/L (89) which does not reflect the possible higher value due to leaded premium being included.

** Estimated using maximum allowable lead content of 0.77 g/L. The reported values are 1 221 tonnes indicating less than the maximum allowable concentration was used.

*** Estimated using an average of 0.71 g/L lead. Cumulative total reported January to November 1983.

5.3.4 Ambient Lead Concentrations at High Traffic Intersections in Greater Vancouver.

Ambient air samples were collected by B.C. Research Ltd. at six high traffic locations in Greater Vancouver in 1972 (Table 15) (93). As there are no Federal Ambient Air Regulations for lead, the British Columbia Provincial Regulations concerning ambient air values in the "Objectives for the Mining, Smelting and Related Industries", and the "B.C. Air Quality Guidelines and Objectives" are used for comparative purposes. The acceptable range for mining and smelting is 1.0 to 2.5 ug/m^3 Pb. According to the regulations "The more stringent values will apply to sensitive environmental situations, the less stringent where it can be shown that unacceptably deleterious changes will not follow" (164). The British Columbia Air Quality Guidelines and Objectives list the following criteria for ambient air.

(ug/m^3)	DESIRABLE LEVEL	INTERIM LEVEL	MAXIMUM LEVEL
24 hour	4	4	6
Annual Geometric Mean	2	2	3

TABLE 15 LEAD CONCENTRATIONS IN AMBIENT AIR AT SIX MAJOR VANCOUVER INTERSECTIONS (1972) (166)

SITE NUMBER AND LOCATION	MEAN VALUE (ug/m^3)	RANGE (ug/m^3)
1 Denman and Georgia	13.48 ± 4.8	3.13 - 21.9
2 Burrard and Cornwall	4.86 ± 2.3	0.84 - 8.12
3 Burrard and Georgia	4.01 ± 2.3	0.80 - 10.0
4 Main and Kingsway	9.95 ± 4.7	1.62 - 17.9
5 Pender and Beatty	6.19 ± 4.1	0.90 - 14.2
6 Broadway and Cambie	10.90 ± 4.2	2.31 - 20.2
Overall Average	8.23 ± 3.8	0.80 - 21.9

The average concentration measured at all sites is 8.2 ± 3.8 ug/m^3. The individual averages range from 4.0 ug/m^3 to 13.5 ug/m^3 with concentrations ranging from 0.8 ug/m^3 to 21.9 ug/m^3 for a 3 hour test period at various traffic densities. According to the Royal Society Report (175) the peak of leaded fuel consumption in Canada occurred in 1975 three years after the Vancouver measurements were made. In April and May of 1983, high volume air samples were set up at ten locations in five Canadian cities including Vancouver, Montreal, Toronto, Edmonton and Ottawa. The samples were in areas experiencing a minimum of 50,000 vehicles per day with the inlets of the samplers located 3 - 5 m from the roadway and a maximum of 4 m above the ground.

All locations experienced above average rainfall and Vancouver experienced double the normal amount in April. (Precipitation will effectively remove particulate matter and reduce its re-entrainment.) In April 1983, Vancouver had the first, second and fourth highest values of the ten sites measured. In May 1983, Vancouver ranked first, second and fifth with the Lions Gate and Main and Kingsway sites consistently the highest of all sites at 2.7 ug/m^2 (220).

5.3.5 Ambient Air Particulate Lead Concentrations in the Greater Vancouver Area.

There are nineteen ambient air monitoring stations in the Greater Vancouver Regional District (GVRD) (Figure 22) and one in Abbotsford and in Chilliwack, B.C. The combined annual geometric mean for air sampled in the Lower Mainland area in 1979 was 0.8 ug/m^3 which decreased to 0.39 ug/m^3 in 1984. This co-relates well to a national trend which shows a decline from a geometric mean of approximately 0.68 in 1974 to 0.28 ug/m^3 in 1983 (167). This downward trend in suspended lead concentrations may be expected to continue with the increased use of non-leaded automotive fuels.

5.3.6 Lead Concentrations in Soils Along Major Traffic Routes in Greater Vancouver.

A soil sampling program at 44 sites in the City of Vancouver showed that lead levels varied from a low value of 20 ppm to a high of 3 989 ppm (Figure 23) in a gutter sample at 800 Thurlow Street

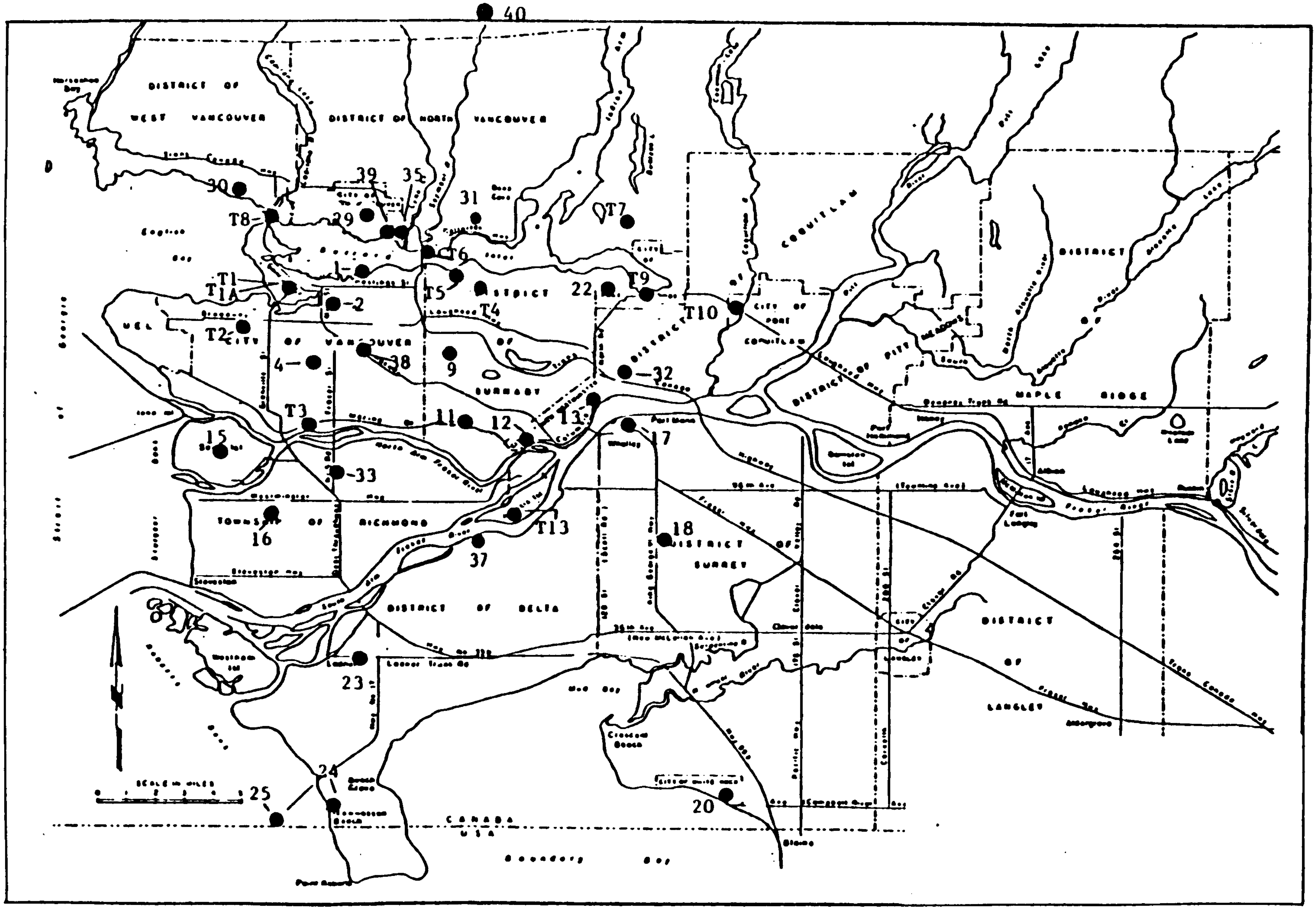

FIGURE 22 GREATER VANCOUVER REGIONAL DISTRICT AMBIENT AIR MONITORING STATIONS LOCATION MAP - 1982

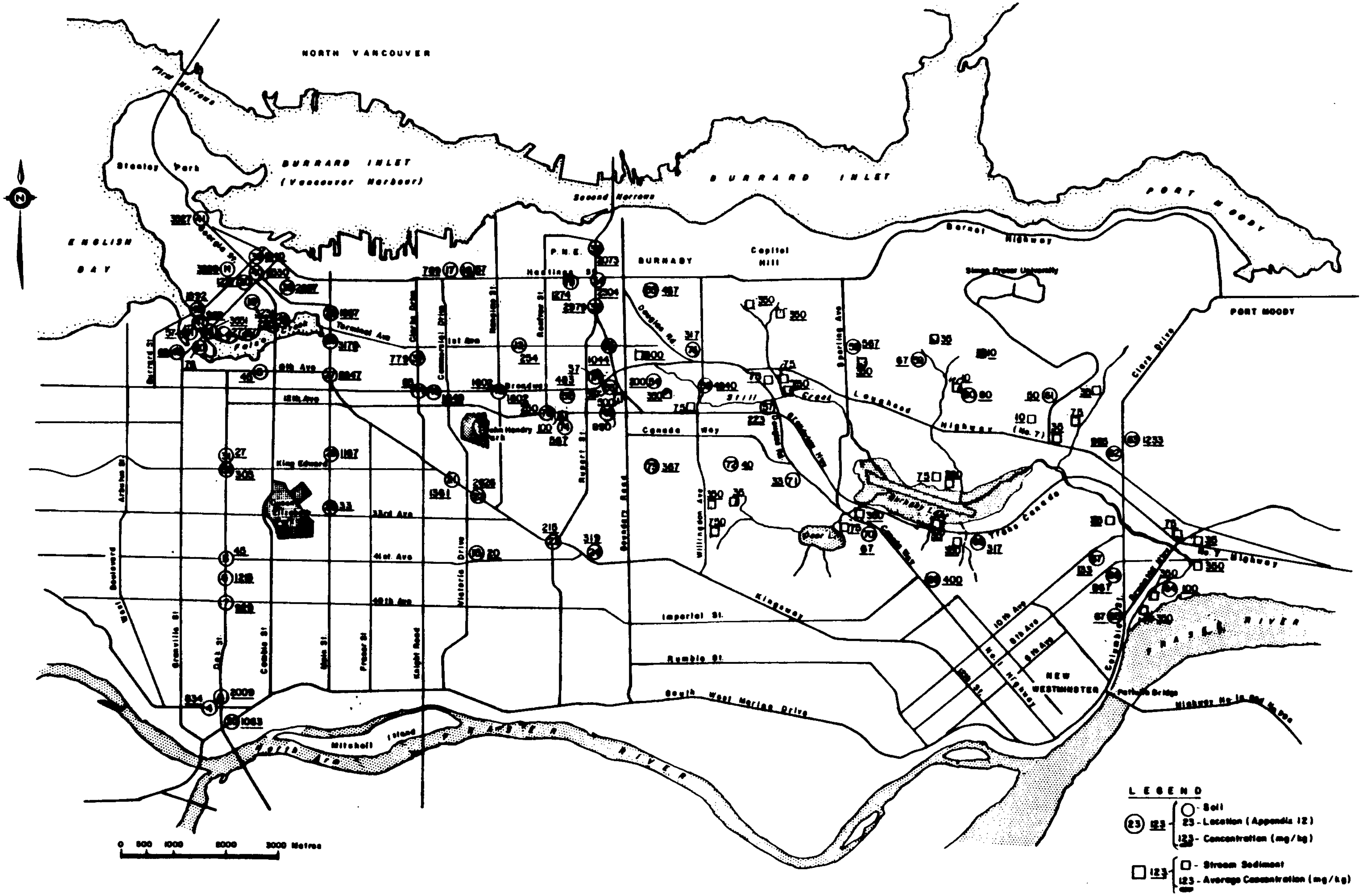

FIGURE 23 LEAD CONCENTRATIONS IN SOIL AND STREAM SEDIMENT SAMPLED NEAR MAJOR AUTOMOBILE TRAFFIC ROUTES IN THE BURNABY, STILL CREEK - BRUNETTE RIVER DRAINAGE BASIN (171)

and areas near the high density housing of the West End of downtown Vancouver. A concentration of 37 ppm in soil from the Thunderbird school at 2300 Cassiar Street was relatively low compared to measurements of 2 073 ppm Pb and 2 979 ppm Pb at the 100 and 1000 blocks of Cassiar Street (57).

In B.C., yellow lead chromate is used in road paint and exterior paint. As the paints weather they become a source of lead to the environment (82, 96). Roadway lead can also come from other sources such as pavement, atmospheric fallout, vegetation, litter, spills, anti-skid compounds, road working paints (Bridgework), crack fillers and expansion joint compounds. Automobiles contribute lead from:

1) Gasoline	663 ug Pb/g	7) Diesel Fuel	12 ug Pb/g
2) Motor Oil	9 ug Pb/g	8) Brake Linings	1 050 ug Pb/g
3) Transmission Fluid	8 ug Pb/g	9) Brake Fluid	7 ug Pb/g
4) Antifreeze	6 ug Pb/g	10) Road Materials	
5) Undercoating	116 ug Pb/g	a) Asphalt	102 ug Pb/g
6) Rubber	1 110 ug Pb/g	b) Concrete	450 ug Pb/g
(as PbO is used as filler in tires)			

5.3.7 <u>Lead Concentrations in Soils Near Commercial, Industrial and Residential Sites in Greater Vancouver</u>.

Lead in paint on the Granville Street Bridge and soil beneath the bridge was sampled and reported in May 1980 by the City of Vancouver Health Department (104).

Dried Bridge surface paint lead content	2 631 ppm
Liquid Grey surface paint lead content	238 ppm
Liquid Red undercoat lead content	834 ppm

Twelve soil samples from below the Granville Street Bridge had lead concentrations ranging from 13 to 140 ppm with a mean value of 66 ppm.

The City of Vancouver Health Department tested soil samples near the north end of the Granville Street Bridge and Canada Metals Property where Expo 86 was situated.

The samples at the Seymour exit to the Granville Street Bridge ranged from 89 mg/kg to 16 800 mg/kg. The soil samples from the former Canada Metals site ranged from 6 520 mg/kg at the towing company lot adjacent to the site to 72 260 mg/kg near the south property line. The geometric mean of three samples from the Canada Metals Site was 25 446 mg/kg.

6.0 LEAD CONTAMINATION IN AGRICULTURAL SOILS, PESTICIDES, PLANTS AND FERTILIZERS

Lead is found as a trace element in most western Canadian soils. Soils that have elevated lead concentrations are adjacent to major transportation routes near industries, lead smelters and battery plants or where lead arsenate sprays have been used on agricultural crops. Other lead components used in agriculture are:

a) Tetraphenyl lead - pesticides
b) Lead, 2-Ethylhexanoate - fungicide
c) Lead tallate - insecticide, wood preservative

Lead contamination was observed in agricultural crops near an express highway in Bratislava Czechoslovakia. The level of lead concentrations in cabbage and rye decreased with distance from the highway and elevated lead concentrations in apples were detectable within 200 m (124) from the road.

The concentrations of Pb, Cu, Zn and Cd were determined in 6 agricultural watersheds in Southern Ontario (63). The concentrations of total metals in the water co-related strongly with suspended sediment levels and values ranged from 10.0 to 19 000 mg/L with a medium value of 20 mg/L (66). It was found that agricultural activity did not add significant amounts of these elements to the water systems.

6.1 Lead Contamination of Agricultural Soils in Western Canada

The concentration of lead in soils has been related to proximity to high density traffic routes with most of the accumulation occurring within 30 m of a road. Agriculture Canada conducted a study of the extractability of lead from 5 agricultural soils by spiking them with lead nitrate and allowing them to incubate for 3, 30 and 360 days. After incubation the samples were leached with nitric acid and lead recovery was 99.1 ± 7% (68) using spectrophotometric analysis.

Soils in B.C. were then sampled at various horizons ranging from the surface to depths of 2.0 meters. The measurements of surface horizons ranged from 0.6 to 180 ppm with an average of 9.1 ppm. Deeper horizons showed less variation where concentrations ranged from 1.7 to 17.3 ppm.

Lead originating as fallout or from decaying plant matter appears to be immobilized by precipitation with various anions. It was concluded that there was no appreciable relation between soil type, pH, or organic matter, therefore, variation in lead concentration was due to pollution (109).

The highest concentration of lead in soils was in the lower mainland region near the highest traffic densities. The concentrations decreased with distance from Vancouver and were lowest in the sparsely populated interior regions. An exception was the area near the Consolidated Mining and Smelting Company (Cominco) which is the worlds largest lead/zinc smelting complex. Tables 16 and 17 give a statistical summary of the results.

TABLE 16 DISTRIBUTION OF LEAD FRACTIONS IN CERTAIN GEOGRAPHICAL REGIONS (68)

REGION	TOTAL LEAD			NITRIC ACID SOLUBLE LEAD		NATIVE LEAD	
	Obsd[1]	Mean (ppm)	SD[2] (ppm)	Mean (ppm)	SD (ppm)	Mean (ppm)	SD (PPM)
Coastal BC surface	63	51.3	19.3	11.3	13.5	40.0	10.0
BC interior surface	102	51.1	7.7	9.3	7.5	41.9	7.4
New Zealand surface	6	41.1	14.4	6.4	1.3	34.6	3.1
Other Canadian surface	4	60.7	12.0	12.2	7.8	48.5	6.3
California surface	2	125.9	54.0	72.1	49.1	53.8	4.9
Coastal BC subsurface	24	51.8	5.0	7.0	2.5	44.7	4.8
All soils	201	51.9	13.2	10.2	10.1	41.7	8.0

[1] Obsd = number of observations
[2] SD = standard deviation

TABLE 17 DISTRIBUTION OF NITRIC ACID SOLUBLE LEAD IN SURFACE AND SUBSURFACE SOIL SAMPLES (68)

LOCATION[3]	DISTANCE FROM VANCOUVER (MILES)	SURFACE HORIZONS				SECOND HORIZONS			
		Obsd[1]	Mean (ppm)	SD[2] (ppm)	Range (ppm)	Obsd	Mean (ppm)	SD (ppm)	Range (ppm)
Delta	13	60	15.8	24.3	1.5 - 134.9	19	9.4	20.2	1.8 - 92.4
Surrey	17	33	12.2	8.9	1.1 - 34.6				
Pitt Meadows	20	23	20.4	35.4	6.4 - 180.4	10	6.8	3.8	2.9 - 16.4
Langley	25	80	6.5	3.6	0.6 - 13.3	2	5.5	2.1	4.0 - 7.0
Matsqui	35	54	11.8	7.4	2.6 - 36.1	5	7.9	2.9	5.2 - 12.5
Mission	40	3	9.3	4.5	5.7 - 14.4				
Sumas	45	16	8.5	3.2	2.8 - 13.2				
Chilliwack	55	38	6.3	2.4	1.1 - 12.1	2	6.1	1.3	5.2 - 7.0
Kent	65	34	7.3	4.0	1.1 - 21.8	2	5.9	1.0	5.2 - 6.6
Ashcroft-Savona	135	24	6.5	1.8	2.9 - 9.9	21	5.3	2.1	0.8 - 8.7
Similkameen	140	22	8.5	2.5	2.2 - 11.4	20	6.8	2.3	3.8 - 12.1
North Okanagan	170	27	7.3	3.5	2.6 - 14.7	21	7.2	2.2	3.4 - 13.7
Shuswap Lake	210	8	24.3	2.2	4.8 - 10.3	6	5.3	1.2	3.8 - 6.4
Kettle-Creston	250	7	10.5	22.9	10.3 - 75.0	7	12.9	3.1	8.7 - 17.2
Kootenay-Elk	350	12	12.2	2.9	5.9 - 16.9	12	11.1	2.7	7.6 - 16.6
Other Canadian Districts		4	72.1	7.8	7.0 - 25.7				
California, U.S.		2	72.1	49.1	23.0 - 121.2				
New Zealand		6	6.4	1.3	5.2 - 8.5				
All Soils		453	10.6	13.2	0.6 - 180.4	127	7.7	8.2	0.8 - 92.4

[1] Obsd = number of observations

[2] SD = standard division

[3] Districts in British Columbia unless otherwise stated

TABLE 17 DISTRIBUTION OF NITRIC ACID SOLUBLE LEAD IN SURFACE AND SUBSURFACE SOIL SAMPLES (68) (CONTINUED)

LOCATION[3]	DISTANCE FROM VANCOUVER (MILES)	DEEPER HORIZONS				ALL HORIZONS		
		Obsd[1]	Mean (ppm)	SD[2] (ppm)	Range (ppm)	Obsd	Mean (ppm)	SD (ppm)
Delta	13	69	4.8	2.7	1.8 - 17.3	148	9.9	17.1
Surrey	17					33	12.2	8.9
Pitt Meadows	20	39	5.4	1.5	3.2 - 10.7	72	10.4	20.1
Langley	25					82	6.5	3.6
Matsqui	35	11	7.5	3.0	4.4 - 15.1	70	10.9	6.7
Mission	40					3	9.3	4.5
Sumas	45					16	8.5	3.2
Chilliwack	55	2	5.7	0.8	5.2 - 6.3	42	6.2	2.3
Kent	65				1.1 - 21.8	36	7.2	4.0
Ashcroft-Savona	135				2.9 - 9.9	45	5.9	2.0
Similkameen	140				2.2 - 11.4	42	7.7	2.4
North Okanagan	170				2.6 - 14.7	48	7.9	3.0
Shuswap Lake	210				4.8 - 10.3	14	6.4	1.8
Kettle-Creston	250				10.3 - 75.0	14	18.6	16.3
Kootenay-Elk	350				5.9 - 16.9	24	10.8	2.8
Other Canadian Districts					7.0 - 25.7	4	12.2	7.8
California, U.S.					23.0 - 121.2	2	72.1	49.1
New Zealand					5.2 - 8.5	6	6.4	1.2
All Soils		121	5.3	2.5	0.6 - 180.4	701	9.1	11.3

[1] Obsd = number of observations

[2] SD = standard division

[3] Districts in British Columbia unless otherwise stated

6.2 Lead Contamination of Agricultural Soils in British Columbia

Lead uptake by plants was tested by sampling 24 Fraser Valley soils and one from the Okanagan, Peace River and Central Interior area (67). Soil extractions were carried out using 1 Normal nitric acid concentrations. Extractable lead concentrations in the leachate measured 1.0 ppm Pb with a standard deviation of 18 ppm Pb (67). The Delta soils were suspected of being contaminated by lead arsenate insecticide sprays used before 1944.

6.3 The Use of Lead-Arsenate Insecticide Sprays in Agricultural Regions of British Columbia

The manufacture of lead-arsenate (Pb-As) insecticides was the second largest use of litharge (lead oxide) during the years 1931 to 1939 (21). Lead-arsenate was used as a stomach poison for biting and chewing insects and was preferred over calcium arsenate (though calcium arsenate was less expensive) as it resisted decomposition and uptake by plants. In the United States annual consumption was 14 318 tonnes in 1941 and reached a high of 45 455 tonnes (19) before it was banned.

In north-eastern Wisconsin 50 tons of Pb-As was applied to a 400 square mile area (78). In mature orchards, spray residues reached 300-600 ppm in the soil which prevented shallow soil plant growth as lead was 30 to 40 times background levels. Agricultural plant uptake increased 3 to 4 times for above ground portions and 2 to 8 times for below ground portions (92).

In Washington State the use of Pb-As spray was similar to that of British Columbia, however, the finer textured soil retained the lead better than the coarser B.C. soils and in some areas phyto toxicity (plant toxicity) required the replacement of 1 meter of topsoil before the orchards could be renewed.

There are no complete records of the use of lead arsenate pesticides in British Columbia (88). Data compiled from spray calendars and non-scientific articles show that Pb-As was used to control foliage and fruit feeding lepidopteran larvae and Codling Moth. The Codling Moth was introduced in Vernon, B.C. in 1916 and spread to all fruit growing areas by 1930 (88).

The number of spray applications depended on the fruit crop, pest problem and grower practices. The sprays were applied according to tree density in the orchard using hand held spray guns. For mature apple trees positioned 7.6 m x 7.6 m (25 x 25 ft.) approximately 11 200 L/ha was required (1000 gal/acre).

6.4 Pb-As Spray Application Practices in British Columbia during the Years 1900 - 1946

6.4.1 1900 - 1918. One application of 5 Pb-As/L prior to bloom was recommended for all fruit trees including apples, apricots, cherries, peaches, pears and plums. If Codling Moth was present, 1-3 additional sprays during the summer was required.

6.4.2 1919 - 1930. During this period Codling Moth spread to all fruit growing areas and the initial 5.0 g/L pre-bloom spray required 1-3 post bloom sprays of 3.75 g Pb-As/L.

6.4.3 1930 - 1939. Codling Moth developed resistance to Pb-As and applications increased to 3 to 8 per season. Pb-As residues on apples and pears became so high that export to the United States was denied.

6.4.4. 1940 - 1944. All fruit trees received a pre- and post-bloom Pb-As spray and late summer sprays of cryolite ($Na_3Al F_6$) replaced Pb-As.

6.4.5 1945 - 1946. 4.0 g Pb-As/L was used to control the cherry slug on cherries, peas and plums and DDT replaced Pb-As and cryolite for Codling Moth.

The use of Pb-As sprays decreased from 1950 to 1967, but the trend reversed with the banning of DDT. In British Columbia the use of lead-arsenate sprays was stopped by early 1950 (88).

6.5 Lead in Fertilizers and Fertilizer Production in B.C.

Fertilizers which are made from or contain additives from sewage sludge, smelter slag, or coal fly ash can have significant concentrations of Pb (91). Table 18 shows that fertilizers from concentrated sludge may contain 12 000 to 61 000 ppm lead, those from copper slags may contain 1 400 to 14 900 ppm lead, and coal fly ash 500 to 6 400 ppm lead.

TABLE 18 SOME FERTILIZERS CONTAINING HIGH LEVELS OF LEAD (SWAINE 1962) (91)

Fertilizer	Pb Level (ppm)
Ammonium sulfate	50 - 200
Cal-nitro	300*
Calurea	800*
Phosphate rock	100*
Colloidal phosphate	300*
Apatite	10 - 500
Apatite (enriched chemically)	>1 000
Carbonate-fluoroapatite	100 - 500
Bone meal	50 - 500
K and Na salt deposits	10 - 1 000
Hardwood ash	800*
Ammoniated phosphate	200 - 500
Fresh sewage solids	900*
Digested sludge	1 900
Milorganite	800 - 2 000
Concentrated sludge	12 000 - 61 000
Dried sludge	6 700
Fish scrap	500*
Limestones	1 - 150
Factory lime	0 - 600
Dolomite	0 - 190
Copper slags	1 400 - 14 900
Fly ash	500 - 6 400
Blast furnace dust	650 - 62 900
Chimney soot	340

* Approximate values

Phosphates are used in fertilizers and phosphate ores may be contaminated with lead, zinc and cadmium. Elevated levels of zinc and cadmium were distributed around two fertilizer plants in Idaho in patterns matching the major wind directions. Lead concentrations in soil did not follow the wind patterns and ranged from 27 ± 5 ppm at 0.8 km to 13 ± 1 ppm at 64 km from the plants (61).

There are two major phosphate fertilizer plants in B.C. operated by Cominco Ltd. They are located at Kimberly and Trail, B.C. and are associated with lead/zinc concentrate and base metal production using ores from the Sullivan Mine at Kimberly. Lead in dustfall from the Kimberly plant averaged 4-10 mg/(m^2 month) (99). Soil samples from various depths below the organic top layer had lead concentrations ranging from 20 to 120 ppm.

The organic layer concentrations were 500 to 1 200 ppm indicating low mobility and appeared to reach a maximum 1 500 m from the fertilizer plant (99).

Figure 24 shows the location of the plant, Figure 25 shows the variation in concentrations of lead in soil with distance from the source (B.C. Ministry of Environment in 1976).

6.6 Lead Uptake in Food Crops Grown in Lead Contaminated Soils

The degree of atmospheric pollution, soil pH, organic content and availability of lead in soil are factors that determine plant uptake (70). Lead uptake by plants grown in Fraser Valley agricultural soil was measured by spiking soil samples with variable amounts of $PbCl_2$. It was found that of the seven test crops of leaf lettuce, spinach leaves, radishes, carrots, broccoli, cauliflower and oats the first four showed markedly higher lead accumulation (70).

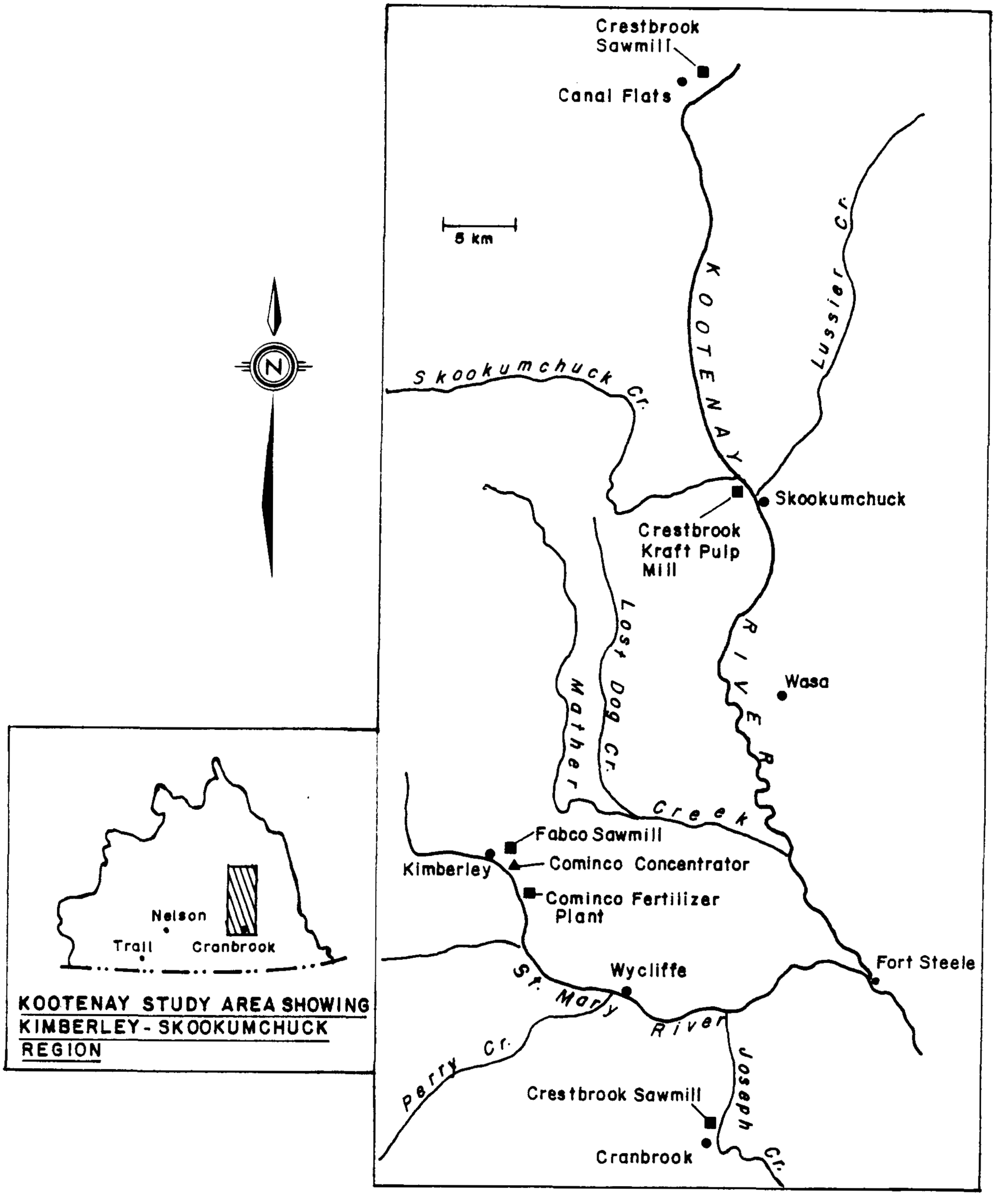

FIGURE 24 LOCATION OF MAJOR AIR EMISSION SOURCES FROM THE KIMBERLEY - SKOOKUMCHUCK REGION (102)

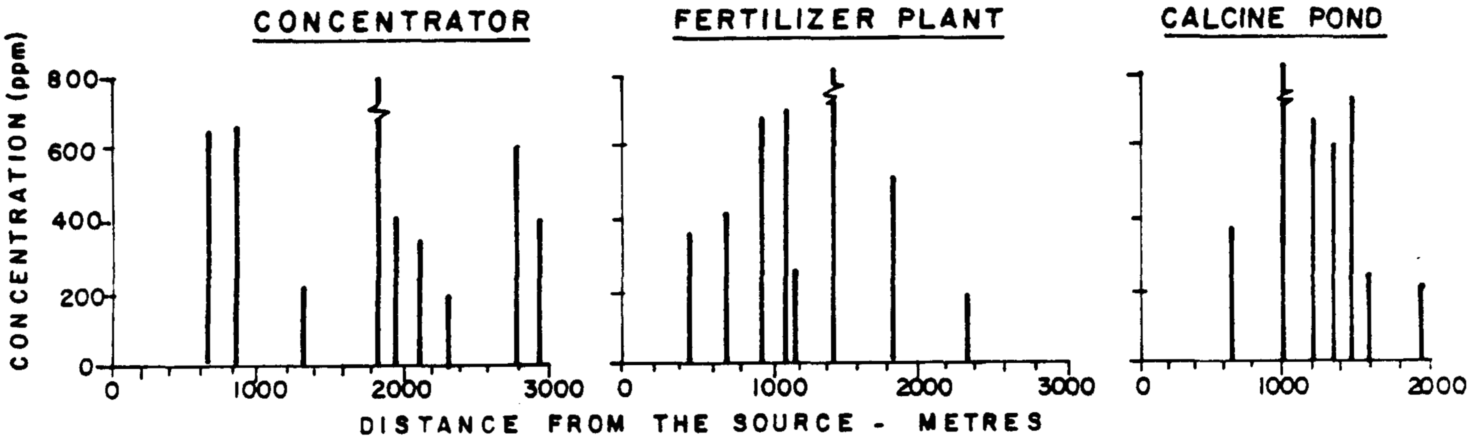

FIGURE 25 CONCENTRATIONS OF LEAD IN SOIL AS A FUNCTION OF DISTANCE FROM THE SOURCE, KIMBERLEY, B.C. (51)

In general the root portions of plants absorbed and retained greater amounts of lead than stems and leaves. Oats had minimal concentrations in the stem but higher concentrations in the leaves and husks.

At concentrations of 200 mg Pb/Kg soil the lead content ranged from 3.0 mg/kg in lettuce leaves to 241 mg/kg in carrot roots. At 1 000 mg Pb/kg soil lead content ranged from 4.9 mg/kg in oat grains to 867.7 mg/kg in lettuce roots (Table 19).

"Since excessive dietary intake of lead is undesirable, growth of lead responsive crops in contaminated soil should be avoided" (70).

TABLE 19 LEAD IN VARIOUS PARTS OF SEVEN EDIBLE PLANTS AT THREE RATES OF SOIL CONTAMINATION (70)

CROP	PLANT PART	PLANT Pb (mg/kg)		
		CONTROL	200 mg Pb/kg	1000 mg Pb/kg
Leaf lettuce	leaves	2.5 a*	3.0 a	54.2 b
	roots	5.8 a	84.5 b	867.7 c
Spinach	leaves	0.7 a	7.9 b	39.2 c
	roots	4.7 a	73.3 a	unavailable
Broccoli	leaves	7.2 a	8.4 a	18.4 b
	roots	6.5 a	83.0 a	745.6 b
Cauliflower	leaves	5.3 a	6.3 a	11.8 b
	roots	2.5 a	55.1 b	532.2 c
Oats	grains	3.2 a	4.4 a	4.9 a
	husks	11.1 a	11.8 a	16.4 a
	leaves	6.0 a	6.8 a	20.1 a
	stalks	1.6 a	2.5 a	9.2 a
	roots	4.5 a	82.0 a	396.6 b
Radish	tops	3.7 a	9.9 a	14.3 a
	tubers	6.3 a	7.0 a	44.6 b
Carrot	tops	2.3 a	8.0 b	17.6 c
	tubers	1.9 a	5.3 a	41.0 b
	roots	8.9 a	241.7 b	561.4 c

* Means, within a row of means, followed by the same letter do not differ significantly at the 5% level

7.0 LEAD IN PAINT

In the late 1950's and 1960's doctors in the U.S.A. began finding an increasing number of children between the ages of 1 and 3 years old with clinical symptoms of lead poisoning. In certain ghetto areas up to 8% of the children were found to suffer from some form of lead poisoning (95). The source of the poisoning was found to be leaded paint which children were ingesting. "A child eating a few chips of leaded paint per day could consume up to 100 times the maximum (daily) adult dosage" (of lead) (42). Leaded paint was defined as 1% lead in the dried film by the "Lead Based Paint Poisoning Prevention Act" of the United States.

After June 1977, leaded paint was defined as "paint containing more than 0.06% lead." Legislation restricting the use of leaded paint in Canada became effective January 1, 1976. The dry film lead content was reduced from 18% to 0.5% (82, 120). Paint used in household or public places where children may contact it was restricted to 0.5%. Children's articles such as toys, furniture and utensils must now be produced lead free. Data for the following text can be found in Appendix XV.

7.1 Paint Production in British Columbia

Statistics Canada (109) lists Canadian consumption of paint and related products in 1980 as follows:

Products	Amount of Consumption
Exterior oil base	18 621 m^3
Exterior water	15 289 m^3
Enamel exterior	18 580 m^3
Auto, Industrial Marine	47 498 m^3
Lacquers (pigmented)	9 860 m^3
Primers	20 426 m^3
Shellac	318 m^3
Stains	7 692 m^3
Thinners	38 555 m^3

Paint production is mainly a physical blending process where base ingredients are blended in large vats to a homogenous mixture. The mixtures are then bulked to the proper viscosity, packaged and sold.

Paints may contain one or more pigments. Table 20 lists the typical Industrial and Commercial lead based compounds found in paint.

TABLE 20 LEAD BASED PAINT ADDITIVES AND THEIR USES

COMPOUND	USE
Lead Chloride	Yellow pigment
Tetra phenyl Lead	Marine antifouling paint
Lead 2-Ethylhexanoate	Paint drier
Lead Acetylacetonate	Varnish and ink drier
Lead Napthenate	Paint and varnish drier
Lead Resinate	Paint and varnish drier
Lead Sterate	Paint and varnish drier
Lead Tallate	Paint and varnish drier
Lead Silica Chromate	Anti-corrosive pigment
Lead Monosilicate	Enamels
Tribasic Lead Silicate	Exterior paint pigment
Red Lead (Pb_3O_4)	Pigment and primer for steel
Lead Antimonate	Pigment and primer for steel
Lead Carbonate	Pigment and primer for steel
Lead Oleate	Paint, varnish and lacquer drier
Lead Borate	Paint, varnish and lacquer drier
Lead Linoleate	Paint, varnish and lacquer drier
Lead Molybdate	Orange pigments
Lead Thiocyanate	Dying
Lead Tumptate	Pigment
Lead Chromate	Pigment (green, yellow, orange)
Lead Bisilicate	Ceramic glaze
White Lead	Paint, ceramic, lubricant
Basic Lead Sulfate	Paint and rubber pigment
Lead/Zinc Oxide	Pigment

A recent survey determined that all paint production facilities in the Pacific Region were located in the Lower Mainland and Greater Victoria areas (170). The survey identified five types of firms and they include:

1) Latex and alkyd base manufacturers
2) Pigment and additive importers and distributors
3) Wholesale warehouse paint distributors
4) Paint and coatings manufacturers
5) Retail sales distributors

In total, 24 firms were primarily involved with the manufacture of paints and coatings and 19 firms were primarily involved in operating distribution warehouses which account for almost 100% of the quantity of coating used in B.C.

Most additives and all pigments are imported into British Columbia and the distributors store these materials in tank farms which may be specifically designed for such products (as in the case of liquids) or in general multi-product warehouse complexes (as for pigments) (170).

The major sources of lead in paints are from lead based pigments, film driers and contaminated additives.

"**Lead Based Pigments**. Basic lead silicate (or basic lead silica chromate) is a synthetic inorganic pigment with the chemical formula $PbO:CrO_3:SiO_2$ (3). This pigment has a dull orange colour with low tinting power and is used in primers and protective coatings for steelworks. The estimated consumption is 18 000 kg/yr in B.C. and the toxic components are PbO and CrO_3. White lead has the chemical formula $2PbCO_3Pb(OH)_2$ and is synthetically produced. The basic pH of the pigment causes it to react with oleoresinous material such as oils found in wood. Consumption is estimated at 3 000 kg/yr and the toxic component is lead. Red lead litharge has the formula PbO_2 2PbO and is synthetically produced (3). It is basic and will react with oleophinic oils such as linseed oil in a saponification reaction producing lead soap. The higher the PbO content the greater the tendency to cause thickening during storage. The main use is in protective primers for metal works. Lead is the toxic component of the pigment and consumption is estimated at 13 500 kg/yr. (170).

"**Driers**. Driers are metallic salts that aid in the crosslinking of unsaturated bonds in oleoresinous binders by acting as oxidation agents. They include calcium, cobalt, copper, lead, manganese, zinc and zirconium napthenates.

Lead napthenate is formulated at 24% to 36% lead metal and acts as a polymerization catalyst for drying oleoresinous paints and consumption is 44 000 kg/yr. Calcium possesses similar film drying properties as lead and enhances the performance of lead when used in combination (3). Calcium driers are used in 4 to 6% metal concentrations and are being used to replace lead for manufacture of lead free paints. Zirconium is used as a lead substitute and is sold in 6 to 18% metal concentrations.

The concentration of driers in the paint blend is critical and ranges from 0.025% for cobalt to 0.5% for lead, based on the solid content of the binder (3). Solid content in a paint blend may be very low for stains to 55 - 60% for some paints (16). (170)

It is not likely that lead will be totally eliminated from paint as other raw materials used in the formulation of coatings are contaminated with lead (Table 21).

TABLE 21 TRACE CONTAMINANTS OF LEAD IN RAW MATERIALS USED IN PAINT PRODUCTION (22)

MATERIAL	REPORTED LEAD CONTAMINATION PPM(BY WEIGHT)	MATERIALS	REPORTED LEAD CONTAMINATION PPM (BY WEIGHT)
Titanium Dioxide	60	Talcs	5 -- 10
Zinc Oxide	700	Aluminum, Calcium, and Zinc Stearates	5 -- 10
Calcium Sulphate	5 -- 10	Mica	5 -- 10
Silica Sand	5 -- 10	Calcium Carbonate	5 -- 10
Fumed Silicates	5 -- 10	Iron Oxides	0 -- 15
Clays	10 -- 50	Organic Yellow Pigment	10 -- 30
Bentonites	5 -- 10		

Lead can be lost to the environment during paint production by: ventilation of the pigment blenders at the plant sites; residuals on bags and cans disposed to waste receptacles; solidified paint skins and sludges disposed of landfill; and supernatant discharged to municipal sewer from the sludge solidification process. At some locations, septic systems were used to dispose of supernatant from the sludge solidification resulting in ground contamination with heavy metals including lead. Analysis of various waste products gave the following lead concentration ranges:

1) Latex effluent	0.22 - 1.02 mg/L
2) Combined effluent	0.04 mg/L
3) Latex sludge	303 ug/g
4) Spent solvent sludge	3330 - 3630 ug/g
5) Paint skins	3560 - 5610 ug/g
6) Baghouse dust	869 - 872 ug/g
7) Latex sludge leachate	43 ug/g
8) Spent solvent sludge leachate	35.9 ug/g
9) Paint skins sludge leachate	25.8 ug/g
10) Baghouse dust leachate	0.8 ug/g

Flaking of paint or deliberate abrasion for the purpose of recoating structures such as buildings, bridges, boats and heavy machinery are sources of release. Another source is the abrasion of leaded yellow centerline paint from asphalt by vehicular traffic.

High lead concentrations in sediment/sludge deposits at Laurel Point in Victoria Harbour were attributed to waste disposed by the Bapco Paint/Resin plant. Concentrations ranged from 14 000 ug/g to 30 300 ug/g. The shoreline has been re-developed and Bapco has arranged for removal and disposal of the material deposited in the harbour.

Soil samples from the pentachlorophenol spill site at the Cloverdale Paint plant in Surrey averaged 73 ± 54 ug Pb/g. Samples in the adjacent surroundings average 16.6 ± 16 ug/g.

A soil sample taken at the plant boundary of Ames Paint in Victoria tested at 785 ug/g.

Soil samples from 5 reinforced polyester resin fabricators in Kelowna averaged 415.4 ± 181 ug/g lead. The lead is believed to be used as pigments in spray applied gelcoat resins with overspray and dusts produced by trim grinding acting as sources of release. Outside the plant boundaries, curbside dusts and storm drain sediment show a progressive decline from 440 ug/g at the nearest manhole to 209 ug/g in the gutter downhill, 87 ug/g at the storm sewer discharge to a creek and 13 ug/g 50 m downstream of the outfall. There are no other potential sources of lead above or below this area. Marine sediment samples were taken adjacent to boat moorages and drydock facilities in Victoria and Esquimalt harbours. The Victoria samples averaged 277.1 ± 185.2 ug/g with a range of 107 - 720 ug/g. The Esquimalt samples averaged 351.4 ± 56 ug/g with a range of 288 ug/g to 420.6 ug/g.

It is suspected that sand blasting, application and leaching of leaded marine paints are the source of the high lead values. A soil and sediment sample taken near the Surrey side of the Patullo Bridge measured 1 480 ug/g Pb and 322 ug/g Pb respectively. The sand blasting of lead based paint from the steel structure of the bridge is the suspected source.

7.2 Lead in Road Centerline Paint

Leaded yellow road paint is difficult to replace with other formulations due to its low cost, superior colour, opacity and durability (102). There are approximately 24 000 km of provincial highways in B.C. in addition to municipal and city roads which require maintenance of paint or new paint (18). The B.C. standard paint contains lead Silico-Chromate at "14% of the 57% of paint solids by mass" (102).

In 1984 the B.C. Department of Highways purchased 567 500 L of leaded yellow centerline paint, 272 400 L of white nonleaded centerline and

83 990 L of nonleaded centerline thinner from B.C. manufacturers for application that year (17).

The exact formulation may vary slightly between manufacturers, however, the estimated quantity of lead Silica chromate used is 174 000 kg. Other pigments used include Lead (basic) Silicate 18 000 kg/yr, Lead White 3 000 kg/yr and red lead letharge 13 500 kg/yr. The quantities of paint purchased for 1984 are normal values and therefore an estimated 64 000 kg of elemental lead is dispersed annually to the roadside environment from road marking paints.

8.0 LEAD IN SOLDER, PLUMBING AND DOMESTIC DRINKING WATER

8.1 Lead in Domestic Water

In 1899, lead piping was found to be the cause of lead poisoning in several towns in the State of Massachusetts. A study of 136 cities in the U.S. found that 71 had used lead piping in their water systems. In 1924 a survey found that 51% of 539 cities in the U.S.A. used lead or lead lined domestic service water mains to some extent. Many of these pipes have never been replaced and are found in areas of older housing (132). Worth et al. reported a study of 54 houses in the Beacon Hill area of Boston where the domestic water in 65% of the houses surveyed exceeded the U.S.A. federal limit of 50 ug Pb/L with some values exceeding 250 ug Pb/L. Samples were drawn from taps at various periods during the day to indicate maximum and minimum contact periods with lead piping. Sampling of household dust and paint were also studied. Table 22 summarizes the results.

TABLE 22 CONCENTRATIONS OF LEAD IN DOMESTIC WATER AFTER VARIOUS PERIODS OF RESIDENCE IN LEADED SUPPLY MAINS TO HOUSES IN THE BOSTON AREA (129)

SOURCE	RANGE OF LEAD CONCENTRATIONS (mg/L)	ug Pb/L*
Running Water	$\leq$ 0.013 - 0.208	208
Standing Water	$\leq$ 0.013 - 1.508	1 508
Composite Water	$\leq$ 0.013 - 0.758	758
Early Morning Water	$\leq$ 0.013 - 1.180	1 108
Dust (mg Pb/g)	0.17 - 99.0	
Maximum	0.90 - 58.0 mg Pb/g	

* Note: The U.S. Federal limit is 50 ug Pb/L

It was found that soft water promotes solution of lead as hard water ions suppress the lead or form impermeable precipitates on the pipe surface (129). Dissolved oxygen and carbon dioxide are corrosive to lead, and chlorides are especially corrosive to new piping (21). The majority of the B.C. population receives soft domestic water supply.

8.2 Lead Piping in B.C. Cities

Cities in B.C. also used lead piping in water service mains (127). The lead pipes were manufactured of pure lead which was soft and malleable. The pipes could easily be bent around corners and required fewer joints. During the 1940's pipes that required more structural rigidity were made of two popular alloys:

1) British Non-Ferrous Metal Research Assoc. Ternary alloy No. 2, containing 98.25% Pb, 0.25% Cd and 1.5% Sn.
2) Tellurium Lead Alloy containing 0.05 to 0.10% tellurium. This alloy allowed a 30% weight reduction due to its superior strength (21).

Lead service pipes were used in the City of Victoria about 40 years ago to convey water to 8 000 to 10 000 homes.

Wong and Birrany (127) collected water samples from 55 homes in Victoria to analyze for lead using atomic absorption spectrophotometry. The tests showed that lead concentrations varied with the volume of water flushed through the system. To determine when maximum concentrations occur, samples were collected in the morning, mid-day and evening and compared with the Federal Limit of 50 ug/Pb/L (127). Sixteen percent of the samples were 25 ug Pb/L or less, 74% were between 25 and 50 ug Pb/L, 5% were between 50 and 100 ug Pb/L and 1% were greater than 100 ug Pb/L. The daily average for nonlead piping systems were all below 25 ug/l.

Taps unused for 24 hours gave concentrations of 130 ug Pb/L at 0.005 L volume flushed and decreased to 7 ug Pb/L at 300 L flushed. Lead in water taken from a tap not used for about six months yielded initial concentrations of 3 000 ug Pb/L for 0.005 L flushed which decreased to 12 ug Pb/L for 200 L flushed.

Lead piping has also been used in houses and water mains in the City of Vancouver. The water mains were initially replaced with copper pipes, however, crystallization and galvanic corrosion in the soil has caused the city water works department to use polyvinyl chloride pipes which are more corrosion resistant (25).

There are no records of the number of Vancouver homes where lead piping was installed, and it is believed that all leaded water mains have been replaced (172). Figure 26 shows a development map of the City of Vancouver with the oldest sections being the ones most likely to contain lead plumbing.

8.3 Lead Contamination of Domestic Water Supplies from Lead Soldered Copper Tubing

The Wong and Birrany study ran tests to show that 50/50, 60/40 and 95/5 tin/lead solder was a source of lead contamination in domestic water supplies. Water was allowed to stagnate for one hour inside a 15.2 m. (50 foot) copper pipe with 20 lead solder joints, and sampled at various flushing volumes as given in Table 23.

TABLE 23 LEAD CONCENTRATION(ppb) IN WATER STAGNANT FOR ONE HOUR IN A NEW SIMULATED HOUSEHOLD COPPER PLUMBING SYSTEM
(50 feet copper tubing joined by 20 soldered joints) (127)

SOLDER (Sn/Pb)	80 L	1200 L	12000 L	25000 L	150000 L
50/50	1 200	150	96	34	9
60/40	1 100	130	49	25	7
95/5	3	2	-	1	-
Silver	2	2	-	1	-
Copper only	1	2	-	1	-

The tests indicated that new joints of 50/50 and 60/40 tin lead solders in copper pipe which are commonly used in household plumbing would produce contaminated water above the 50 ug Pb/L limit for the first 12 000 L - 25 000 L of water usage.

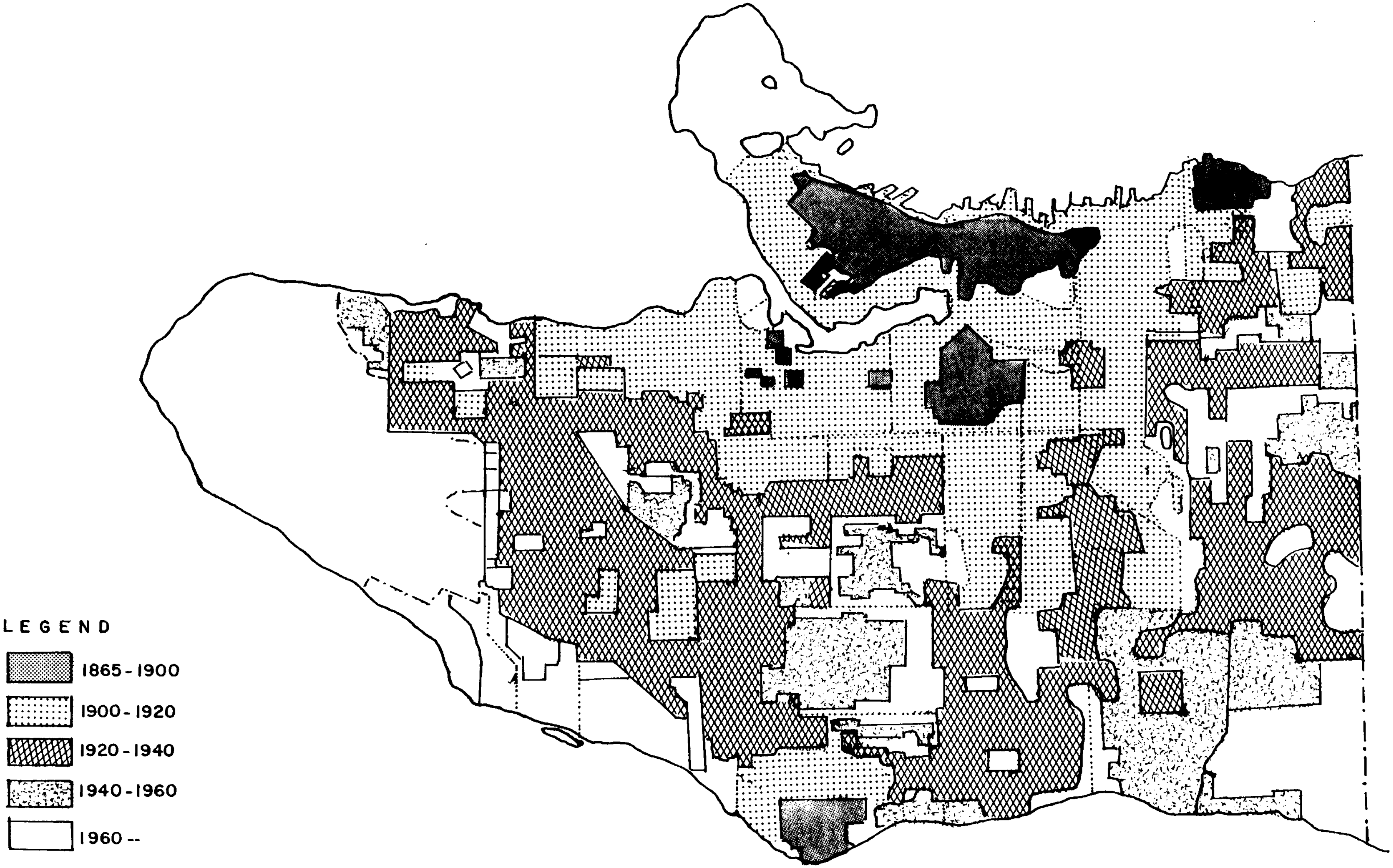

FIGURE 26 SETTLEMENT PATTERNS FOR THE CITY OF VANCOUVER 1865-1960
(Courtesy of the City of Vancouver Planning Department)

The following three recommendations were made:

1) Substitute the tin/lead solder commonly used in house plumbing with a 95/5 tin/lead solder.
2) Flush the plumbing systems in new homes with water equivalent to one years usage.
3) Do not use the first two litres of water from taps for human consumption if stagnant for a day (127).

95/5 tin/lead solder is brittle, and in practice is more difficult to use and tends to fail in service (76). Plumbing contractors would prefer if a higher percentage solder was available such as 75/25 Pb/Sn which would wear better. Lead/tin solders of 50/50 and 40/60 ratios are currently used in the housing industry.

8.4 Lead Sheeting in Plumbing Fixtures

Prior to 1960 lead sheet was used as flashing to make water proof floors under baths, showers, kitchens and laundries. Lead lined shower stall floors were used in B.C. up till 1978 after which they have been replaced by moulded plastic/fiberglass (19, 76). Lead seals in cast iron drain pipes were discontinued in B.C. around 1968 when rubber seals with steel clamps were introduced (76). Previously plumbers connected the iron pipes by stuffing the joint with felt or a lead wool and then pouring molten lead to seal the joint (19).

Lead stops for toilets are currently used only where building codes require cast iron drain pipes for fire regulations. In most domestic construction plastic ABS piping and seals are used (76).

Lead roof flashings which form the seal between a domestic drain vent and the roof are also being replaced by plastics.

8.5 Lead Solder Used for Hobby Work

Lead solder is used by custom designers and hobbyists fabricating stained glass windows and Tiffany lamps. Lead poisoning can occur during the lead soldering of joints if proper ventilation of the work area is not maintained. Chronic lead poisoning occurs in isolated cases in B.C. When poisoning is suggested or diagnosed the case is referred to the Drug and Poison Information Center at St. Paul's Hospital Vancouver. Several poisonings have occurred including one of a young girl who suffered lead poisoning from fumes generated during the construction of Tiffany Lamps in the household basement. Her blood level was 200 ug Pb/100 ml, more than ten times the acceptable level.

9.0 LEAD IN MUNICIPAL SEWAGE TREATMENT PLANTS AND LEACHATES FROM LANDFILLS

Lead in landfills leachate and groundwater has been monitored at various lower mainland locations in relation to the Fraser River estuary studies. There are fourteen major landfills which have been or are presently operational in the Lower Mainland area. No data on landfills outside this area is included in the appendices. Landfills in the GVRD area are rapidly being filled and municipal incineration and recycling are handling greater volumes of waste. The two major landfills still in operation are the Richmond and the Burns Bog landfill. A survey of Burns Bog landfill by Atwater in 1979 monitored 12 groundwater and surface water wells. Concentrations ranged from less than the detectable to 0.30 mg/L (136). Richmond landfill leachate/drainage ditches had lead concentrations ranging from <0.02 to 1.01 mg/L, and benthic sediments were from 0.0 to 100 ug/L. Abandoned landfill leachates ranged from less than detectable to 0.15 mg/L. Daily loadings are generally low due to low flows. See Appendix XIII for sewage treatment plant data and Appendix XIV for landfill data.

9.1 Lead in Sewage Treatment Plant Effluents

The Pollution Control Objectives for Municipal Type Waste Discharges in British Columbia list two levels of water quality for lead. They are Level AA = 0.05 mg/L maximum, and Level BB = 0.5 mg/L maximum. Seventy-one percent of the facilities met Level AA guidelines. The Yukon Territory does not have similar guidelines.

These outfalls are monitored under Provincial Waste Management Branch Permits and the municipalities submit monthly or quarterly sampling reports. The major outfalls are located in the Lower Mainland and Southern Vancouver Island. They include Annacis Island STP, Iona Island STP, Lulu Island STP, Lions Gate STP, Clover Point Outfall in Victoria and Macaulay Point outfall in Esquimalt. Other outfalls that show significant lead loading (above 100 g/d) are the Kamloops and Prince George outfalls.

The annual averages indicate that the lead loading to the lower Fraser River downstream of Patullo Bridge and Estuary has decreased from approximately 48 700 g/d during 1975 to 1980 to 26 801 g/d for 1980 to 1985. Lead loading through sludge production averages 17 064 g/d (Table 25). The sludges are discharged directly to outfalls, as fly ash to landfill and as inorganic fertilizer supplements.

TABLE 24 SEWAGE EFFLUENT, SLUDGE AND TOTAL LEAD LOADINGS FROM THE FOUR MAJOR SEWAGE TREATMENT PLANTS IN THE B.C. LOWER MAINLAND 1980 - 1985[1]

STP	EFFLUENT PRODUCTION (m^3/d)	SLUDGE PRODUCTION (m^3/d)	LEAD LOADING FROM EFFLUENT (g/d)	LEAD LOADING FROM SLUDGE (g/d)
Iona Island	444 174	635	11 021	9 337
Annacis Island	265 750	379	12 728	5 586
Lulu Island (3)	34 182	49	2 096	718
Lions Gate (4)	317 800	98	956	1 423
TOTAL	1 061 906	1 161	26 801	17 064

[1] All values based on arithmetic means
[2] All sludge characteristics assumed similar to those produced at Iona Island STP
[3] Sludge incinerated and ash disposed to landfill
[4] Sludge discharged directly through diffuser to First Narrows of Burrard Inlet

9.1.1 <u>Iona Island STP</u>.

The effluent flow rate from Iona Island STP has averaged 444 174 ± 27 760 m^3/d from 1975 to 1985 (based on data reported to EQUIS). The effluent flows through a chlorine contact tank and discharges to the Fraser River Estuary foreshore through an outfall channel. lead loadings averages 11 000 g/d.

The average effluent total lead concentration from 1975 to 1980 was 0.085 mg/L which decreased to 0.026 mg/L for 1981 to 1985. Sludges with 3.11% solids are produced at a rate of 454 to 635 m^3/day in digesters and are discharged to lagoons that have several years capacity. Groundwater test wells at various lagoon locations were sampled and all results were less than 0.05 mg/L total lead. The supernatant from the settled sludge is recycled through the plant. Lead removed via sludge averages 6 681 to 9 337 g/d. After a lagoon is full it is allowed to drain and the solids are allowed to dry. The dry sludges are stockpiled for processing into fertilizers. Lead concentration in the sludges after lagooning average 670 ppm. After dewatering and stockpiling the concentration decreases to 518 ppm. The sludge is then sterilized in a rotary kiln and blended with inorganic fertilizer. The maximum allowable fertilizer lead content is 500 ppm total lead which is accomplished by dilution of the sludges with other materials that comprise the finished blend.

9.1.2 Annacis Island STP. The effluent flow from the Annacis STP has averaged 265 750 ± 28 253 m^3/d from 1976 to 1985. The effluent discharges from the south side of Annacis Island through a diffuser to the south arm of the Fraser River. The average effluent total lead concentration for 1975-1979 was 0.026 ± 0.004 mg/L, which increased to 0.052 ± 0.03 mg/L during 1980-1985.

Effluent lead loading averaged 5 920 ± 1 035 g/d from 1976 to 1979 and 12 728 ± 6 785 g/d from 1980 to 1985. The standard deviation shows that there can be considerable variation in loading due to flow and concentration fluctuations during the latter period. Effluent flows appear to have increased from an average of 227 000 m^3/d prior to 1980 to 283 000 m^3/d in 1985.

Sludge is lagooned similar to the Iona process. Daily production is estimated at 379 m^3/d with 5 586 g/d of total lead removed.

9.1.3 Lulu Island STP. The effluent flow from Lulu Island STP has averaged 34 182 ± 2 569 m^3/d from 1975-1985. Discharge is through a diffuser to the South Arm of the Fraser River. Daily average total lead loading from the effluent decreased from 7 758 g/d in 1975 to 3 496 ± 34 g/d for the period 1976 to 1982. A further decline to 2 096 ± 200 g/d occurred from 1983 to 1985. Flows appear to have remained relatively constant while concentrations in effluent decreased from an average 0.108 mg/L (1976-1982) to 0.59 mg/L (1983-1985) (Attributed to improved industrial waste water control). Screenings from the influent are buried in landfill. Sludge is incinerated and the ash is also used as landfill.

9.1.4. Lions Gate STP. The average flow from Lions Gate STP was 67 700 ± 7 000 m^3/d for the period 1979-1985. The effluent discharges through a diffuser to the First Narrows of Burrard Inlet. Total lead concentrations averaged 0.014 ± 0.007 mg/L yielding average loadings of 956 ± 481 g/d for the same period. The collection basin has been a stable mix of residential and commercial areas which is reflected in the maximum monitored concentration of 0.05 mg/L total lead. Sludge production is estimated at 98 m^3/d and is discharged through the diffuser directly to second narrows during suitable tidal flows.

9.1.5 Capital Regional District. Lead in municipal effluent data for the CRD is very limited. The two major outfalls are the Clover Point and Macaulay Point outfalls. The effluents are screened and then discharged directly to marine waters.

Macaulay Point Outfall. The Macaulay Point Marine outfall south of Esquimalt is the largest volume outfall in the CRD at 18 150 m^3/d. One sample at 0.01 mg/L total lead was recorded on the EQUIS Data System in December 1979. This yields a loading estimate of 181 g/d. Goyette et al. reported a surface sediment survey, sampling from the outfall at progressively distal arcs over a period from June to November 1979 (213). A mean surface sediment concentration of 36.8 mg/kg (12.2-69.2 mg/kg) occurred within 400 m of the outfall. Background levels were reached within 600 to 2 000 m of the outfall. Sediment concentrations were higher during periods of high surface runoff.

Clover Point Outfall. The Clover Point Outfall in Victoria has an average flow of 1 556 m^3/day. A single measurement of 0.023 mg/L reported on EQUIS in December 1979 indicates a possible loading of 35.8 g/d. More data would be required to make any conclusions, however, the values are typical for screened domestic sewage.

9.1.6 **Kamloops STP.** The Kamloops lagoon outfall averaged 20 000 m^3/d from 1976 to 1982. The total lead concentrations average 0.021 ± 0.03 mg/L with daily loadings averaging 414 ± 496 g/d. Concentrations appear to be increasing from 1980 through 1982. The source of this lead has not been determined, however, National Air Pollution Stations (NAPS) have measured higher than average, mean, air lead concentrations. These levels have persisted relatively unchanged with the closure of the Afton Mines Copper smelter outside the city. One suspected source may be a higher than average consumption of leaded gasoline, however, this has not been thoroughly researched.

Sludge is produced in two anaerobic settling basins in a recently reconstructed treatment system. The basins have an expected capacity of 10 to 15 years. Sludge generated in the old basins was used as road bed fill on the plant site.

9.1.7 **Prince Rupert STP.** The EQUIS data regarding the Prince Rupert Municipal Outfalls are limited to one set of samples taken in March 1981, and no flows were recorded. The effluent discharges untreated to marine waters. Subtidal, surface sediment samples taken near the marine outfall ranged from 9.39 to 365.5 mg/kg. Data from municipal effluents is limited and most appear to meet the Waste Management Branch Guidelines.

10.0 LEAD IN STORM WATER RUNOFF

Sources of lead contamination to storm water are:

a) Particulate from lead process industries including:

- i) smelters
- ii) battery plants
- iii) coal burning

b) Automobile exhausts and road paints

c) Corrosion products from building (roofing) materials

d) Process and domestic wastes which are incorrectly connected to storm sewers (Data for this section is in Appendix XVI)

The roadside dust and atmospheric fallout collected along roadsides is washed into storm drains during storm events and discharged to receiving waters. In most lower mainland and coastal regions of British Columbia the storm drains flow even during periods of prolonged dry weather. This was observed in the Victoria and Vancouver area (9).

The initial loading of contaminants in the early stages of a storm event can produce a peak load to the receiving environment for short periods with high concentrations of contaminants and high Biochemical, or Chemical Oxygen Demand, decreasing dissolved oxygen.

Many storm sewers in the lower mainland are affected by tidal action. The variation in concentration of heavy metals during the tidal flush of storm sewers in the Fraser River Estuary was monitored over 3 1/2 hour period on August 3, 1978 by the B.C. Ministry of Environment. The concentration of lead rose above the detectable limit of 0.001 mg/L to 0.003 mg/L during the first thirty minutes of the flow and then fell back below the detectable limit.

A test designed to measure the surface concentrations vs the subsurface concentrations of lead in storm water showed that surface concentrations were significantly higher. Values ranged from 0.003 to 0.300 mg/L at the surface and <0.001 to 0.07 mg/L at subsurface samplings. An average estimated loading of lead in the lower mainland by storm water runoff is 27.4 kg/d (9).

Land use affects the concentration of lead in storm water. Clark et al. (9) broke down the average loadings as follows:

Residential	0.19 mg/L
Landfill	0.015 mg/L
Industrial	0.026 mg/L
Commercial	0.323 mg/L
Agricultural	0.003 mg/L

The loading values were calculated using an estimated average dry weather flow of 365 000 m^3/day. The high values in commercial areas is suspected to be due to improper disposal of wastes and increased automotive traffic.

The highest concentrations of total lead measured in storm water was at the Willingdon Street discharge to Still Creek in Burnaby. The values averaged 0.654 ± 1.56 mg Pb/L total lead with a range of 0.047 to 4.8 mg Pb/L.

11.0 LEAD IN CERAMIC, ALUMINUM, TIN AND PEWTER WARE USED AS FOOD CONTAINERS

The Hazardous Products Act defines ceramic containers as "products that are:

(a) for use or that may be used in storing, preparing or serving any food defined in the Food and Drugs Act; and
(b) made in whole or in part of ceramics having a glaze that contains lead or cadmium (56)."

A product would be considered safe for public use if it leaches less than 7 ppm Pb under specified test conditions (57).

Glazed containers such as china, pottery, stoneware and enamel ware may constitute a source of lead contamination of the foods stored in them. The production of ceramic and tin containers may be a source of lead to the environment. The most durable ceramic glazes are lead-silicates. Lead bisilicate is a relatively insoluble glaze but can become soluble if improperly formulated. Acid media such as fruit juice and tomatoes can leach lead from improperly glazed articles (82).

11.1 Canadian Deaths Due to Lead Poisoning from Ceramics

Two young boys in Montreal who had been drinking fruit juice that had been stored for 3 hours in a ceramic pitcher suffered symptoms of lead poisoning. One of the boys died from poisoning, the other recovered after extensive treatment (59). The pitcher was made by a potter from Cape Breton and the lead that leached from it measured 185 ppm.

In British Columbia, ceramic ware seized by the Consumer and Corporate Affairs from store shelves have leached up to several thousand parts per million lead (124). Recent seizures (1983) of ceramic dishes leached 34.3 to 315 parts per million lead. The most common sources of leachable lead glazes on ceramics are from Pacific Rim countries and China. Use of leaded glazes and improper firing are the major cause of poor glaze formation (48).

Similar problems were found in ceramic ware from Japan and Mexico. As trade restrictions are enforced these countries are co-operating by enforcing production criteria. Consumer and Corporate affairs exercises control by making periodic random inspections of store shelves and warehouses. Cases have occurred where store keepers removed articles off the shelves and slowly re-introduce stock in small quantities so as to sell it off and avoid losses (48). Major ceramic articles such as bathroom fixtures are manufactured using high fire glazes which are zirconium based.

11.2 Lead in Tin Can Food Containers

Settle and Patterson (176) of California Institute of Technology found that during the storage, butchering, and canning of tuna the lead content increased 1000 times over the level when fish were caught. Packaging of tuna in soldered cans increased the lead content 50 times over tuna packed in non-soldered containers. The scientists stated that over 50% of the lead in American diets originates from lead soldered cans and that these containers should be eliminated as they pose a serious health hazard.

Tin cans with lead solder seals are manufactured in Vancouver and Kelowna, B.C. The containers are used for a wide range of products and only a small quantity of lead is used.

11.3 Lead in Wine Bottle Caps

The average metal wine bottle cap is 96.8% lead and several percent tin. It has been shown that lead caps can cause an increased lead content in wine (122).

Lead carbonate hydroxide is a white powdery substance frequently found on corroded wine bottle caps, the cork and the mouth of the bottle. The solubility of lead carbonate is 1.75 mg Pb/L (pure water @ 18°C) and it was found that pouring the wine from the bottles with contaminated edges increased the lead content of the wine 4 to 7 times. Many wines are stored so as to keep the cork moist which aids in the corrosion process. Canadian consumer lead levels in wine should not exceed 0.50 mg Pb/L (122). There was no documented evidence of lead contaminated wines in British Columbia.

11.4 Lead in Pewter Ware and Food Utensils

Pewter is a metal alloy made of combinations of two or more of the following metals; lead, antimony, tin and copper. It is widely used as a metal for food serving utensils and there are no federal guidelines or restrictions on the sale of Pewter articles to the public (21).

The lead in pewter is considered safe and would only present a hazard if a residue of lead oxide or lead salt were left on the product after manufacture (21). Possible health hazards exist in pewter manufacture if the raw materials (especially lead and antimony) are not handled under proper safety precautions (21).

In British Columbia, pewter souvenir ware is manufactured at Port Alberni. Wastes from this operation are considered acceptable for disposal in a municipal landfill.

12.0 MISCELLANEOUS INDUSTRIAL USES OF LEAD

There is a wide variety of miscellaneous uses of lead. These are outlined in the following sections (Data is listed in Appendices XVII - XIX).

12.1 Lead in Lubricants

Lead oleate is used in high pressure lubrication where it can withstand film penetration pressures five to six times above the highest grade mineral oils. The high film rupture strength allows the lead oleate to be blended with low viscosity oils for gear and chain speed reducers, and with high viscosity oils in automobile and industrial applications (19).

Metal iodides such as PbI_2 are used as solid lubricants. Lubricants that contain Pb, Zn and Cd iodides may be replaced by products containing molybdenum which are dispersions of solid lubricants in organic resin/solvent systems (118). New lubricating and cleaning oils contain varying amounts of lead for example, Mobil Oil 46-SAE-90 Gear Oil contains 9279 ppm lead. Mobil Oil Special SAE 40 contains 4.6 ppm level (94).

12.2 Plastics Manufacture

The manufacture of polyvinyl chloride resin (PVC) involves the addition of lead stearate. The blood lead concentrations of workers at PVC resin manufacturing plants has been measured to range from 12 - 57 ug/100 ml (91). There is no PVC resin manufacturing in the Pacific and Yukon region and no lead additives are used in the thermoplastic extrusion industry in B.C. (171) Samples of PVC resin powder blends, pipe trimmings and cyclone dusts had lead concentrations from nondetectable to 16 ug Pb/g. Samples of plant sludges, cooling water sludge discharges to storm sewer and receiving water sediments near the plants averaged 217 ± 455 ug Pb/g with a range of 6.0 to 1 700 ug Pb/g (214).

The sources of lead are attributed to other industry using the same sewer systems.

Rubber based shields for protection from cosmic rays, radiation, microwave, and noise are prepared by vulcanizing rubbers of molecular weights ranging from 2 000 to 200 000. Additives include lead compounds, blowing, vulcanizing and anti-oxidizing agents. An estimated 9 000 kg of lead naphthenates are used in resin and rubber manufacturer in B.C. (171).

A typical rubber composition would be:

PbO	660 ppm
ZnO	5 ppm
MgO	3 ppm
Plasticiser	40 ppm
Vulcanizing Agent	4 ppm
Anti Oxidant	5 ppm
Blowing Agent	8 ppm
Santogard	0.1 ppm

which is rolled into sheets 0.005 m thick.

Plastic additives may include the following chemicals:

a) Lead Phosphate	-	Plastics stabilizer
b) Lead 2-Ethylhexanoate	-	Plasticiser
c) Lead Stearate	-	Vinyl Stabilizer
d) White Lead	-	Plasticisers
e) Red Lead	-	Rubber pigment
f) Lead Sulphate	-	Rubber additive (vulcaniser)

12.3 Match Manufacturing

Lead Thiosulphate is used in safety matches where the lead acts as a burn controller and forms a stable metallic ash which does not fall off the stick (19). This chemical was not included in the raw materials used in match manufacture in the Pacific Region.

12.4 Shipbuilding

Shipbuilding uses lead as keel ballast in sail boats, solder for joints and plumbing, and as lining in walls and floors for rooms such as bulk heads or cold storage of corrosives where moisture could accumulate (19).

12.5 Manufacture of Leaded Glass

Lead bonded in the glass matrix is considered safe, however, lead levels in the glass manufacturing areas have been measured at 2.5 to 3.3 ug/m^3 and up to 79 ug/m^3 in the grinding and polishing areas. The airborne particles are generally less than 1.0 um (91). There is no lead crystal production in the Pacific region.

12.6 X-ray Insulation and Sound Proofing

Lead sheet is used in the lining of walls and equipment for x-ray analysis. X-ray rooms must be lead lined and the lead joints sealed to prevent leakage. The degree of protection depends on the thickness of the sheet (19). No significant lead emissions after the initial installation have been recorded.

12.7 Ornamental Objects

Lead is easily cast in shaped moulds and has been used extensively in garden moulds and in ornamental construction built prior to 1950 (19).

12.8 Fusible Alloys

Fusible alloys are commonly two to four component systems of lead, tin, bismuth and cadmium. For lower melting points mercury (60°C fuse) and indium and gallium (0°C fuse) can be used. The principal use of these alloys has been for safety equipment in automatic sprinkler systems, alarms and releases for fire doors. A typical alloy may consist of 42% Pb, 42% Bi, 16% Sn by weight (19).

12.9 Lead Foil and Collapsible Tubing

In the 1930's tin foil was used in tubes to contain toothpaste, paint, salves, ointments, grease, glue and shoe polish. During World War II a tin shortage resulted in the use of lead/tin bonded foils, aluminum, zinc and silver/lead alloy foils. The lead tube replaced tin toothpaste tubes and wax and resinous coatings were developed to protect against contamination of the contents (19). Modern polymer materials have replaced a majority of these materials.

12.10 Automobile Repair

Mechanics involved in auto repair are exposed to various sources of lead contamination. Crank case oil contains approximately 25% of the lead present in leaded gasoline. Blood lead levels of mechanics tested for lead ranged from 50 to 125 ug/100 ml (91).

Lead solder is used extensively in the repairing of automobile radiators. This is a high hazard occupation for workers inhaling the fumes.

12.11 Plating Industry

The following lead compounds are used in the plating industry.

a) Lead Fluorosilicate - Electrolyte in plating glass
b) Lead Iodide - Bronzing
c) Lead Thiosulphate - Mirror Deposit
d) Lead Bisilicate - Reflective signs

The quantities used in this region have not been determined.

12.12 Lead in Pharmaceuticals

In May of 1983, the Health Protection Branch of Health and Welfare Canada, Ottawa, released a warning to the Poison Control Centers concerning lead in a Mexican digestive product. The product has been recalled in Texas where it had been marketed under trade names such as Breta, Azarcon, Rueda, Coral Alcaron, Liga or Maria Luisa. The yellow to orange powder was found to be almost pure lead oxide (58). Similar products have not been reported in the Pacific Region.

13.0 LEAD USE IN AMMUNITION

Firing ranges are used by law enforcement agencies for firearms training and by the public for recreational use. Indoor facilities require proper ventilation to maintain safe levels of combustion products and minimize exposure to patrons. Gunpowder combustion produces nitrogen, hydrogen, CO_2, NO and organo-nitrates. Lead oxide fumes are produced by combustion of lead in primer compounds, friction generated in the gun barrel and fragmentation of the bullet on impact with the target or backstop (49).

Elevated blood lead levels of instructors working in firing ranges have been documented by Fishbein et al. (49) where the average was 64.5 ug/100 ml which is more than double the national average.

Two pathways of lead to the environment from indoor ranges are via air ventilation exhaust and dust on clothing. Lead concentrations in air at three U.S. indoor ranges reached more than 4.5 times the OSHA regulations with averages ranging from 210 to 3 750 ug Pb/m^3 (49). The environmental impact of such emissions have not been monitored in this region.

13.1 Lead Shot Used in Hunting Ammunition

Lead has been the principal metal used in the production of ammunition. Bullets are first cast as slugs of lead and then pressed and smoothed into the proper form. Hardnosed bullets are jacketed with a hard metal coat such as a cupro nickel alloy and soft nosed bullets have a lead exposed tip (19) or may have a plastic insert. Copper and steel shot have been used to replace lead shot, however, these have not achieved widespread use as they are much more expensive materials and their hardness can be damaging to gun barrels.

13.2 The Manufacture of Lead Shot

In the manufacture of lead shot, lead is alloyed with up to 1% arsenic and 2% antimony. The arsenic is used to reduce surface tension in the molten metal and aids in the formation of spherical shot. In order to reduce lead toxicity to waterfowl, 1.5% magnesium is added to promote rapid disintegration in the aquatic environment. The constraints on the alloy are that is must be of sufficient density for use as shot and must be inexpensive. Shot up to 5.8 mm diameter is formed by dropping molten lead through a sieve and shot 5.8 mm to 11.2 mm diameter is cast in moulds (19). There were no lead shot manufacturers located in the study area, however, shot production for personal use may be carried out.

13.3 Wildlife Poisoning Due to Lead Shot

Lead shot accumulates in marshlands which are heavily hunted. The shot resembles small stones which are eaten to aid digestion in the birds gizzard. The digestive acids dissolved small amounts of lead which eventually cause paralysis of the gizzard and death due to starvation (78).

Lead appears to adversely effect the heart function in waterfowl after it has been ingested. Sileo et al. (1978) dosed five Canada Geese with fifteen #6 lead shot pellets (122 - 265 mg Pb). All of the geese eventually died, those with higher doses exhibited progressive electrocardiogram changes and myocardial damage (fibrinoid necrosis) (91).

13.4 Lead Shot in Bottom Sediment at Cowichan Bay, B.C.

A test for lead shot in the sediment of a well used waterfowl area in Cowichan Bay, B.C. revealed that lead pellets were present in significant concentrations. Sixteen 0.90 m^2 plots were selected within a 2.8 ha marked zone in a 20 ha tidal flat. Sediment samples were taken at a 0.6 cm depth at all sites, 2.5 cm depth at five sites and at 5.0 cm depth at one site. Wire mesh sieves of 0.16 cm and 0.12 cm were able to collect shot samples of 0.13 cm and larger. The four sections yielded the following numbers of shot:

	Number of Shot
Grid #1	19
Grid #2	21
Grid #3	16
Grid #4	6

Grid #4 was not sampled at a depth greater than 0.6 cm and may be a low bias as significant numbers were found at the 2.5 cm depth in other locations.

Assuming a calculated average of 15.5 shot/0.09 m^2 a total of 670 kg of lead may be spread over a 20 ha area. It should be noted that hunting density and therefore lead density would vary over the site, being heaviest at overflight routes and where waterfowl rest and feed. There are numerous foreshore and marshland areas where waterfowl are hunted in British Columbia.

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