HMCS CHAUDIERE

MONITORING SURVEY RESULTS

April 1993 DR 93-01

Waste Management Division
Environmental Protection
Conservation and Protection
Pacific and Yukon Region

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Regional Data Report DR 93-01

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1. INTRODUCTION

On December 5, 1992 the HMCS CHAUDIERE, a decommissioned destroyer escort, was sunk in Sechelt Inlet by the Artificial Reef Society of British Columbia to create a diving attraction and artificial reef. The sinking was carried out following the issuance of an Ocean Dumping Permit under the authority of the Canadian Environmental Protection Act, Part VI.

As there were a number of environmental concerns raised during the review of the permit application, a commitment was made to carry out a post-sinking monitoring program.

This report summarizes the findings of the monitoring program. The program focuses on examination of water samples collected in Sechelt Inlet in the vicinity of the HMCS CHAUDIERE and observations of the biological colonization of the ship. The water samples were analysed for oil and grease, trace metals and fibres. Fibre analyses were included because of the possible effect asbestos-containing materials, remaining in the vessel, may have if they are released into the marine environment.

2. METHODOLOGY

2.1 SAMPLING LOCATIONS

Sampling locations are shown on the attached site map and vessel schematic. The locations are described in Appendix A.

2.1.1 WATER SAMPLING METHODS

Water samples were collected on February 9, 1993 by divers. The sample depths ranged from 20 to 30 metres because the vessel is lying on a sloping sea floor.

Water samples were collected in 2 litre plastic bags and decanted into glass jars for fibre and oil and grease analysis, and 250 ml bottles for ICP trace metal analysis. Samples for oil and grease analysis were preserved with sulphuric acid and samples for ICP trace metal analysis were preserved with nitric acid. All samples were maintained on ice in a cooler until reaching the respective laboratories (Appendix A).

Fibre analysis was carried out on samples from four locations; REF1, ER1, BR1, and BW1. Sampling methods for fibres were based on discussions with Dr. H. Schreier, University of British Columbia, and Bacon Donaldson Consulting Engineers, the analytical laboratory.

2.1.2 COLONIZATION EVALUATION

Through the use of video recordings of the vessel, qualitative evaluation of biota and colonization activity within and in the vicinity of the ship were undertaken on February 10, 1993. The images were taken and prepared by the Royal Canadian Mounted Police (RCMP) Underwater Recovery Unit.

Observations of the hull state in terms of colonization were made along the exterior and within the vessel at identifiable points for future reference.

2.2 ANALYTICAL METHODS

2.2.1 OIL AND GREASE AND ICP METAL ANALYSIS

Analyses were carried out at the Environment Canada West Vancouver Laboratory. Samples for oil and grease, and trace metal from all seven locations were analyzed. Oil and grease were analyzed using the laboratory's standard infrared detection method. Trace metals were analyzed using an inductively coupled plasma system (ICP).

2.2.2 FIBRE ANALYSIS

Fibre analysis was carried out by Bacon Donaldson Consulting Engineers. The method followed was the same as that used for analysis of asbestos in drinking water. Details are given in Appendix C. It should be noted that, although reference is made to asbestos, the results are presented as fibres per litre. As Appendix C states, the fibre size was such that it was not possible to determine if the fibres observed were asbestos.

Details of QA/QC and examples of mineral fibres which might occur are stated in Appendix B. With reference to the precision and accuracy of the method, it should be noted that at 1 million fibres per litre (1 MFL) it is estimated that the results should be within a factor of 10 of the actual fibre content. For future reference, pH was measured in each sample (Appendix C).

The laboratory reports for the ICP analyses are presented in Appendix D.

3. DISCUSSION

3.1 WATER SAMPLING RESULTS

Results of fibre analyses at the four locations exhibited low fibre counts (0.7 - 2.0 MFL). The fibres were observed to be very small (<1μm). Because of these factors, the fibres could not be analyzed to determine fibre types. No fibres over 2μm and no fibre bundles were observed. It is suggested by the analyst that any disruption of asbestos-containing material in the vessel would likely have introduced larger fibres and fibre bundles into the surrounding water. The results for the samples in and around the vessel are similar to the results noted in the reference site. It was also noted that fragments of diatoms may have contributed to the fibre count.

The fibre levels observed would be considered in the low end of the range for natural occurrence (10^6 fibres/litre). Schreier (1989) reports background levels in the Fraser River to be 10^6 to 10^9 fibres per litre. The laboratory advised that the results for all four samples were essentially the same given the QA/QC of the method. The three results for the vessel range from 0.7 to 2.0 MFL (million fibres per litre) and are comparable to the results for the reference site (0.8 MFL). Therefore, the results are considered indicative of background fibre concentrations.

Oil and grease concentrations were determined to be 0.2 mg/L or less in all samples. ER1 (Engine Room) and BR1 (Burma Road) were 0.2 mg/L. The remaining samples were less than 0.2 mg/L.

The ICP trace metal results are presented in Appendix D. They show similar values between the vessel sites and the reference site and are considered indicative of the background levels for Sechelt Inlet.

3.2 VIDEO OBSERVATIONS

3.2.1 COLONIZATION OBSERVATIONS

The video record provides a baseline of biological information against which to measure, in a qualitative fashion, the colonization of the vessel by marine organisms. The initial observations taken February 10, 1993 indicated that, since the sinking on December 5, 1992, algal growth had developed over the entire surface of the HMCS CHAUDIERE. Plankton were observed in the water column outside and around the ship. The outer hull supported a variety of organims including rockfish, starfish, shrimp and sculpins. Adjacent to the ship in the surrounding water column, large numbers of juvenile pelagic fish were noted.

3.2.2. OTHER OBSERVATIONS

Certain areas within the ship appeared to contain some unidentified suspended material which was easily disturbed by the divers. The material did not appear to be settling in the water during the short period of observation. Subsequent observations and sampling may determine the character of this material. It is recommended that those areas noted in the video as having particulate matter be reinspected to determine if the condition continues to exist. Supplementary samples should be taken for assessment if the material is found to persist.

4. CONCLUSIONS

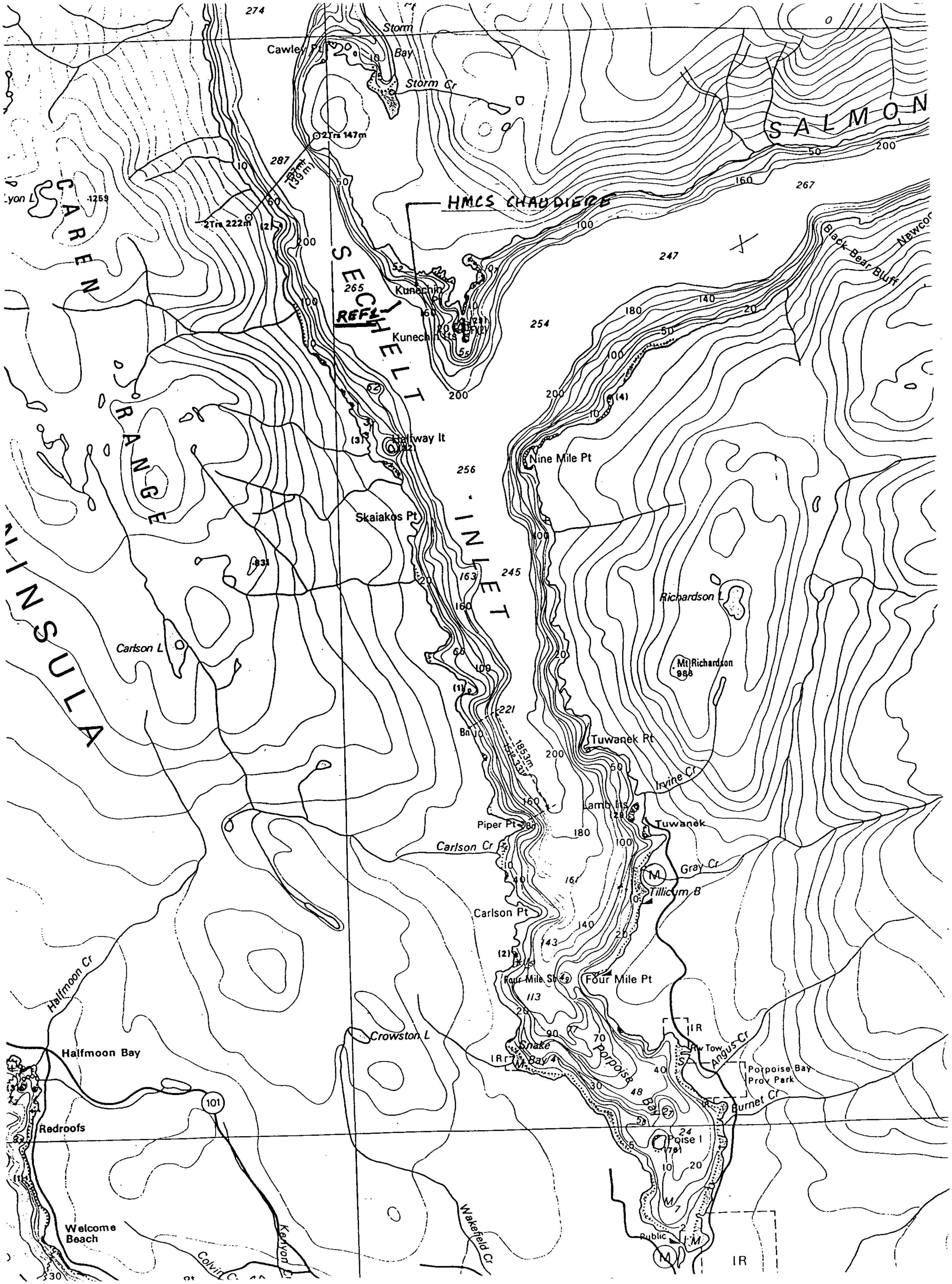
The data generated from this sampling program indicated that water quality conditions around the vessel were comparable to those at the reference site. There has been no elevation in the concentration of any of the water quality parameters measured.

5. FUTURE MONITORING

Environment Canada intends to work with the RCMP to conduct monitoring surveys biannually to record the conditions at the site. The video record will continue to be an important part of the program and future surveys will include observations of the sediments in the vicinity of the vessel. The Artificial Reef Society of BC has a commitment to record the behaviour of the vessel over the long term and make the information available to Environment Canada.

6. REFERENCES

Shreier, H., 1989. Asbestos in the Natural Environment, Studies in Environmental Science 37. Elsevier, Amsterdam.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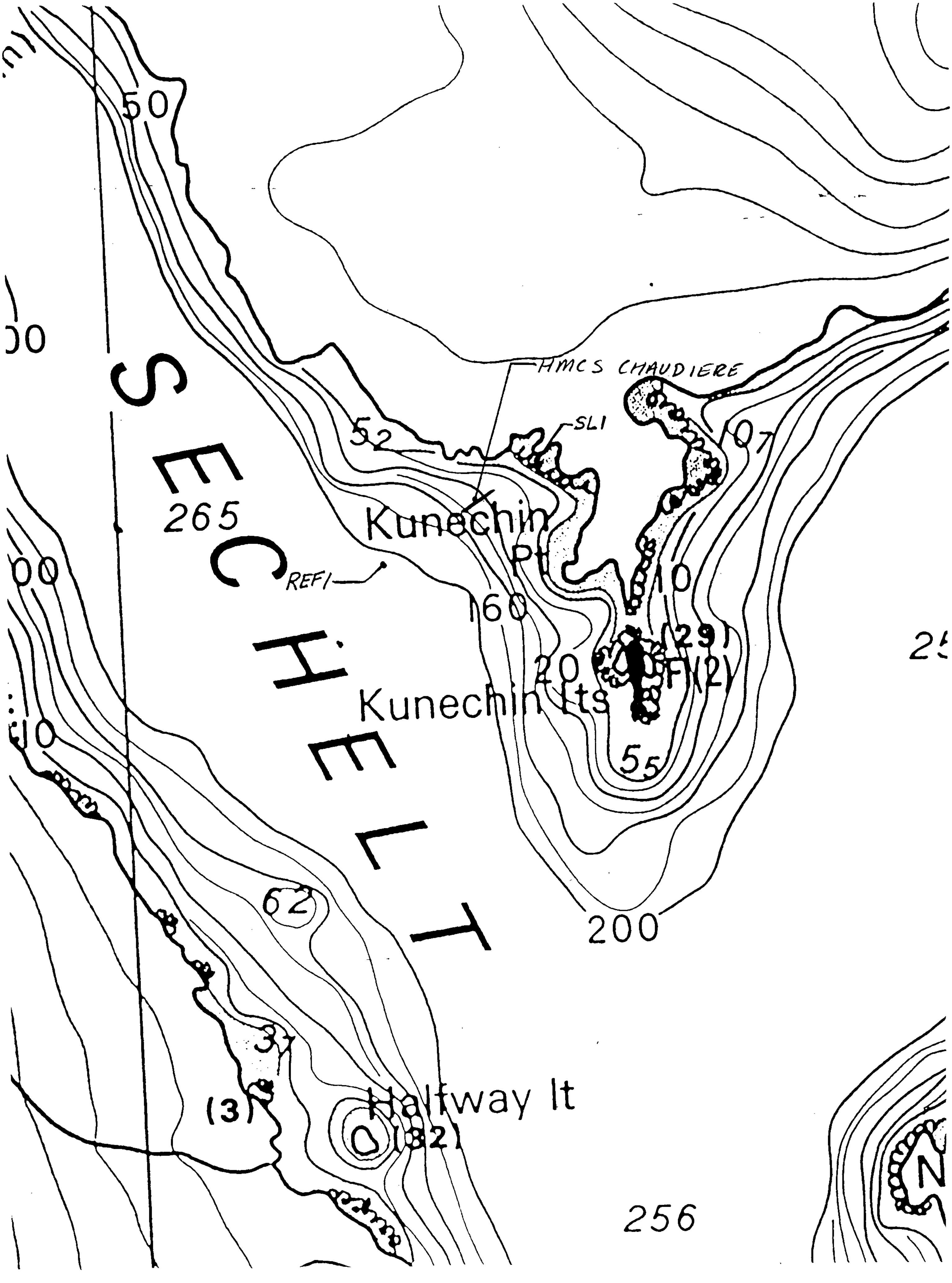

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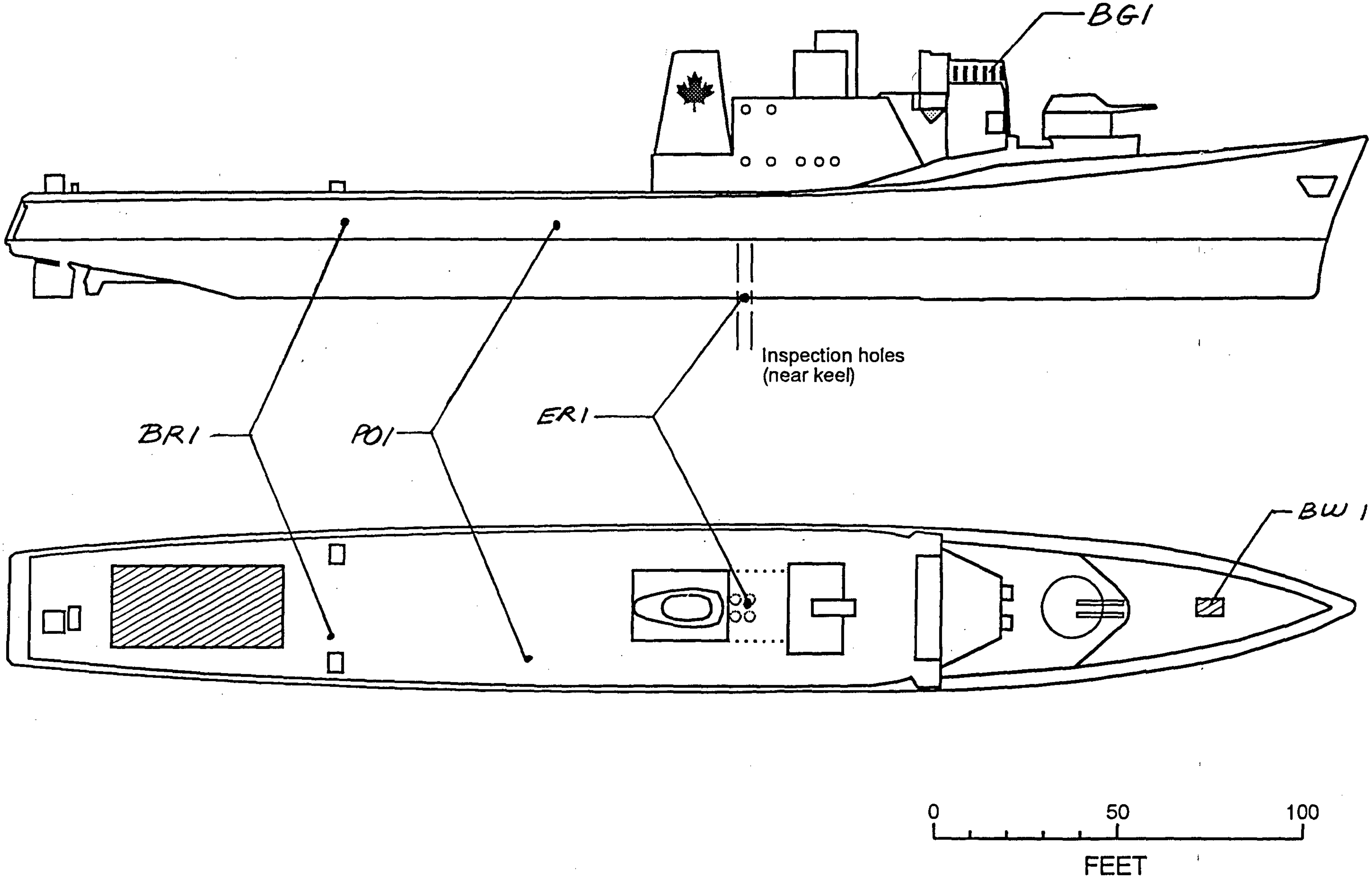

APPENDIX A

SAMPLE LOCATION AND INSPECTION REPORT

SAMPLE LOCATIONS

SITE	DESCRIPTION
ER 1	Engine Room. Through holes in vessel bottom.
BR 1	Burma Road. At the generator room ahead of the mortar well on Deck 3.
BW 1	Bow. At opening cut in the deck ahead of the forward gun turret.
BG 1	Bridge. Inside the Command Position.
PO 1	Inside the Petty Officers Mess on Deck 3.
SL 1	Shoreline, northeast of the vessel.
REF1	Reference Station. Approximately 300 metres southwest of the vessel at a depth of 30 metres.

CONSERVATION AND PROTECTION **CONSERVATION ET PROTECTION**

MEMORANDUM **NOTE DE SERVICE**

To/À

David Ellis
Waste Management Division

From/De

Emmanuel Mendoza
Environmental Enforcement Engineer

Security-Class.-Sécurité
Our File-N / Référence
Your File -V / Référence
Date: April 5, 1993

OBJET
SUBJECT: Chaudiere - Field Monitoring Notes

The analytical results for the Chaudiere environmental effects monitoring have been completed. A copy of the analytical data are attached and summarized below.

All of the samples were taken on Tuesday, February 9, 1993 at or near Kunetchin Point, Sechelt Inlet between the hours of 1300-1530. The following grab samples were submitted to appropriate laboratories for analysis.

Sample	Location	Analysis	Laboratory	Result
ER1	Engine Room	Oil/Grease	C&P	0.2 mg/L
BR1	Burma Road	Oil/Grease	C&P	0.2 mg/L
BW1	Bow	Oil/Grease	C&P	<0.2 mg/L
BG1	Bridge	Oil/Grease	C&P	<0.2 mg/L
REF1	Sechelt Inlet	Oil/Grease	C&P	<0.2 mg/L
SL1	Shoreline (surface)	Oil Grease	C&P	<0.2 mg/L
PM1	P.O. Mess	Oil Grease	C&P	<0.2 mg/L
ER2	Engine Room	Metals/Ext	C&P	*
BR2	Burma Road	Metals/Ext	C&P	*
BW2	Bow	Metals/Ext	C&P	*
BG2	Bridge	Metals/Ext	C&P	*
REF2	Sechelt Inlet	Metals/Ext	C&P	*
SL2	Shoreline (surface)	Metals/Ext	C&P	*
PM2	P.O. Mess	Metals/Ext	C&P	*
ERA2	Engine Room	Asbestos	BDCE	0.7 MFL
BRA1	Burma Road	Asbestos	BDCE	2.0 MFL
BWA2	Bow	Asbestos	BDCE	0.9 MFL
REF2	Sechelt Inlet	Asbestos	BDCE	0.8 MFL

* - analysis includes 29 different metals done through ICAP method

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Weather Condition:

The weather at Kunetchin Point on February 9, 1993 was partly cloudy. The waters in and around the Kunetchin Point were calm.

Sampling Technique and Preservation:

All of the samples were taken by RCMP divers. The water samples were collected using new sealable plastic bags (approximately 2 liters capacity) and 250 ml plastic bottles for those requiring metals analysis. An initial dive conducted by the divers using glass bottles proved to be ineffective in collecting the water samples. The RCMP divers found opening the jars to be very difficult when working at depths of the ship. In addition, the lids on the jars did not provide adequate seal which resulted in the loss of the water sample during delivery to the surface. Considering these findings, future sampling should be conducted using plastic bottles preferably with teflon coated lids.

Samples submitted for metals were preserved on site with nitric acid. Samples submitted for oil/grease were preserved on site with sulfuric acid. All of the samples were placed in a cooler packed with ice until they were submitted to the appropriate labs.

Please do not hesitate to contact me, should you require further clarification.

Emmanuel Mendoza
6-2724

cc: Kay Kim

APPENDIX B

BACON DONALDSON WATER SAMPLE REPORT

APPENDIX I. EXAMPLES OF MINERALS WHICH MAY OCCUR IN FIBROUS HABIT

Mineral Name(s)	Formula	Detectable Elements By Energy Dispersive X-Ray Analysis	a) Occurrence b) Associated Minerals c) Similar Minerals
Serpentine (Chrysotile) (Antigorite)	$Mg_6(OH)_8Si_4O_{10}$	Mg-Si	a) hydrothermally decomposed olivine; proxene, amphibole b) olivine, tremolite, talc, opal, pyrope garnierite c) ----------------------------------
Talc (Steatite)	$Mg_3(OH)_2Si_4O_{10}$	Mg-Si	a) alteration of serpentine; anthophyllite b) chlorite, serpentine, magnetite, pyrite, dolomite c) pyrophyllite; kaolinite
Amosite (Cummingtonite) (Grunerite)	$(MgFe)_7[OHSi_4O_{11}]_2$	Mg-Si-Fe	a) variety of cummingtonite b) ---------------------------------- c) chrysotile asbestos
Riebeckite (Crocidolite)	$Na_2Fe_3Fe_2$ $[(OH,F)Si_4O_{11}]_2$	Na-Si-Fe	a) in crystalline schists, yellow tiger eye b) ---------------------------------- c) ----------------------------------
Tremolite	$Ca_2Mg_5(OH,F)_2$ $[Si_4O_{11}]_2$	Mg-Si-Ca	a) in metamorphic limestone & dolomite, in talc schists b) ---------------------------------- c) chrysotile, pectolite, wollastonite
Actinolite	$Ca_2(MgFe)_5Si_8O_{22}(OH)_2$	Mg-Si-Ca-Fe	a) in impure limestone or dolomite b) ---------------------------------- c) pyroxenes
Byssolite	$Ca_2Mg_5(OH,F)_2$ $[Si_4O_{11}]_2$	Mg-Si-Ca	a) in metamorphic limestone and dolomites, in alpine cracks b) ---------------------------------- c) ----------------------------------
Anthophyllite	$(MgFe)_7[OHSi_4O_{11}]_2$	Mg-Si ± Fe	a) in crystalline schists, mica schists, in metamorphic rock b) ---------------------------------- c) chrysotile
Hornblende	$CaNa(MgFe)(AlFeTi)_3$ $Si_6O_{22}(O,OH)_2$	Na-Mg-Al-Si-Ca-Ti-Fe	a) in metamorphic & igneous rocks, in crystalline schists b) biotite, garnet, epidote, magnetite c) augite, tourmaline
Epsomite (Bitter Salt)	$Mg[SO_4]7H_2O$	Mg-S	a) weathering product in ore deposits, efflorescent crusts, alteration product of kieserite b) ---------------------------------- c) kieserite
Wollastonite (Table Spar)	$Ca_3[Si_3O_9]$	Si-Ca	a) in contact metamorphic limestone, in crystalline schists b) quartz, garnet, vesuvianite, pyroxene c) pektolite, tremolite
Pectolite	$Ca_2NaH[Si_3O_9]$	Na-Si-Ca	a) in fissures in igneous rocks b) zeolite, calcite c) tremolite, wollastonite
Zeolite (Natrolite)	$Na_2Al_2Si_3O_{10}\cdot 2H_2O$	Na-Al-Si	a) in cavities in igneous rocks, in fissures in granites & crystalline schists b) other zeolites, calcite, apophyllite c) aragonite scolezite, thomsonite, mesolite, wavellite
Pyrophyllite	$Al_2[(OH)_2Si_4O_{10}]$	Al-Si	a) in quartz veins & ore veins, in slate clays b) ---------------------------------- c) talc, kaolinite

Appendix I. Examples of Minerals Which May Occur in Fibrous Habit

Mineral Name(s)	Formula	Detectable Elements By Energy Dispersive X-Ray Analysis	a) Occurrence b) Associated Minerals c) Similar Minerals
Stilpnomelan	$(K,H_2O)(Fe,Mg,Al)_3[(OH)_2Si_4O_{10}](H_2O)_2$	Mg-Al-Si-K-Fe	a) in ore veins b) pyrite, siderite, limonite sphalerite, quartz c) -------------------------------
Anhydrite	$Ca[SO_4]$	Ca-S	a) in ore veins, in salt deposits b) halite, gypsum, dolomite c) cryolite, gypsum, barytes, calcite
Sillimanite (Fibrolite)	$Al_2[OSiO_4]$	Al-Si	a) in crystalline schists, granulites eclogites, in contact-metamorphic rocks b) ------------------------------- c) cyanite
Zoisite & Clino-zoisite	$Ca_2Al_2[OOHSiO_4Si_2O_7]$	Al-Si-Ca	a) in crystalline schists & metamorphic rocks b) amphibole, garnet, vesuvianite epidote, quartz c) tremolite
Epidote & Pistacite	$Ca_2(FeAl)Al_2[OHSiO_4Si_2O_7]$	Al-Si-Ca-Fe	a) in fissures & vesicles of basic igneous rocks & crystalline schists b) zeolite, calcite, axinite garnet, copper, vesuvianite c) hemimorphite, aragonite, staffelite; tourmaline, actinolite,
Zeolite (Thomsonite)	$NaCa_2[Al_2(AlSi)Si_2O_{10}]_2 \cdot 6H_2O$	Na-Al-Si-Ca	a) in vesicles in basic igneous rocks, in vesuvianite lavas b) other zeolites, analcite, calcite c) natrolite, prehnite
Palygorskite (Attapulgite)	$(MgAl)_2[OHSi_4O_{10}] \cdot 4H_2O$	Mg-Al-Si	a) weathering product of serpentine b) chalcedony, opal, chlorite, magnesite c) -------------------------------
Sepiolite (Meerschaum)	$Mg_4[(OH)_2Si_6O_{15}] \cdot 2H_2O + 4H_2O$	Mg-Si	a) weathering product of serpentine b) opal, chalcedony, magnesite, chlorite c) -------------------------------
Halloysite	$Al_2Si_2O_5(OH)_4$	Al-Si	a) weathering product of kaolinite b) feldspars, other clays c) -------------------------------
Brucite (Nemolite)	$Mg(OH)_2$	Mg	a) low temperature in serpentine or dolomite metamorphic rocks b) periclase c) -------------------------------
Magnesite	$MgCO_3$	Mg	a) metasomatic deposits replacing limestone & dolomite, in serpentine in talc schists b) ------------------------------- c) ankerite, calcite, dolomite
Zeolite (Laumontite)	$Ca[AlSi_2O_6]_2 \cdot 4H_2O$	Al-Si-Ca	a) in ore veins, in cavities & fissures in eruptive rocks b) other zeolites, calcite, chlorite c) feldspars
Aragonite & Calcite	$CaCO_3$	Ca	a) in rock-fissures, in ore deposits embedded in sulfur as sinter formation b) ------------------------------- c) calcite, barytes, coelestine, strontianite, natrolite, topaz, dolomite
Apjohnite	$MnAl_2[SO_4]_4 \cdot 22H_2O$	Mn-Al-S	a) in rock as weathering product of sulphides b) ------------------------------- c) alunogen

Appendix I. Examples of Minerals Which May Occur in Fibrous Habit

Mineral Name(s)	Formula	Detectable Elements By Energy Dispersive X-Ray Analysis	a) Occurrence b) Associated Minerals c) Similar Minerals
Gypsum & Selenite	$CaSo_4 \cdot 2H_2O$	S-Ca	a) rocks in salt deposits, weathering product of sulphides in sedimentary rocks, in ore deposits b) anhydrite, aragonite, sulphur c) mica, talc, kaolinite
Valentinite (Antimony Bloom)	Sb_2O_3	Sb	a) weathering product of antimony ores b) antimonite, galena c) cerussite
Arsenopyrite	$FeAsS$	S-Fe-As	a) in ore veins b) galena, silver c) lollingite, chloanthite, skutterudite
Lollingite (Leucopyrite)	$FeAs_2$	Fe-As	a) in ore veins b) arsenopyrite c) ----------------------------
Gedrite	$(MgFe)_6Al_2$ $[OH(AlSi)Si_3O_{11}]_2$	Mg-Al-Si-Fe	a) in metamorphic rocks, in crystalline schists, in granites, in ore veins b) ---------------------------- c) bronzite
Pyroxene Family			
1) Diopside	$CaMg[Si_2O_6]$	Mg-Si-Ca	a) in magnetite lodes, in fissures in metamorphic rocks b) chlorite, hessonite, magnetite, apatite, biotite c) clinochlore, augite
2) Violane	$CaMg[Si_2O_6] \pm Mn, Fe$	Mg-Si-Ca ± Mn, Fe	a) ---------------------------- b) ---------------------------- c) ----------------------------
3) Enstatite	$Mg_2[Si_2O_6]$	Mg-Si	a) rock constituent in serpentine, in pegmatic apatite veins b) apatite, phlogopite, olivine, bronzite c) hypersthene
4) Augite	(Ca,Mg,Fe_2,Fe_3,Ti,Al) $[(SiAl)_2O_6]$	Mg-Si-Ca,Ti-Fe	a) rock constituent in basic rocks, in tuffs, lavas & volcanic ejecta b) ---------------------------- c) amphibole
5) Hedenbergite	$CaFe[Si_2O_6]$	Si-Ca-Fe	a) in metamorphic & metasomatic rocks b) magnetite, pyrite c) ----------------------------
6) Acmite-Aegirite	$NaFeSi_2O_6$	Na-Si-Fe	a) common in high-soda, low-silica rocks b) ---------------------------- c) nepheline, leucite
Alunogen	$Al_2(SO_4)_3 \cdot 18H_2O$	Al-S	a) in ore veins, in coal piles, in clays b) pyrite melanterite c) alunite
Halotrichite	$FeAl_2(SO_4)_4 \cdot 22H_2O$	Al-S-Fe	a) weathering product of pyrites in ore deposits, in lignites b) ---------------------------- c) sjohnite
Celestite	$SrSO_4$	S-Sr	a) in sedimentary rocks, in sandstone or limestone b) fluorite, calcite, gypsum, dolomite, galena, sphalerite c) ----------------------------

reagents for carrying out asbestos analyses. Analytical determinations of asbestos can be carried out only after an acceptably low level of contamination has been established.

9. Calculations

9.1 Fiber Concentrations

Grid Square Counting Method - If the Grid Square Method of counting is employed, use the following formula to calculate the total asbestos fiber concentration in MFL.

$$C = (\overline{F} \times A_f)/(A_g \times V_o \times 1000) \qquad (1)$$

where: C = Fiber concentration (MFL)

$\overline{F}$ = Average number of fibers per grid opening

A_f = Effective filtration area of filter paper (mm^2) used in grid preparation for fiber counting

A_g = Average area of one grid square (mm^2)

V_o = Original volume of sample filtered (ml)

If ashing is involved, use the same formula but substitute the effective filtration area of the 25-mm diameter filter for A_f instead of that for the 47-mm diameter filter. If one-half the filter is ashed, multiple C by two.

Field-of-View Counting Method - If the Field-of-View Method of counting is employed, use the following formula to calculate the total asbestos fiber concentrations (MFL).

$$C = (\overline{F} \times A_f \times 1000)/(A_v \times V_o) \qquad (2)$$

where: C = Fiber concentration

$\overline{F}$ = Average number of fibers per field of view

A_f = Effective filtration area of filter paper (mm^2) used in grid preparation for fiber counting

A_v = Area of one field of view (μm^2)

V_o = Original volume of sample filtered (ml)

If ashing is involved, use the same formula but substitute the effective filtration area of the 25-mm diameter filter for A_f instead of that for the 47-mm diameter filter.

9.2 Estimated Mass Concentration

Calculate the mass (μg) of each fiber counted using the following formula.

$$M = L \times W^2 \times D \times 10^{-6}$$

If the fiber content is predominantly chrysotile, the following formula may be used.

$$M = \frac{\pi}{4} \times L \times W^2 \times D \times 10^{-6} \qquad (3)$$

where: M = Mass (μg)

L = Length (μm)

W = Width (μm)

D = Density of fibers (g/cm^3)

Then calculate the mass concentration (μg/l) employing the following formula.

$$M_c = C \times \overline{M}_f \times 10^6$$

where: M_c = mass concentration (μg/l)

C = fiber concentration (MFL)

$\overline{M}_f$ = mean mass per fiber (μg)

To calculate $\overline{M}_f$ use the following formula.

$$\overline{M}_f = \sum_{i=1}^{n} M_i/n \qquad (4)$$

where: M_i= mass of each fiber, respectively

n = number of fibers counted

NOTE 1: Because many of the amphibole fibers are lath shaped rather than square in cross section the computed mass will tend to be high because laths will, in general, tend to lie flat rather than on edge.

NOTE 2: Assume the following densities: chrysotile 2.5, amphibole 3.25.

9.3 Aspect Ratio

The aspect ratio for each fiber is calculated by dividing the length by the width.

10. Reporting

10.1 Report the following concentration as MFL for sample and blank using 95% confidence intervals.

a. Chrysotile

b. Amphibole

c. Total asbestos fibers

10.2 Use two significant figures for concentrations greater than 1 MFL, and one significant figure for concentrations less than 1 MFL.

10.3 Tabulate the size distribution, length and width.

10.4 Tabulate the aspect ratio distribution.

10.5 Report the calculated mass as μg/l.

10.6 Indicate the detection limit in MFL.

10.7 Indicate if less than five fibers were counted.

10.8 Include remarks concerning pertinent observations, (clumping, amount of organic matter, debris) amount of suspected though not identifiable as asbestos fibers (ambiguous).

11. Precision

11.1 Intra-Laboratory

The precision that is obtained within an individual laboratory is dependent upon the number of fibers counted. If 100 fibers are counted and the loading is at least 3.5 fibers/grid square, computer modeling of the counting procedure shows that a relative standard deviation of about 10% can be expected.

In actual practice some degradation from this precision will be observed but should not exceed ± 15% if several grids are prepared from the same filtered sample. The relative standard deviation of analyses of the same water sample in the same laboratory will increase as a result of sample preparation errors and a relative standard deviation of about about ± 25 to 35% will occur. As the number of fibers counted decreases, the precision will also decrease approximately proportional to $\sqrt{N}$ where N is the number of fibers counted. The precision for mass concentration is generally poorer than that for fiber concentration.

Based upon the analysis of one laboratory utilizing a different analyst for each of three water samples, intra-laboratory precision data are presented in Table 1.

11.2 Inter-Laboratory

Based upon the analysis by various government and private industry laboratories of filters prepared from nine water samples, inter-laboratory precision data of the method are presented in Table 2.

12. Accuracy

12.1 Fiber Concentrations

As no standard reference materials are available, only approximate estimates of the accuracy of the procedure can be made. At 1 MFL, it is estimated that the results should be within a factor of 10 of the actual asbestos fiber content.

This method requires the positive identification of a fiber to be asbestos as a means for its quantitative determination. As the state-of-the-art precludes the positive identification of all of the asbestos fibers present, the results of this method, as expressed as MFL, will be biased on the low side and, assuming no fiber loss, represent 0.4 to 0.8 of the total asbestos fibers present.

TABLE 1. INTRA-LABORATORY PRECISION

Sample Type	Number of Sample Aliquots Analyzed	Mean Fiber Concentration MFL (millions of asbestos fibers/l)	Precision, Relative Standard Deviation	Mass Concentration (µg/l)	Precision, Relative Standard Deviation
Chrysotile (UICC)	26	23	37%	0.32	71%
Crocidolite (UICC)	20	8	36%	1.5	48%
Taconite (raw water)	20	16	24%	10.5	65%

TABLE 2. INTER-LABORATORY PRECISION

Sample Type	Number of Labs Reporting	Mean Fiber Concentration, MFL (millions of asbestos fibers/l)	Precision, Relative Standard Deviation
Chrysotile	10	877	35%
	9	119	43%
	11	59	41%
	9	31	65%
	9	28	32%
	3	25	35%
Amphibole	11	139	50%
	4	95	52%
	14	36	66%

12.2 Mass Concentrations

As in the case of the fiber concentrations, no standard samples of the size distribution found in water are available. The estimated mass concentration is often very inaccurate because of poor counting statistics associated with large fibers that are few in number but represent most of the actual mass concentration.

13. Suggested Statistical Evaluation of Grid Fiber Counts

13.1 Because the fiber distribution on the sample filter, resulting from the method of filtration, has not been fully characterized, the fiber distribution obtained on the electron microscope grids for each sample should be tested statistically against an assumed distribution and a measure of the precision of the analysis should be provided.

13.2 Assume that the fibers are uniformly and randomly distributed on the sample filter and grids. One method for confirming this assumption is given below.

Using the chi-square test, determine whether the total number of fibers found in individual grid openings are randomly and uniformly distributed among the openings using the following formula.

$$X^2 = \sum_{i=1}^{N} \frac{(n_i - np_i)^2}{np_i} \qquad (5)$$

where: X^2 = Chi-square statistic

N = Number of grid openings examined for the sample

n_i = Total number of fibers found in each respective grid opening

n = Total number of fibers found in N grid openings

p_i = Ratio of the area of each respective grid opening to the sum of the areas of all grid openings examined

NOTE: If an average area for the grid squares has been measured as outlined in 8.4.5, the term np_i represents the mean fiber count per grid square.

If the value for X^2 exceeds the value listed in statistical tables for the 0.1% significance level with N-1 degrees of freedom, the fibers are not considered to be uniformly and randomly distributed among the grid openings. In this case, it is advisable to try to improve the uniformity of fiber deposition by filtering another aliquot of the sample and repeating the analysis.

13.3 If uniformity and randomness of fiber deposition on the microscope grids has been demonstrated as in 13.2, and the fiber concentration is assumed to be normally distributed about the mean value, the 95% confidence interval about the mean fiber concentrations for chrysotile, amphibole, and total asbestos fibers may be determined using the following formulae.

$$S_c = \left[\frac{N \sum_{i=1}^{N} X_i^2 - \left(\sum_{i=1}^{N} X_i \right)^2}{N(N-1)} \right]^{1/2} \qquad (6)$$

where: S_c = Standard deviation of the chrysotile fiber count

N = Number of grid openings examined for the sample

X_i = Number of chrysotile fibers in each grid opening, respectively

Obtain the standard deviations of the fiber counts for amphibole asbestos fibers and for total asbestos fibers by substituting the corresponding value of X_i into equation (6).

$$X_u = \bar{X} + \frac{tS_c}{\sqrt{N}} \qquad (7)$$

$$X_L = \bar{X} - \frac{tS_c}{\sqrt{N}} \qquad (8)$$

where: X_u = Upper value of 95% confidence interval for chrysotile

X_L = Lower value of 95% confidence interval for chrysotile

$\overline{X}$ = Average number of fibers per grid opening

t = Value listed in t-distribution tables at the 95% confidence level for a two tailed distribution with N-1 degree of freedom

S_c = Standard deviation of the fiber counts for chrysotile

N = Number of grid openings examined for the sample

The values of X_u and X_L can be converted to concentrations in millions of fibers per liter using the formula in section 9 and substituting either X_u or X_L for the term F.

Obtain the upper and lower values of the 95% confidence interval for amphibole asbestos fibers and total asbestos fibers by substituting the corresponding values of $\overline{X}$ and S into equations (7) and (8).

Report the precision of the analysis, in terms of the upper and lower limits of the 95% confidence interval, for chrysotile, amphibole, and total asbestos fiber content. If a lower limit is found to be negative, report the value of the limit as zero.

APPENDIX C

BACON DONALDSON INFORMATION OF METHOD, FIBRE TYPES AND QUALITY ASSURANCE/QUALITY CONTROL

BACON DONALDSON
CONSULTING ENGINEERS

Head Office
12271 HORSESHOE WAY
RICHMOND, B.C. V7A 4Z1
PHONE: (604) 277-2322
FAX: (604) 274-7235

FIBRE COUNTS IN FOUR WATER SAMPLES BY TEM (CHAUDIER MONITORING PROGRAMS)

Prepared for:

ENVIRONMENT CANADA - C & P
Waste Management Division
224 West Esplanade, 5th Floor
North Vancouver, B.C.
V7M 3H7

Attention: Mr. Dave Ellis

File Number: EO3018
March 11, 1993
WIP\EO\EO3018R1.AL

A. Lacis, Electron Microscopist

1.0 INTRODUCTION

Four 1-litre water samples were delivered to Bacon Donaldson by Emmanuel Mendoza of Environment Canada.

The samples were part of the "Chaudier Monitoring Program" and were identified as follows:

REF 2A
BRA 1
BWA 2
ERA 2

Bacon Donaldson was to perform fibre counts by Transmission Electron Microscopy (TEM) on the four water samples in order to determine if any differences existed in the fibre content of the water samples. The pH of the four samples was also to be determined.

2.0 TESTING PROCEDURES

100 ml of each sample was filtered using 47 mm Nuclepore membrane filters with .4 µm hole size. The filtration was performed within 8 hours of the sample delivery.

Segments of each filter were carbon coated in a vacuum evaporator, 3 mm squares were cut from each filter segment and placed on carbon coated 100 mesh TEM sample grids.

The "Modified Jaffe Wick" method was used to dissolve the carbon coated nuclepore filter squares, leaving any particulates enclosed by the remaining carbon films. The samples were examined in a Hitachi HU-11E TEM.

Initial examination was carried out at lower magnifications in order to determine the overall fibre loading and the quality of the carbon films. Since the fibre loading was found to be very low, the so-called Grid Square Method was used to perform the fibre counts. This method consists of counting all the fibres found in twenty grid squares (ten on each of two sample grids). The criteria used to identify a feature as a fibre were: parallel sides and aspect ratio greater than 3:1. The actual fibre counting was performed at 20,000X magnification.

3.0 RESULTS AND DISCUSSION

The fibre count in all four water samples was found to be quite low and most of the fibres were very small, less than 1 µm in length. No fibres over 2 µm and no fibre bundles were observed.

The number of fibres found in 20 grid squares, the fibre concentration in MFL (Millions of Fibres per Litre), and the pH for each sample are presented in the table below.

Sample	No. of Fibres in 20 Squares	Fibre Concentration MFL	pH of Water
REF 2A	16	0.8	7.4
BRA 1	41	2.0	7.4
BWA 2	18	0.9	7.5
ERA 2	14	0.7	7.6

Even though sample BRA 1 showed a higher fibre count than the other three samples, the overall fibre concentration is quite low. A significant fact is that no large fibres and no fibre bundles were found in any of the samples. Any disruption of asbestos-containing material in the vicinity of the sampling locations very likely would have introduced larger fibre fragments as well as fibre bundles into the surrounding water. Diatoms and diatom fragments were also present in all four water samples. Some of the fragments were quite small and could have the appearance of fibres, thus adding to the fibre count.

All of the fibres counted were too small to produce electron diffraction patterns that could have been used to identify specific asbestos types.

Separate filter segments were also examined in a scanning electron microscope in order to check for large fibres and also photograph some of the diatoms found in the water samples. Three scanning electron micrographs are enclosed with this report.

We trust that these findings will satisfy you needs, but should any questions arise, please do not hesitate to call.

Yours truly,

BACON DONALDSON

A. Lacis
Electron Microscopist

APPENDIX D

ICP TRACE METAL RESULTS

nvironment Canada
&P Laboratories
195 Marine Drive
est Vancouver, B.C.
7V 1N8 (604)666-6767

Lab Reference #
930213

00:27 27-Mar-93

FINAL REPORT

Identification: KUNETCHIN PT-CHAUDIERE

Flagged: RUSH

Type of Sample: MARINE WATER

Submitted by: MENDOZA,EMMANUEL
EP NORTH VAN
INSPECTIONS
ENFORCE. & EMERG
EP PAC/YUKON

Logged in: 22-Feb-93 (7 samples)

Completed: 26-Mar-93 (218 results)

Charged to: 2531-263
COD - OCEAN DUMPING A3210/89

Analyzed for: METALS

Checked by: ____________________

otes:

[1] -extractable metals: use graphite furnace (GF) results, where reported, in preference to ICP results due to better precision and accuracy.

RESULTS FOR KUNETCHIN PT-CHAUDIERE SAMPLES

Parameter Analyzed		Units	ER-2 930213-001	BR-2 930213-002	BW-2 930213-003	BG-2 930213-004	REF-2 930213-0
METALS/EXT.(WATER-GF)	CD	mg/l	<.0004	<.0004	<.0004	<.0004	<.000
(WATER-ICP SCAN)	AG	mg/l	<.01	<.01	<.01	<.01	<.01
	AL	mg/l	<.05	.06	<.05	<.05	<.05
	AS	mg/l	<.05	.08	.05	.07	<.05
	B	mg/l	3.61	3.69	3.52	3.54	3.26
	BA	mg/l	<.001	<.001	<.001	<.001	<.001
	BE	mg/l	<.001	<.001	<.001	<.001	<.001
	CA	mg/l	296	302	292	293	272
	CD	mg/l	<.005	<.005	<.005	<.005	<.005
	CO	mg/l	<.005	<.005	<.005	<.005	<.005
	CR	mg/l	.005	<.005	<.005	<.005	<.005
	CU	mg/l	<.005	<.005	<.005	<.005	<.00
	FE	mg/l	.037	.019	.02	.009	.026
	K	mg/l	324	332	312	321	296
	MG	mg/l	1040	1060	1060	1050	1030
	MN	mg/l	<.001	<.001	<.001	<.001	<.001
	MO	mg/l	<.01	.01	<.01	<.01	<.01
	NA	mg/l	9060	9200	7200	9050	8960
	NI	mg/l	<.02	<.02	<.02	<.02	<.02
	P	mg/l	.1	.2	.2	.2	.1
	PB	mg/l	<.05	<.05	<.05	<.05	<.05
	SB	mg/l	<.05	<.05	<.05	<.05	<.05
	SE	mg/l	<.05	<.05	<.05	<.05	<.05
	SI	mg/l	2.72	2.7	2.65	2.59	2.44
	SN	mg/l	<.05	<.05	<.05	<.05	<.05
	SR	mg/l	5.37	5.49	5.21	5.27	4.86
	TI	mg/l	.005	.005	.006	.007	.00
	V	mg/l	<.01	<.01	<.01	<.01	<.01
	ZN	mg/l	<.002	<.002	<.002	<.002	<.00
.HARDNESS/CA+MG	HC	mg/l	5020	5110	5100	5040	4920
/TOTAL	HT	mg/l	5030	5110	5110	5050	4930

RESULTS FOR KUNETCHIN PT-CHAUDIERE SAMPLES

Parameter Analyzed		Units	SL-2 930213-006	PM-2 930213-007
TALS/EXT.(WATER-GF)	CD	mg/l	<.0004	<.0004
(WATER-ICP SCAN)	AG	mg/l	<.01	<.01
	AL	mg/l	.08	<.05
	AS	mg/l	.08	<.05
	B	mg/l	2.6	3.38
	BA	mg/l	<.001	<.001
	BE	mg/l	<.001	<.001
	CA	mg/l	214	279
	CD	mg/l	<.005	<.005
	CO	mg/l	<.005	<.005
	CR	mg/l	<.005	<.005
	CU	mg/l	<.005	<.005
	FE	mg/l	.015	.013
	K	mg/l	232	303
	MG	mg/l	800	1050
	MN	mg/l	<.001	<.001
	MO	mg/l	<.01	<.01
	NA	mg/l	6970	9190
	NI	mg/l	<.02	<.02
	P	mg/l	.1	.1
	PB	mg/l	<.05	<.05
	SB	mg/l	<.05	<.05
	SE	mg/l	<.05	<.05
	SI	mg/l	2.22	2.43
	SN	mg/l	<.05	<.05
	SR	mg/l	3.86	5.02
	TI	mg/l	.005	.005
	V	mg/l	<.01	<.01
	ZN	mg/l	<.002	<.002
.HARDNESS/CA+MG	HC	mg/l	3830	5040
/TOTAL	HT	mg/l	3840	5040

LABORATORY SERVICES (EPS-FMS)
CHEMISTRY

☐ Fresh Water
☑ Marine Water
☐ Effluent
☐ Sediment
☐ Biota
☐ Other

Location Kuvetchin Pt.- Chaudiei
Date Sampled February 9, 1993
Sampled By E. Mendoza
Submitted By E. Mendoza
Send Report To E. Mendoza.
Collator ~~2531-263~~

Coordinator
Quality Control ☐

Lab Number 930213
Date Received Feb 10, 1993

SAM. # (1, 2, 3 . . .)	I.D. & PRESERVATION (IF NECESSARY)	ANALYSIS REQUESTED	NUMB OF BOT
1	ER2	Metals (Extractables)	1
2	BR2	↓ ↓	1
3	BW2	↓ ↓	1
4	BG2	↓ ↓	1
5	REF2	↓ ↓	1
6	SL2	↓ ↓	1
7	PH2	↓ ↓	1

Return Equipment To: [✓ Hold For:]
E. Mendoza
Inspections
- Teflon Coated Lids
+ Jars. (Amber).

Phone

Checked By
Date

Remarks

nvironment Canada
&P Laboratories
195 Marine Drive
est Vancouver, B.C.
7V 1N8 (604)666-6767

Lab Reference #
930214

00:17 05-Mar-93

FINAL REPORT

Identification: KUNETCHIN PT-CHAUDIERE

Flagged: RUSH

Type of Sample: MARINE WATER

Submitted by: MENDOZA,EMMANUEL
EP NORTH VAN
INSPECTIONS
ENFORCE. & EMERG
EP PAC/YUKON

Logged in: 22-Feb-93 (7 samples)

Completed: 04-Mar-93 (8 results)

Charged to: 2531-263
COD - OCEAN DUMPING A3210/89

Analyzed for: ORGANICS

Checked by: ____________

RESULTS FOR KUNETCHIN PT-CHAUDIERE SAMPLES

Parameter Analyzed	Units	ER-1 930214-001	BR-1 930214-002	BW-1 930214-003	BG-1 930214-004	REF-1 930214-0
OILS & GREASES	mg/l	0.2	0.2	<0.2	<0.2	<0.2

Parameter Analyzed	Units	SL-2 930214-006	PM-2 930214-007
OILS & GREASES	mg/l	<0.2	<0.2

LABORATORY SERVICES (EPS-FMS)
CHEMISTRY

RWSH

☐ Fresh Water
☑ Marine Water
☐ Effluent
☐ Sediment
☐ Biota
☐ Other

Location Kunetchin Pt- Chaudiere
Date Sampled February 9, 1993
Sampled By E. Mendoza
Submitted By E. Mendoza
Send Report To E. Mendoza
Collator 2531-863

Coordinator
Quality Control ☐

Lab Number 930214
Date Received Feb. 10, 1993

SAM. # (1, 2, 3 . . .)	I.D. & PRESERVATION (IF NECESSARY)	ANALYSIS REQUESTED	NUMBER OF BOTTLES
1	ER1	Oil and Grease.	1
2	BR1		1
3	BW1		1
4	BG1		1
5	REF1		1
6	SL1 SL2	} Bottles labelled	1
7	RM1 PM2		1

Return Equipment To: / [✓ Hold For:]
E. Mendoza
Inspections
– Teflon Coated lids &
Jars. (Archer)

Phone

Checked By
Date

Remarks