Assessment of Existing Chemical and Biological Data for Clinton Creek Mine, Yukon

Report Prepared for:

Assessment and Abandoned Mines Branch
Energy, Mines and Resources
Government of Yukon
Whitehorse, Yukon

Report Prepared by:

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November 2009

EXECUTIVE SUMMARY

This report summarizes the compilation and analyses of existing toxicological and ecological data and identifies information gaps pertinent to closure plans for the Clinton Creek Mine site. Although historical concentrations of small chrysotile asbestos in Clinton Creek were at or above levels shown in the literature to have adverse effects on aquatic life, concentrations have not been measured in the past 10 years. Also, some substances in water and sediment have been measured at concentrations above guidelines for the protection of aquatic life. However, characterizations of nearby reference areas and seasonal variability are incomplete and thus context is lacking. Previous attempts to collect benthic macroinvertebrates were unsuccessful so reliable data on this important aquatic health indicator do not exist. Several reports show that fish regularly utilize Clinton Creek but information on their relative abundance and condition in reference versus mine-influenced areas would be useful for closure planning. The water and sediment chemistry, benthic macroinvertebrate, and fish samples collected in the summer of 2009 will fill many of the information gaps that currently exist. However, characterizing seasonal and annual variability in conditions and/or collecting direct evidence that links changes in biological community structure to asbestos exposure are data gaps that may still need to be addressed in future. Irrespective of any effects of asbestos or altered water chemistry on the health of downstream receiving environments, past mining activities in the Clinton Creek area have resulted in obvious alterations to the surrounding aquatic habitat and potential habitat remediation should be considered.

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1.0 INTRODUCTION

1.1 Site History

The former Clinton Creek Asbestos Mine is located 100 km northwest of Dawson City, Yukon (Figure 1.1). The mine site is located on Clinton Creek, a tributary of the Forty-mile River which flows into the Yukon River (Figure 1.2). The mine was operated by Cassiar Asbestos Corporation Ltd. from 1967 to 1978 when it was shut down due to poor economic circumstances (Table 1.1). A waste rock dump failure in 1974 impounded Clinton Creek and resulted in the formation of Hudgeon Lake upstream of the mine. The same year, the south lobe of the tailings deposit slid into Wolverine Creek, a tributary to Clinton Creek. Channel reconstruction and reinforcement in the early 1980s were unsuccessful; in 1984 Clinton Creek escaped the reinforced channel and undercut the north valley wall, and in 1985, the north lobe of the tailings area slide also slid into Wolverine Creek. In 1986, Cassiar submitted a rehabilitation and abandonment plan for the site, which was not immediately accepted by regulatory authorities. Negotiations continued through 1991 when Princeton Mining Corp. purchased Cassiar and continued with remediation. In 1992, the Government of Canada assumed responsibility for the site. After a flood destroyed channel reinforcements and weir structures in Clinton Creek in 1997, the government began to investigate environmental liabilities (1999). Attempts to stabilize the Clinton Creek channel included installation of gabion structures in 2002-2004. The Yukon Government assumed a project management role for the site in 2003 and has overseen various additional site clean-up and stabilization efforts to move towards official site closure.

1.2 Project Objectives

In support of closure planning, Minnow Environmental Inc. was asked to review all existing information related to aquatic ecosystem health at the Clinton Creek Mine. This report summarizes the compilation and analysis of existing toxicological and ecological data related to the aquatic environment and identifies information gaps pertinent to closure plans for the Clinton Creek Mine site.

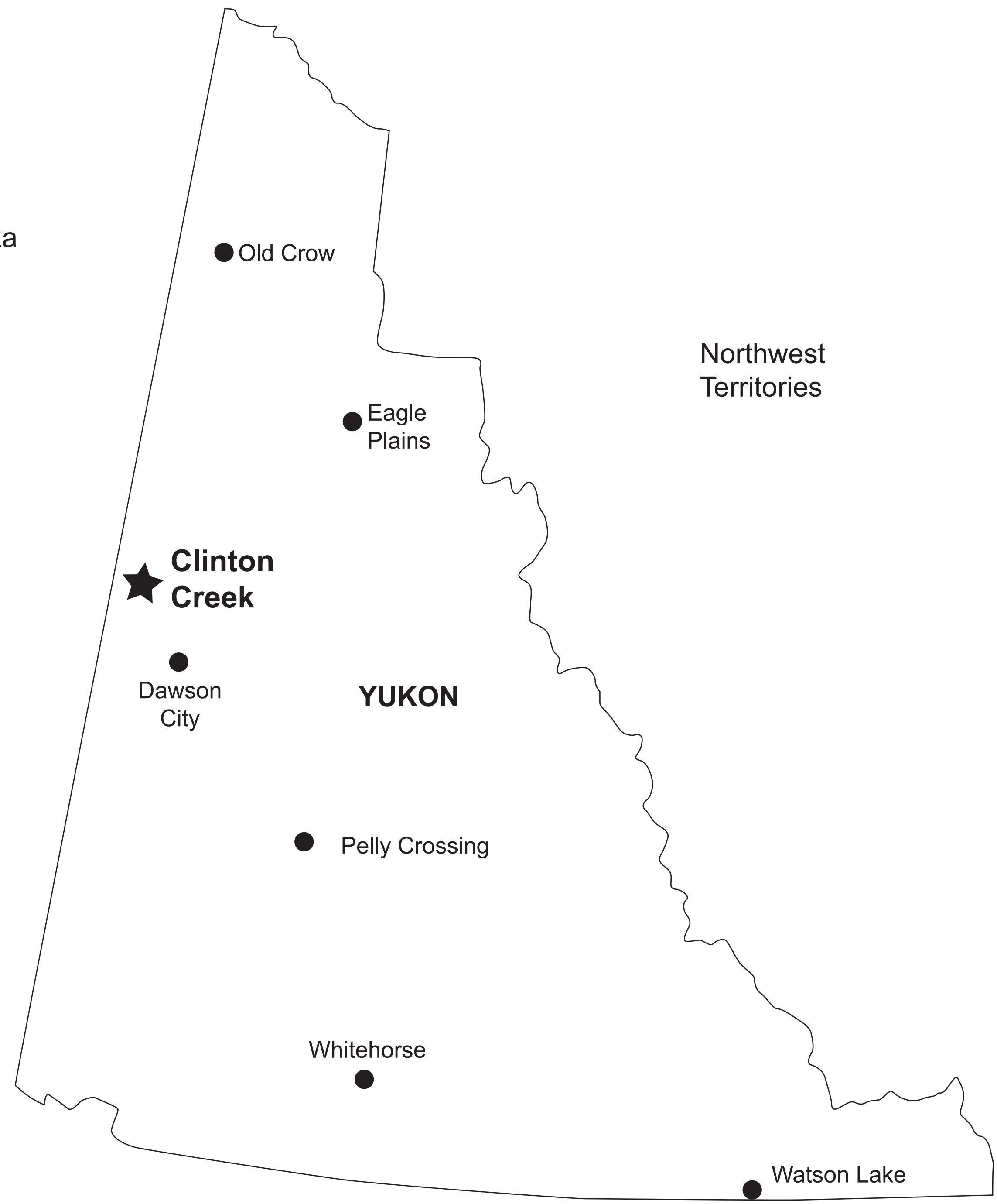
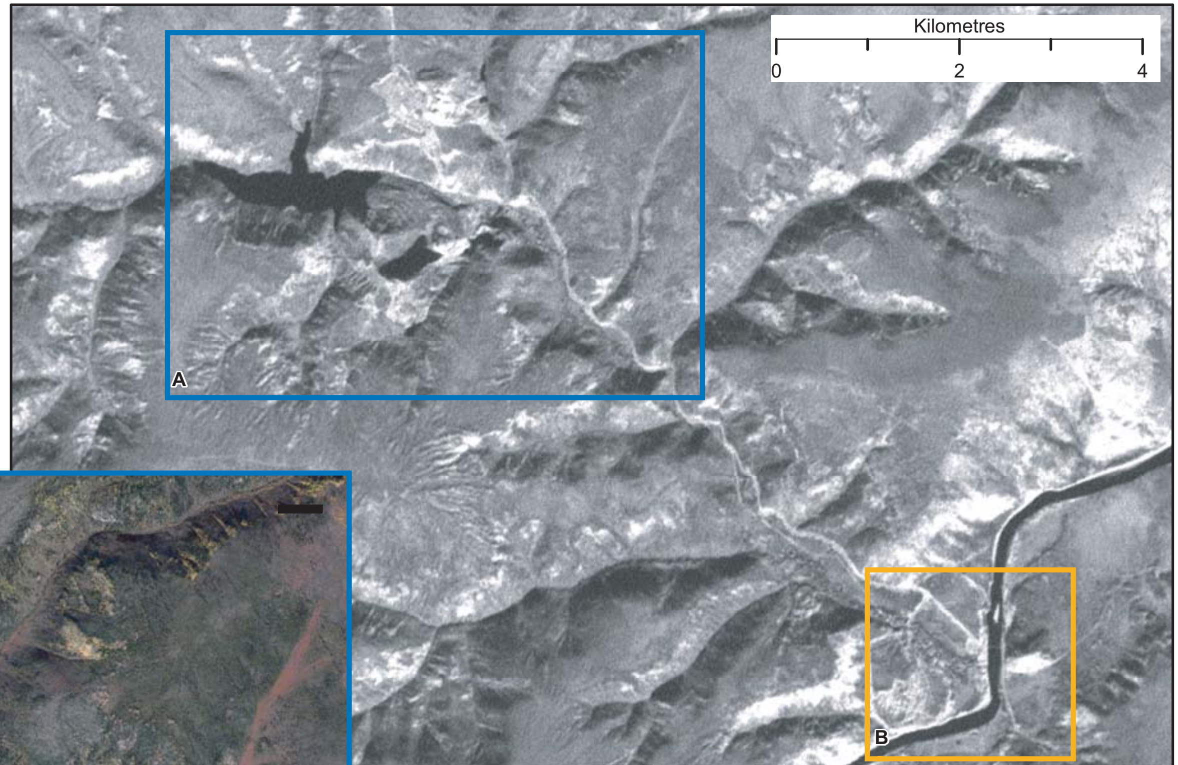


Figure 1.1

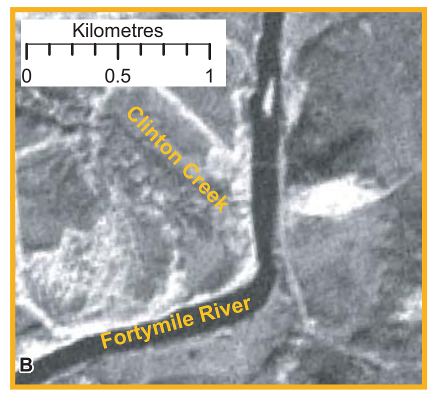
minnow environmental inc.

Location of Clinton Creek Mine

Ref: 2298
Date: November 2009



Quickbird Satellite image captured September, 2008.



Landsat 7 Satellite image captured May 2002.

Figure 1.2

Clinton Creek Mine Site

Ref: 2298
Date: November 2009

Table 1.1: Chronology of major operational, failure and remediation events at Clinton Creek Mine, 1967 - 2008.

Year	Operational, Failure and Remediation Events	Source
1967	Cassiar Asbestos Corporation Ltd. commences mining operations. Three waste rock dumps (Clinton, Porcupine, Snowshoe) were created during operation which totalled approximately 60 million tonnes of waste rock.	Roach 1998, Royal Roads, 1999, SENES 2003
1974	Failure of Clinton waste rock dump, impoundment of Clinton Creek and creation of Hudgeon Lake.	Royal Roads, 1999
1974	Failure of the south lobe tailings deposit and impoundment of Wolverine Creek.	Royal Roads, 1999
1974	The Yukon Territory Water Board issues a water license to Cassiar Asbestos Corporation Ltd. for the removal of water from and deposition of sewage to the Forty Mile River for the purposes of serving the Clinton Creek town site.	Royal Roads, 1999
1977	The last of the waste rock material is consigned to the waste rock dumps.	Royal Roads, 1999
1978	The Yukon Territory Water Board issues a water license to Cassiar Asbestos Corporation Ltd. for the operation of the mill site.	Royal Roads, 1999
1978	Cassiar Asbestos Corporation Ltd. ceases mining operations and removes the main sections of the concentrator, most mining equipment and the primary structures from the town site and auctions off the mill buildings and town site.	Royal Roads, 1999
1978	Cassiar Asbestos Corporation Ltd. constructs a rock-lined outfall channel and weirs to convey Wolverine Creek over the south lobe tailings deposit and terraces both the south and north lobe tailings deposit to increase stability.	Royal Roads, 1999
1978	Progressive failure of the north lobe tailings deposit begins.	Royal Roads, 1999
1981	Cassiar Asbestos Corporation Ltd. installs culverts and an apron at Hudgeon Lake outflow and constructs rock weirs and channel armoring in Clinton Creek.	Royal Roads, 1999
1982	Clinton Creek escapes armored channel during freshet and undercuts north valley wall.	Royal Roads, 1999
1982	The Yukon Territory Water Board water license for the mill site expires.	Royal Roads, 1999
1983	The Yukon Territory Water Board extends the water license for the mill site until 1987 to maintain a regulatory basis for achieving satisfactory mine abandonement.	Royal Roads, 1999
1984	Cassiar Asbestos Corporation Ltd. reconstructs channel armoring in Clinton Creek.	Royal Roads, 1999
1985	The north lobe tailings deposit mass reaches and impounds Wolverine Creek.	Royal Roads, 1999
1986	Cassiar Mining Corporation Ltd. submits an abondonement plan for the Clinton Creek mine to the Yukon Territory Water Board.	Royal Roads, 1999
1987	The Yukon Territory Water Board holds public hearings on the abondonement plan and subsequently recommends acceptance of the plan and extension of the water license. The Water Board also recommends that the $400,000 security bond posted by Cassiar at the time of the orginal license application be retained to establish a monitoring and risk management plan.	Royal Roads, 1999
1987	The Minister of Indian and Northern Affairs refuses to sign the proposed water license amendment.	Royal Roads, 1999
1987	The water license expires and DIAND retains the bond.	Royal Roads, 1999
1988	A Minesite Management Plan is developed to serve as a basis for an agreement on the ongoing monitoring and risk management activities to be undertaken by Cassiar and DIAND. DIAND holds negotiations with Cassiar and reaches a verbal agreement that Cassiar would address the requirements outlined in the Mineseite Management Plan in return for the bond.	Royal Roads, 1999
1988	Cassiar Mining Corporation Ltd. removes the primary and secondary crushing units from the crusher building complex at the mill site.	Royal Roads, 1999
1989	Cassiar Mining Corporation Ltd. erects a series of warning signs and undertakes additional clean up of the abondoned mine site.	Royal Roads, 1999
1989	Cassiar requests that the bond held in association with the expired water license be returned. DIAND responds that there are outstanding issues and the matter is referred for legal review.	Royal Roads, 1999
1991	Cassiar Mining Corporation Ltd. has been bought by Princeton Mining Corporation Ltd.	Royal Roads, 1999
1991	DIAND and Princeton meet in September and the meeting is followed up with a letter from DIAND outlining the work requires in return for relinquishment of the bond. Princeton provides no written agreement.	Royal Roads, 1999
1991	Princeton undertakes further remedial activites at the Clinton Creek site and requiests that DIAND return the bond.	Royal Roads, 1999
1992	DIAND staff prepares a breifing note recommending that the bond be returned to Princeton.	Royal Roads, 1999
1997	A significant flood event largely destroys the channel armoring and weir structures in Clinton Creek.	Royal Roads, 1999
1999	Progressive channel degradation in Clinton Creek (i.e., erosion/down-cutting) since 1986 evaluation. Degradation is in first 500m of channel downstream of the outlet.	UMA Engineering, 2008
2000	Study conducted that identified hazards associated with continued degradation of the Clinton Creek channel through the waste rock dump.	UMA Engineering, 2000 (referenced in UMA 2008)
2001	Progressive channel degradation in Clinton Creek (i.e., erosion/down-cutting) compared to 1986 and 1999 evaluations. Degradation is in first 500m of channel downstream of the outlet.	UMA Engineering, 2008
2002 - 2004	Gabion baskets constructed in the first 180 meters of Clinton Creek downstream of Hudgeon Lake due to deteriorating conditions that may eventually lead to a breach of the waste rock at the Hudgeon Lake outlet	UMA Engineering, 2008
2005	Gabion baskets were evaluated and found to be deformed with some loss of rocks. There were plans to fix the baskets the same year.	DFO, July 6-7 2005
2008	Review of potential improvements to Hudgeon Lake undertaken	UMA Engineering, 2008

2.0 APPROACH

Data on water, sediment, and biological quality from relevant historical surveys of streams in the Clinton Creek drainage were obtained from the Yukon Government and reviewed for quality and pertinence to closure planning (Table 2.1). Data included asbestos, nutrient, and metal content of water and aquatic sediments, and benthic macroinvertebrate and fish community structure.

Water and sediment quality data were compiled from the past studies (Table 2.1) along with unpublished water quality data collected by the Yukon Government in 2003-2008. Water data were compared to water quality benchmarks, which were mostly comprised of federal and provincial water quality criteria for protection of aquatic life (Appendix A). Sediment data were compared to Canadian Sediment Quality Guidelines (CCME 1999).

Asbestos is one of the key contaminants at the Clinton Creek Mine site but there are no guidelines in Canada for protection of aquatic life (or drinking water). A literature search was conducted (using the Web of Science) to augment relevant citations provided by the Assessment and Abandoned Mines Branch. These citations were used to identify the concentrations of asbestos in water that have been associated with toxicity to aquatic biota. This information was summarized and compared to levels found in surface water and aquatic sediments at the mine site.

Existing biological data were also summarized and evaluated to the extent permitted by the data quantity and quality.

The collective information on water, sediment, and biological quality were evaluated with respect to implications for site closure. Information gaps were identified and recommendations for follow up studies were developed.

Table 2.1: Studies with data relevant to closure of the Clinton Creek Mine

Year	Title	Reference	Data Type[a]
1978	An Environmental Assessment of the Effects of Cassiar Asbestos Corporation on Clinton Creek, Yukon Territory	Landucci 1978	Asb, WQ, F
1998	Abandoned Clinton Creek Asbestos Mine	Roach 1998	Asb, F
1999	An Environmental Review of the Clinton Creek Abandoned Asbestos Mine, Yukon, Canada	Royal Roads University 1999	Asb, WQ, F
2003	Human Health Screening Level Risk Assessment for Clinton Creek Abandoned Asbestos Mine	SENES 2003	WQ
2004	Report on Operations Under License to Collect Fish Number 04-17	Copeland 2004	F
2005	Inspection, July 6-7, 2005	von Finster 2005a	F
2005	Inspection, July 6-7, 2005	von Finster 2005b	F
2005	Overflight, August 9, 2005	von Finster 2005c	F
2005	Clinton Creek, tributary to the Fortymile River, Yukon River North Mainstem sub basin - record of 2005 sampling	von Finster 2005d	F
2006	Clinton Creek, tributary to the Fortymile River, Yukon River North Mainstem sub basin - record of 2006 sampling	von Finster 2006	F
2007	Clinton Creek, tributary to the Fortymile River, Yukon River North Mainstem sub basin - record of 2007 sampling	von Finster 2007	F
2007	Rearing and Overwintering Access Restoration	Smart 2007	F
2008	Clinton Creek Mine Site Fisheries and Benthic Invertebrate Assessment Monitoring, 2007	White Mountain Environmental Consulting 2008	BMI, F
2009	Clinton Creek, tributary to the Fortymile River, Yukon River North Mainstem sub basin - record of 2008 sampling	von Finster 2009	F

[a] Asb = asbestos, WQ = water quality, BMI = benthic macroinvertebrates, F = fish

3.0 WATER AND SEDIMENT QUALITY

3.1 Asbestos Toxicity

Asbestos is a generic term for fibrous minerals having a length-to-width ratio of 3:1 or greater but chrysotile asbestos is the main type of asbestiform fibre mined for industrial use (Speil and Leinweber 1969). Chrysotile asbestos, which is the form found at Clinton Creek mine, is a fibrous silicate mineral in the serpentine sub-group, distinct from other asbestiform minerals in the amphibole group.

There are numerous studies on the carcinogenic and toxicological properties of chrysotile asbestos in mammals but information on the effects on aquatic life is relatively scarce (e.g., Belanger et al. 1986a). The toxic effects of chrysotile asbestos that have been documented for various life stages of algae, macrophytes, invertebrates, and fishes range from tissue and behavioural abnormalities to mortality (Table 3.1, Appendix Table B.1). These toxic effects were documented at asbestos concentrations in the range of 10^2 - 10^{10} fibres per litre. Some studies reported asbestos in mg/L which cannot be converted to units of fibres per litre (or vice versa) unless fibre weights or densities are also reported. Past measurements made on samples collected at the Clinton Creek Mine were reported in units of number of fibres per litre so the studies which reported toxicity in the same units were most relevant for this assessment.

The toxicity studies also show that toxic effects of asbestos (including mortality) are related to fibre size and shape whereby short (< 50 µm) and thin fibres are most toxic (Stewart and Schurr 1980, Woodhead et al. 1983, Belanger et al. 1986a, Belanger et al. 1986b). In addition, water turbulence results in more fibres in suspension which increases the opportunity for toxic effects to occur (Stewart and Schurr 1980).

3.2 Observed Asbestos Concentrations

Asbestos levels in the Clinton Creek drainage above 10^8 fibres per litre were reported for mine-exposed Hudgeon Lake near the outfall, Wolverine Creek, and Clinton Creek in the 1970s and 1990s (Figure 3.1). However, asbestos levels during the same surveys were in the 10^6 range in the un-exposed tributaries of Clinton Creek and the Forty-mile or Yukon Rivers. These results are consistent with reported background levels of asbestos in Canadian waters of 10^5-10^7 fibres per litre (Lawrence and Zimmerman 1977) and 10^7 fibres per litre or more in areas where it is being mined and processed (Cunningham and Pontefract 1971, Selikoff and Lee 1978, Battermann and Cook 1981). Studies in the Clinton Creek drainage also showed that the type of asbestos found in water was exclusively

Table 3.1: Summary of information on the toxicity of chrysotile asbestos in water from peer-reviewed journal articles.

Common Name	Scientific Name	Life stage at initiation	Effect exposure conditions	Minimum Effect Concentration	Observed Toxic Effects	Reference
Planktonic algae	*Cryptomonas erosa*	-	48 hours	1-1.5 x 10^6 fibers/L	clumping of *Cryptomona cells* with intertwining asbestos fibers, fibers clinging to cell surface	Lauth and Schurr 1983
Duckweed	*Lemna gibba*	-	7-21 days	0.5-5.0 µg/mL (<30 um length fibers)	biochemical changes to glutathione indicate possible shift toward oxidative cellular environment	Trivedi et al. 2007
Brine shrimp	*Artemia* sp.	2-3 days old	22 - 26 hours, with turbulence	2 x 10^2 mg/L (short fiber)	increased mortality	Stewart and Schurr 1980
Asiatic clam	*Corbicula* sp.	adult	48 hrs - 30 days	10^{2} - 10^8 fibers/L	depressed siphoning, reduced growth, changes to gill microstructure, less larvae released, increased larval mortality	Belanger et al. 1986a
Clam	*Corbicula fluminea*	juvenile	30 days	10^{2} - 10^8 fibers/L	depressed siphoning, reduced growth, increased water content in body tissue, changes to gill microstructure	Belanger et al. 1986b
Amazon molly	*Poecilia formosa*	2 months	6 months	0.1-1.0 mg/L coarse fibers	kidney, gill, and heart damage	Woodhead et al. 1983
Coho salmon	*Oncorhynchus kisutch*	larvae	13-40 days	1.5-3.0 x 10^6 fibers/L	mortality, abonormalites in epidermal tissue and swimming behaviour	Belanger et al. 1986c
Green sunfish	*Lepomis cyanellus*	juvenile	52-67 days	1.5-3.0 x 10^6 fibers/L	loss of scales and skin tissues, abnormal swimming behaviour	Belanger et al. 1986c
Japanese Medaka	*Oryzias latipes*	egg-adult	13 days - 20 weeks	10^{4}-10^{10} fibers/L	increased days to hatch, decreased growth, increased mortality, abnormal epidermis, lower spawning frequency	Belanger et al. 1990

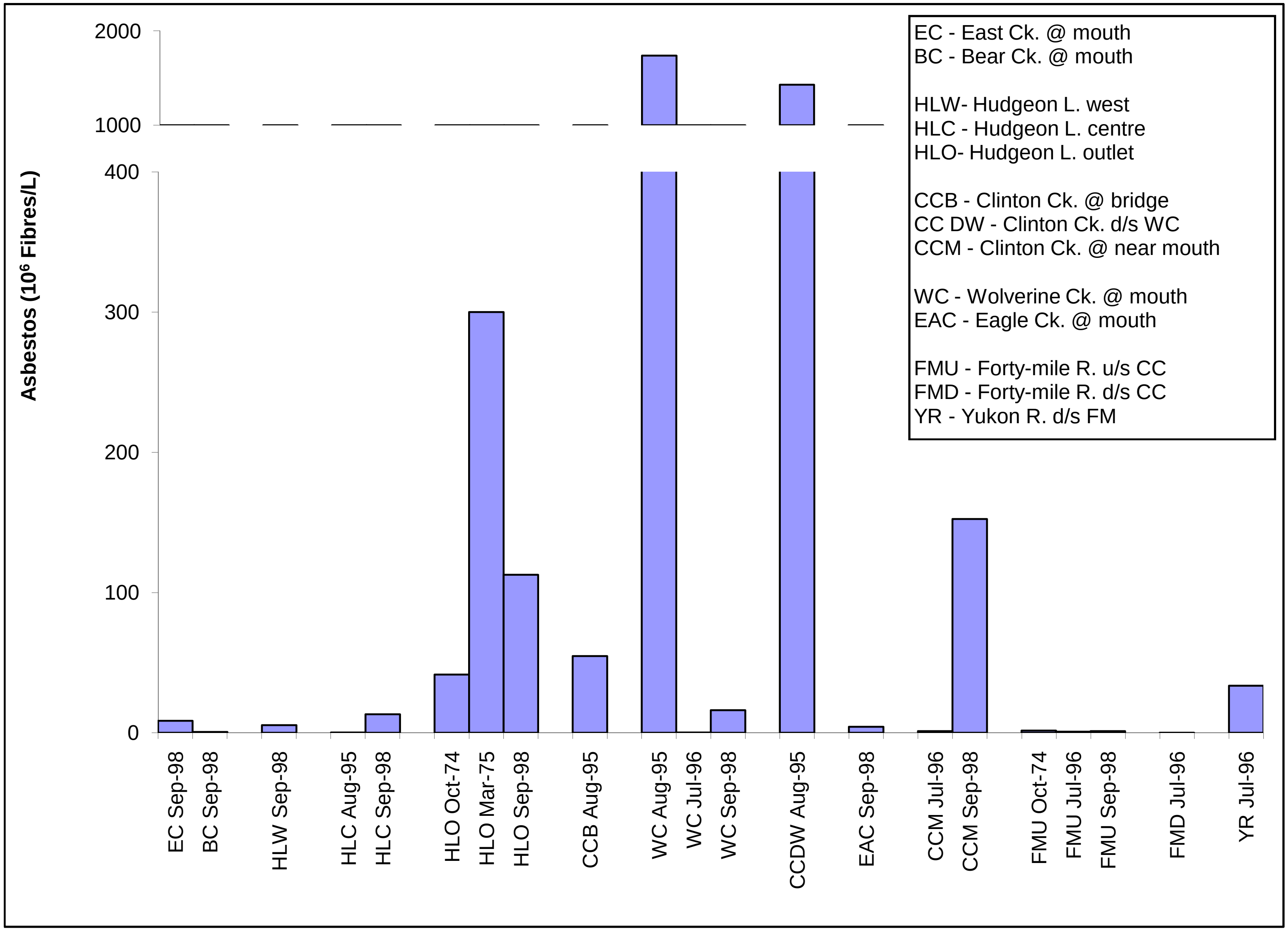


Figure 3.1 Asbestos concentrations (data from Landucci 1978, Roach 1998, Royal Roads University 1999)

chrysotile and that the vast majority of the fibres were very short (i.e., <5µm in length; Landucci 1978, Roach 1998, Royal Roads 1999).

Although historical concentrations of small chrysotile asbestos in Clinton Creek (10^6-10^9 fibres/L) were at or above levels shown in the literature to have adverse effects on aquatic life (10^2-10^6 fibres/L), concentrations were highly variable over time (Figure 3.1) and samples have not been collected in the past decade so the data may not reflect current conditions. In addition, asbestos toxicity depends on specific fibre properties (size, shape), making it difficult to assess the precise concentration at which toxic effects will occur. Asbestos concentrations in water are also dependent on turbulence (Stewart and Schurr 1980) so more than one sample per year is necessary to characterize the ranges in asbestos levels occurring in various flow conditions at the site.

The study by Royal Roads (1999) also provided some information on the amount of asbestos in stream sediments in the Clinton Creek drainage. Asbestos levels in sediment ranged from 1-2% upstream of the mine (i.e., East Creek and NW Hudgeon Lake) to 3-10% downstream of the mine (i.e., Hudgeon Lake outfall and Wolverine Creek). Better characterization of asbestos levels in sediment at the mine site would provide an indication of how much asbestos could potentially be mobilized during high flow events.

3.3 Other Contaminants

The most recent water quality data (2003-8) collected at key mine-exposed (i.e., Hudgeon Lake impoundment, waste rock, tailings) and nearby reference areas were compared to water quality benchmarks (Table 3.2, Appendix Table C.2). Interpretation of results was hampered by poor analytical method detection limits for some substances (i.e., above water quality benchmarks), particularly in 2005 and 2006 (Appendix Table C.2) Also, analytical method detection limits were not reported for samples collected in 2003, in which cases it could not be determined whether the reported data represent quantified sample concentrations or less-than-detection values.

Considering only data for samples collected in 2004, 2007 and 2008, when method detection limits were reported and were mostly below applicable water quality benchmarks, it is evident that concentrations of aluminum, boron, cadmium, calcium, chromium, copper, iron, magnesium, selenium, and zinc were somewhat elevated in some samples relative to benchmarks. There were no data available for reference areas in 2004, 2007, or 2008. Some values were substantially higher in Porcupine Creek, but were not reflected in concentrations measured in Clinton Creek downstream of Porcupine Creek. As noted above for asbestos (Section 3.2), another significant limitation of the existing water quality data is

Table 3.2: Water quality data at mine-exposed stations in the vicinity of Clinton Creek Mine[a]

Station Description	Units	Water Quality Benchmark [b]	Hudgeon Lake Outlet			Clinton Creek u/s of Wolverine Creek		Porcupine Creek near confluence with Clinton Creek			Clinton Creek d/s of Eagle Creek		Wolverine Creek d/s of tailings		Clinton Creek d/s of Eagle Creek	
Station ID			HL-06			CC-01		PC-04			CC-04		WC-05		CC-06	
Parameters			16-Sep-04	21-Sep-07	2-Oct-08	21-Sep-07	2-Oct-08	16-Sep-04	21-Sep-07	2-Oct-08	16-Sep-04	21-Sep-07	21-Sep-07	2-Oct-08	17-Sep-04	21-Sep-07
Aluminum	mg/L	0.1	0.051	0.089	0.0563	0.078	0.0302	< 0.005	0.009	4.31	< 0.005	0.091	0.347	0.0116	< 0.005	0.219
Antimony	mg/L	0.02	0.0003	0.0004	0.0003	0.0004	0.00037	0.0017	0.0188	0.0012	0.0006	0.0004	0.0008	0.00055	0.0004	0.0004
Arsenic	mg/L	0.005	0.0007	0.0006	0.0007	0.0011	0.00129	0.0035	0.0049	0.0024	0.0014	0.0011	0.0013	0.00074	0.0009	0.0011
Barium	mg/L	1.0	0.052	0.051	0.0396	0.049	0.0357	0.024	0.008	0.0209	0.062	0.049	0.051	0.022	0.065	0.05
Beryllium	mg/L	1.1	< 0.0001	< 0.0001	< 0.00050	< 0.0001	< 0.00050	< 0.0001	< 0.0001	< 0.0050	< 0.0001	< 0.0001	< 0.0001	< 0.00050	< 0.0001	< 0.0001
Bismuth	mg/L	0.26	< 0.0005	< 0.0005	< 0.00050	< 0.0005	< 0.00050	< 0.0005	< 0.0005	< 0.0050	< 0.0005	< 0.0005	< 0.0005	< 0.00050	< 0.0005	< 0.0005
Boron	mg/L	1.2	0.032	0.012	< 0.10	0.014	0.038	0.156	5.91	0.59	0.134	0.039	0.096	0.051	0.099	0.033
Cadmium	mg/L	0.00006	0.00005	0.00004	< 0.000050	0.00004	< 0.000050	0.00016	0.00014	< 0.00050	0.00005	0.00005	0.00002	< 0.00050	0.00007	0.00005
Calcium	mg/L	116	56.5	53	50.2	55.6	68.3	241	102	245	117	60.6	44.8	56.9	113	52.6
Chromium	mg/L	0.001	0.0009	0.0018	0.00154	0.0023	0.00159	0.0016	0.0018	< 0.0050	0.0008	0.0021	0.0038	0.0009	0.0009	0.0024
Cobalt	mg/L	0.004	0.0004	0.0006	0.00033	0.0006	0.00056	< 0.0001	0.0005	< 0.0010	0.0012	0.0007	0.0003	< 0.00010	0.0009	0.0008
Copper	mg/L	0.004	0.003	0.004	0.00317	0.003	0.00259	< 0.001	0.002	0.0092	< 0.001	0.003	0.003	0.00083	< 0.001	0.004
Iron	mg/L	0.3	0.2	0.3	0.216	0.3	0.318	< 0.1	< 0.1	< 0.030	0.4	0.4	0.5	0.102	0.3	0.5
Lead	mg/L	0.007	< 0.0001	0.0002	0.000085	< 0.0001	0.000085	< 0.0001	0.0002	0.00108	< 0.0001	0.0002	0.0002	< 0.000050	< 0.0001	0.0002
Lithium	mg/L	0.65	0.007	0.005	< 0.0050	0.006	0.0099	0.054	0.176	0.149	0.033	0.012	0.006	< 0.0050	0.031	0.01
Magnesium	mg/L	82	36.4	32.8	26	34.2	50.1	314	558	380	113	44.3	39.4	53.4	99	38.7
Manganese	mg/L	1.5	0.131	0.107	0.0935	0.11	0.114	< 0.005	0.0070	0.00212	0.335	0.14	0.039	0.0124	0.324	0.137
Mercury	mg/L	0.000026														
Molybdenum	mg/L	0.073	< 0.001	0.001	0.000976	0.001	0.00129	0.003	-	0.00243	0.003	0.001	< 0.001	0.000557	0.002	0.001
Nickel	mg/L	0.150	0.0058	0.0071	0.00486	0.0084	0.0115	0.0921	0.059	0.0961	0.0278	0.0139	0.0112	0.00538	0.0244	0.0126
Phosphorus	mg/L	0.03			< 0.30		< 0.30			< 0.30				< 0.30		
Potassium	mg/L	53	0.6	0.6	< 2.0	0.6	< 2.0	2.7	4.8	4.6	1.3	0.8	0.7	< 2.0	1.2	0.7
Selenium	mg/L	0.001	0.0008	0.0008	0.0016	0.0003	0.0016	0.0035	0.0063	< 0.010	0.0012	0.0009	0.001	< 0.0010	0.001	0.0008
Silicon	mg/L	-	3.78	4.5	4.77	4.46	4.89	5.47	0.77	7.4	4.82	4.73	6.12	5.5	4.69	5.01
Silver	mg/L	0.0001	< 0.0001	< 0.0001	< 0.000010	< 0.0001	< 0.000010	< 0.0001	< 0.0001	< 0.00010	< 0.0001	< 0.0001	< 0.0001	< 0.000010	< 0.0001	< 0.0001
Sodium	mg/L	200	2.9	2.9	2.5	3.1	4.1	14	35.0	35.1	8.3	4	3.4	4.4	8.1	3.5
Strontium	mg/L	9.3	0.33	0.304	0.21	0.308	0.335	1.57	0.557	2.72	0.882	0.393	0.269	0.125	0.842	0.328
Thallium	mg/L	0.0008	< 0.00005	< 0.00005	< 0.00010	< 0.00005	< 0.00010	0.00009	0.0002	< 0.0010	< 0.00005	< 0.00005	< 0.00005	< 0.00010	< 0.00005	< 0.00005
Tin	mg/L	0.35	< 0.001	< 0.001	< 0.00010	< 0.001	< 0.00010	0.006	< 0.001	< 0.0010	< 0.001	< 0.001	< 0.001	< 0.00010	< 0.001	< 0.001
Titanium	mg/L	1.83	0.0054	0.0049	< 0.010	0.0045	< 0.010	0.0408	0.0421	0.01	0.0141	0.0065	0.0216	< 0.010	0.0124	0.02
Uranium	mg/L	0.015	0.0029	0.0023	0.00152	0.0022	0.00187	0.0074	0.0079	0.0109	0.0038	0.0022	0.0017	0.000879	0.0039	0.0017
Vanadium	mg/L	0.006	0.0003	0.0007	< 0.0010	0.0005	< 0.0010	0.0003	0.0004	< 0.010	0.0002	0.0006	0.0015	< 0.0010	0.0002	0.0009
Zinc	mg/L	0.030	0.003	0.006	0.0024	0.007	0.0012	0.016	0.012	0.142	0.004	0.006	0.007	< 0.0010	0.004	0.006
Hardness[c]	mg/L	-	291	267	233	280	377	1895	2553	2180	757	334	274	362	690	291

Value exceeds benchmark. Some values represent elevated MDLs, but this could not be confirmed based on the information provided.

method detection limit exceeds benchmark

[a] Data provided by the Yukon Government

[b] see Appendix A for sources

[c] 2004 and 2007 hardness values were calculated based on calcium and magnesium concentrations

Note: values less than the detection limit were not indicated for 2004 and 2007. Values equal to the detection limit were therefore assumed to be less than detection.

that samples were generally taken only once in late summer so there is no measure of seasonal variability.

Information on sediment quality (apart from asbestos levels) is limited to one sampling event in one area (i.e., Wolverine Ck. near the tailings in 1998). Sediment arsenic and particularly chromium concentrations were above sediment quality guidelines in samples collected from Wolverine Creek, both above and below the tailings (Table 3.3). Detection limits for lead were above sediment quality guidelines. These data were collected over a decade ago and may not reflect current conditions. Also, there are no sediment data for other reference or exposure areas of the watershed to provide regional context.

Table 3.3: Sediment quality in Wolverine Creek, 1998 [a].

Station ID / Location description	Units	ISQG[b,c]	PEL[b,d]	CLWC-1S Wolverine Creek u/s of tailings	CLWC-2S Wolverine Creek next to tailings	CLWC-3S Wolverine Creek d/s of tailings
Physical Tests						
Moisture (%)	%			45.5	29.2	27.2
pH	pH units			6.46	8.53	8.37
Total Metals						
Antimony	mg/kg			<20	<100	<100
Arsenic	mg/kg	5.9	17.0	11	11	9
Barium	mg/kg			223	41	49
Beryllium	mg/kg			<0.5	<3	<3
Cadmium	mg/kg	0.6	3.5	0.6	<0.1	<0.1
Chromium	mg/kg	37.3	90.0	62	1580	1670
Cobalt	mg/kg			11	88	89
Copper	mg/kg	35.7	197	26	<5	5
Lead	mg/kg	35.0	91.3	<50	<300	<300
Mercury	mg/kg	0.17	0.486	0.080	0.011	0.016
Molybdenum	mg/kg			5	<20	<20
Nickel	mg/kg			70	1920	1860
Selenium	mg/kg			1.6	0.1	0.2
Silver	mg/kg			<2	<10	<10
Tin	mg/kg			<10	<50	<50
Vanadium	mg/kg			30	14	21
Zinc	mg/kg	123	315	97	19	25

[a] data from Royal Roads University, 1999

[b] CCME (Canadian Council of Ministers of the Environment). 1999. Canadian Environmental Quality Guidelines. 1999 (updated in 2001), Canadian Council of Ministers of the Environment, Winnipeg

[c] ISQG - Interim Sediment Quality Guideline

[d] PEL - Probable Effect Level

value exceeds ISQG (blue)

value exceeds PEL (green)

method detection limit exceeds ISQG or PEL (grey)

4.0 BIOLOGICAL COMMUNITIES

4.1 Benthic Macroinvertebrate Surveys

Benthic invertebrate communities are indicative of localized water quality conditions over time, they are important components of aquatic food webs, and there are standardized methods for their collection and evaluation. Surveys to collect benthic macroinvertebrates at the Clinton Creek Mine were conducted using artificial substrates in 1975 (Landucci 1978) and 2007 (White Mountain Environmental Consulting 2008). The total number of individuals collected per area in the 1975 survey was low (0-186); no invertebrates were found in Wolverine Creek and only three individuals were found in the Forty-mile River upstream of the confluence of Clinton Creek (Landucci 1978). Although total invertebrate abundance per area was higher in the 2007 survey (148-1,345), water levels declined after the substrates were deployed so they were not entirely submerged when collected for analyses. Thus, the surveys conducted to date have not adequately quantified the spatial extent or magnitude of mine-related effects on benthic invertebrate communities.

4.2 Fish Surveys

The numerous fish surveys that have been conducted at the Clinton Creek mine site consistently show that various fish species typical of Yukon streams utilize Clinton Creek and the Fortymile River (Table 4.1, Appendix Table C.6). However, fish have not been found in any of the upstream tributaries to Clinton Creek or Hudgeon Lake and only rarely have fish been found in Hudgeon Lake itself (e.g., 3 arctic grayling in 1980, one arctic grayling in 2005). Although the tributaries offer a limited amount of shallow-water, well-oxygenated habitat suitable for seasonal fish utilization, the limiting factor appears to be a lack of deeper over-winter habitat (White Mountain Environmental Consulting 2008). Also, Hudgeon Lake is anoxic below five metres depth and thus offers limited usable habitat for fish even in the ice-free season. Furthermore, gabian structures at the outlet of the lake into Clinton Creek represent a barrier to upstream migration under most flow conditions.

Although the surveys that have been done to date are useful for summarizing patterns in fish presence/absence, the areas sampled, methods used, and fishing effort varied widely among studies (Appendix Table C.6). More standardized information on the relative abundance and condition of fish in reference versus mine-influenced areas would be useful in assessing whether the Clinton Creek mine site is adversely affecting fisheries resources.

Irrespective of any effects of asbestos or altered water chemistry on the health of downstream receiving environments, past mining activities in the Clinton Creek area have

Table 4.1: Presence of fish species at Clinton Creek, 1975 - 2008.

Area	Arctic grayling	Chinook salmon	Lake Whitefish	Round Whitefish	Slimy sculpin	Longnose sucker	Lake chub	Sources
Tributary to upper Clinton Creek								White Mountain Environmental Consulting, 2008
Clinton Creek upstream of Hudgeon Lake								Landucci, 1978; White Mountain Environmental Consulting, 2008
Hudgeon Lake	P							Royal Roads University, 1999; EVS 1980 data; DFO Dec 6, 2005; DFO Oct 31, 2006; White Mountain Environmental Consulting, 2008
Bear Creek								White Mountain Environmental Consulting, 2008
East (or Easter) Creek								White Mountain Environmental Consulting, 2008
Clinton Creek upstream and within gabion baskets	P	P				P		Roach et al., 2003; DFO Oct 31, 2006; DFO Dec 23, 2007; DFO Jan 16, 2009
Clinton Creek downstream of gabions and within/near gabion areas prior to their construction	P	P		P	P	P	P	Landucci, 1978; Roach and Ricks, 2003; Roach et al., 2003; DFO July 14, 2005; DFO Aug 2, 2005; DFO Dec 23, 2007; White Mountain Environmental Consulting, 2008; DFO Dec 23, 2007; DFO Jan 16, 2009
Clinton Creek near Wolverine Creek (including road crossing)	P	P			P	P	P	Landucci, 1978; EVS 1980 data; Royal Roads University, 1999; Roach and Ricks, 2003; DFO July 14, 2005; DFO Aug 2, 2005; DFO Dec 6, 2005; DFO Oct 31, 2006; DFO Dec 23, 2007; DFO Jan 16, 2009
Clinton Creek near confluence of Eagle Creek	P	P			P	P		Landucci, 1978; EVS 1980 data; Royal Roads University, 1999; DFO July 14, 2005; DFO Aug 2, 2005; DFO Jan 16, 2009
Clinton Creek near confluence with Fortymile River	P	P	P	P	P	P		Landucci, 1978; EVS 1980 data; Royal Roads University, 1999; DFO Dec 6, 2005; DFO Oct 31, 2006; DFO Dec 23, 2007; Smart 2007;
Wolverine Creek								Landucci, 1978; White Mountain Environmental Consulting, 2008
Fortymile River	P	P			P	P		Landucci, 1978

resulted in obvious alterations to the surrounding fish habitat (e.g., formation of Hudgeon Lake, hanging culvert at mouth of Wolverine Creek). Potential fish habitat mitigation or remediation options should be identified and evaluated with respect to feasibility and cost.

5.0 CONCLUSIONS

1. Historical concentrations of small chrysotile asbestos in Clinton Creek were at or above levels shown in the literature to have adverse effects on aquatic life but asbestos levels had not been measured in water or sediment for more than a decade.

2. Seasonal variability in water quality had not been assessed, even though ambient concentrations of asbestos and other contaminants are likely linked to flow conditions.

3. Method detection limits for some substances measured in water and sediment samples in some years were above guidelines, precluding definitive conclusions regarding the potential for such substances to be affecting biota.

4. Previous attempts to collect benthic macroinvertebrates were relatively unsuccessful so reliable data on this important aquatic health indicator do not exist.

5. Several reports show that various fish species regularly utilize Clinton Creek but lack of accessibility and overwintering habitat are likely causes of the near absence of fish in Hudgeon Lake and its tributaries.

6. Characterizations of chemical and biological characteristics in nearby reference areas are lacking.

7. Overall, there is insufficient information to make conclusions regarding the health of aquatic ecosystems downstream of the Clinton Creek Mine.

6.0 RECOMENDATIONS

1. Implement a routine (e.g., monthly) water quality monitoring program to characterize concentrations of asbestos and other contaminants in different seasons and flow scenarios. (Note: Water samples collected in the summer of 2009 captured both very low and very high flow conditions in both reference and mine-exposed areas, so this information will contribute to the understanding of spatial and temporal variability).

2. Consider collection of water samples for the purpose of conducting laboratory toxicity tests, particularly in a high flow event when suspension of asbestos fibres is likely to be maximal. Histological analysis of the tissues of exposed biota may also be appropriate to characterize the extent of contamination by asbestos fibres; this would assist in characterizing concentrations that may be toxic to resident biota.

3. Collect sediment samples to characterize the concentrations of asbestos and other contaminants (Note: Some samples were collected in summer 2009 which will assist in addressing this recommendation.)

4. Consider potential collection of sediment samples for laboratory toxicity testing. As with water, this will contribute to the understanding of the concentrations, particularly of asbestos, that causes effects on aquatic biota.

5. Assess benthic invertebrate health through collection of resident organisms using a method other than artificial substrates. In particular it is recommended that a kick sampling technique be used as there is potential for reference data collected by this method in other parts of the Yukon to be used as part of future benthic invertebrate community health assessments. Samples should also be collected from reference areas possessing similar habitat to the mine-exposed areas in the Clinton Creek watershed so that reference-exposure area comparisons can be made (Note: In anticipation of this recommendation, benthic invertebrate samples were collected in August 2009 from reference and exposure areas by kick sampling and the results will at least partially address this recommendation).

6. Conduct a comparative evaluation of fish communities in mine-exposed areas relative to local reference areas possessing similar habitat characteristics in order to better understanding potential mine-related effects on fish. Evaluations should include estimates of abundance and condition of a sentinel species (Note: A fish survey was undertaken in September 2009, but there was difficulty identifying local reference areas that support fish. Regardless, this new information will contribute to a better

understanding of potential mine-related effects on fish in the Clinton Creek watershed).

7. Evaluate technical options and costs associated with fish habitat remediation that could be made at the site (e.g., removing barriers to fish passage, remediating the amount of or access to over-wintering habitats, etc.)

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APPENDIX A

Water Quality Benchmarks

APPENDIX A: EFFECTS-BASED WATER QUALITY BENCHMARKS

In all cases where a Canadian Water Quality Guideline (CWQG) exists for a parameter, such a guideline was selected as the benchmark for evaluation of water quality at Clinton Creek (Appendix A.2). In the absence of a CWQG, the most conservative provincial water quality criterion from British Columbia, Saskatchewan, or Ontario was selected, if such value(s) existed. An exception was the uranium guideline from Saskatchewan which is based on more recent information than the Ontario water quality objective for uranium. In the absence of either a Canadian or provincial criterion for protection of aquatic life, a Canadian drinking water quality guideline was selected. For parameters for which no water quality criteria have been developed, alternative benchmarks were identified that represent a low- or no- observed effect concentration reported in the scientific literature for a sensitive aquatic species.

Some water quality criteria vary on the basis of water hardness (beryllium cadmium, copper, lead, manganese, nickel). In such cases, the criterion corresponding to a hardness of 200 mg/L as $CaCO_3$ was selected. A hardness value of 200 mg/L can be considered conservative since water hardness concentrations ranging from 214 to 2553 mg/L (Table 3.2) have been observed in mine-affected and reference areas in the vicinity of the Clinton Creek Mine.

The CWQG for ammonia is expressed on the basis of un-ionized ammonia, which comprises an increasing fraction of the total ammonia present in water as either water pH or temperature increases (or both). Because the temperature and pH of surface waters near Clinton Creek Mine have typically been below a temperature of 15°C and pH of 8.5 in the past (Appendix Table A.4b), it is conservative to use as the benchmark the total ammonia concentration corresponding to an un-ionized concentration of 0.019 mg/L (the CWQG) under such conditions.

Similar to the CWQG for ammonia, the guideline for aluminum is pH-dependent. At the Clinton Creek Mine, the applicable aluminum CWQG is for surface waters with a pH greater than 6.5.

Although separate CWQGs exist for the two main valence states of chromium, speciation of chromium in water samples is not readily available from commercial laboratories and the lower value of 0.001 mg/L (for hexavalent chromium) is generally applied for data screening purposes.

Table A.1: Effects-based water quality benchmarks.

Measurements	Units	Water quality criteria					Alternative Aquatic Effects-Based Benchmarks[e]
		Canadian water quality guideline (for protection of FW aquatic life)[a]	British Columbia (freshwater)[b]	Saskatchewan[c]	Ontario Provincial Water Quality Objective[d]	Canadian Drinking Water Quality Guideline[a]	
Total metals							
Aluminum	mg/L	0.005 - 0.100[g]	0.05	0.005 - 0.100[g]	0.015 - 0.075[h]	0.1	
Antimony	mg/L				0.02[h]	0.006	0.15[i]
Arsenic	mg/L	0.005	0.005	0.005	0.005[h]	0.005 proposed	
Barium	mg/L					1.0	5.8[j]
Beryllium	mg/L				0.011 - 1.1[k]		0.0038[l]
Boron	mg/L		1.2		0.2[h]	5.000	
Cadmium	mg/L	0.000017 or more depending on hardness[B]		0.000017 or more depending on hardness[B]	0.0001 - 0.0005[h]	0.005	
Calcium	mg/L						116[j]
Chromium	mg/L	0.001 (hexavalent), 0.0089 (trivalent)		0.001 (hexavalent), 0.0089 (trivalent)	0.001 (hexavalent), 0.0089 (trivalent)	0.05	
Cobalt	mg/L		0.004		0.0009		
Copper	mg/L	0.002-0.004[n]	0.002-0.008[o]	0.002-0.004[n]	0.001-0.005[h]	1.0[p]	
Iron	mg/L	0.3		0.3	0.300	0.3[p]	
Lead	mg/L	0.001 - 0.007[q]	0.005-0.011[o]	0.001 - 0.007[q]	0.001 - 0.005[h]	0.010	
Lithium	mg/L						0.65[F]
Magnesium	mg/L						82[j]
Manganese	mg/L		hardness dependent[o]			0.05[k]	
Mercury	ug/L	0.026[r] (0.004)[s]	0.004 - 0.02[s]	0.026[r]	0.2 (filtered)	1.0	
Molybdenum	mg/L	0.073	1		0.04[h]		
Nickel	mg/L	0.025 - 0.150[t]		0.025 - 0.150[t]	0.025		
Potassium	mg/L						53[j]
Selenium	mg/L	0.001	0.002	0.001	0.100	0.01	
Silicon	mg/L						
Silver	mg/L	0.0001	0.00005/0.0015[u]	0.0001	0.0001		
Sodium	mg/L					200[p]	680[s]
Strontium	mg/L						9.3[v]
Thallium	mg/L	0.0008			0.0003[h]		
Tin	mg/L						0.35[j]
Titanium	mg/L						1.83[w]
Uranium	mg/L			0.015	0.005[h]	0.02	0.011[x]
Vanadium	mg/L				0.006[h]		0.024[y]
Zinc	mg/L	0.030	0.0075-0.090[o]	0.030	0.02[h]	5.0	
Non-metals							
Alkalinity - Total	mg/L as $CaCO_3$				no decreases more than 25% of natural concentration[f]		
Ammonia - total	mg/L	0.24[A]	1.9[A]		0.25[A]		
Chloride - dissolved	mg/L					250[p]	
Conductivity - laboratory	µS/cm						
Conductivity - in situ	µS/cm						
Fluoride	mg/L	0.120				1.5	
Hardness - Total	mg/L as $CaCO_3$						
Nitrate	mg/L	13	40		narrative	10	
Nitrite	mg/L	0.06	0.02-0.2[C]		0.06	3.2	
pH - Laboratory	pH units	6.5-9.0	6.5 - 9.0		6.5-8.5	6.5-8.5	
pH - in situ	pH units	6.5-9.0	6.5 - 9.0		6.5-8.5	6.5-8.5	
Phosphorus - nutrient analysis	mg/L		0.005-0.015 (lakes)		0.03 for rivers[h]		
Sulphate	mg/L		50			500[p]	
Temperature - in situ	˚C						

(grey shading) criteria selected for effects-based benchmark

[a] CCME (Canadian Council of Ministers of the Environment). 1999. Canadian Environmental Quality Guidelines. 1999 (plus updates), Canadian Council of Ministers of the Environment, Winnipeg
[b] BCMOE (British Columbia Ministry of Environment). 2006. British Columbia Approved Water Quality Guidelines (Criteria), 2006 Edition. Updated August 2006. For parameters with both maximum and 30-day average values, the 30-d average is shown.
[c] Saskatchewan Environment. 2006. Surface Water Quality Objectives. Interim Edition. EPB356. July 2006. 9pp.
[d] OMOE (Ontario Ministry of Environment and Energy). 1994. Policies, Guidelines, Provincial Water Quality Objectives of the Ministry of the Environment and Energy (Ontario), July 1994
[e] toxicity reference value for most sensitive aquatic receptor (aquatic plants, phytoplankton, benthic invertebrates, zooplankton, fish). From Senes Consultants Limited, Richmond Hill, Ontario.
[f] computed from data presented in this report and shown in Table B.2
[g] 0.005 mg/L at pH<6.5; 0.1 mg/L at pH ≥ 6.5
[h] interim objective
[i] for phytoplankton; U.S. EPA (United States Environmental Protection Agency). 1978. In-depth Studies on Health and Environmental Impacts of Selected Water Pollutants. Contract No. 68-0104646, U.S. EPA, Duluth, MN.
[j] for zooplankton; Biesinger, K.E. and G.M. Christensen. 1982. Effects of Varioue Metals on Survival, Growth, Reproduction, and Metabolism of *Daphnia magna*. *J. Fish. Res. Bd. Canada.* 29:1691-1700.
[k] 0.011 for hardness <75 mg/L and 1.1 for hardness >75 mg/L.
[l] for zooplankton; Kimball, G. n.d. The Effects of Lesser Known Metals and One Organic to Fathead minnows [*Pimephales promelas*] and *Daphnia magna*. U.S. Environmental Protection Agency, Duluth, MN.
[n] 0.002 at [$CaCO_3$] = 0-120 mg/L, 0.003 at [$CaCO_3$] = 120-180 mg/L, 0.004 at [$CaCO_3$] > 180 mg/L
[o] manganese = 0.0044 (hardness) + 0.605
[p] Canadian drinking water quality guideline, aesthetic objective (CCME 1999).
[q] 0.001 at [$CaCO_3$] = 0-60 mg/L, 0.002 at [$CaCO^3$] = 60-120 mg/L, 0.004 at [$CaCO_3$] = 120-180 mg/L, 0.007 at [$CaCO_3$] > 180 mg/L
[r] Inorganic mercury
[s] Organic mercury
[t] 0.025 at [$CaCO_3$] = 0-60 mg/L, 0.065 at [$CaCO^3$] = 60-120 mg/L, 0.110 at [$CaCO_3$] = 120-180 mg/L, 0.150 at [$CaCO_3$] > 180 mg/L
[u] hardnesses of ≤100 mg/L and >100 mg/L, respectively
[v] for fish; Dwyer, F.J., S.A. Burch, C.G. Ingersoll, and J.B. Hunn 1992 Toxicity of Trace Element and Salinity Mixtures to Striped Bass (Morone saxatilis) and Daphnia magna. Environ.Toxicol.Chem. 11(4):513-520
[w] for fish; Birge, W.J., J.A. Black, A.G. Westerman, and J.E. Hudson. 1979. In: C. Gale (Ed.) EPA-600/9-80-022, Oil Shale Symposium: Sampling, Analysis and Quality Assurance, March 1979, U.S. EPA, Cincinnati, OH: 519-534 (US NTIS PB80-221435).
[x] for phytoplankton and zooplankton; Franklin, N.M., J.L.Stauber, S.J. Markich, and R.P. Lim. 2000. pH-dependent Toxicity of Copper and Uranium to a Tropical Freshwater Algae (*Chlorella sp.*). *Aquatic Toxicology*. 48:275-289.
[y] for benthic invertebrates; Fargasova, A. 1997. Sensitivity of *Chironomus plumosus* Larvae to V^{5+}, Mo^{6+}, Mn^{2+}, Ni^{2+}, Cu^{2+}, and Cu^{+} Metal Ions and their Combinations. *Bull. Environ. Contam. Toxicol.* 59(1):956-962.
[A] based on conservative assumption of pH 8.5 and temperature of 15C to achieve un-ionized ammonia of <0.02 mg/L
[B] cadmium = $10^{\{0.86[\log(hardness)] - 3.2\}}$ in ug/L
[C] Depends on chloride concentration
[F] for Hyallela azteca; Borgman, U., Y. Couillard, P. Doyle, and D.G. Dixon. 2005. Toxicity of sixty-three metals and metalloids to Hyallela azteca at two levels of water hardness. Environ. Toxicol. Chem. 24:641-652.

Table A.2: Selected water quality effects benchmarks for Clinton Creek Mine closure assessment.

Measurements	Units	Selected water quality benchmarks[a]
Total metals		
Aluminum	mg/L	0.1
Antimony	mg/L	0.02
Arsenic	mg/L	0.005
Barium	mg/L	1.0
Beryllium	mg/L	1.1
Boron	mg/L	1.2
Cadmium	mg/L	0.00006
Calcium	mg/L	116
Chromium	mg/L	0.001
Cobalt	mg/L	0.004
Copper	mg/L	0.004
Iron	mg/L	0.3
Lead	mg/L	0.007
Lithium	mg/L	0.65
Magnesium	mg/L	82
Manganese	mg/L	1.5
Mercury	mg/L	0.000026
Molybdenum	mg/L	0.073
Nickel	mg/L	0.150
Potassium	mg/L	53
Selenium	mg/L	0.001
Silicon	mg/L	
Silver	mg/L	0.0001
Sodium	mg/L	200
Strontium	mg/L	9.3
Thallium	mg/L	0.0008
Tin	mg/L	0.35
Titanium	mg/L	1.83
Uranium	mg/L	0.015
Vanadium	mg/L	0.006
Zinc	mg/L	0.030
Non-metals		
Ammonia - total	mg/L	0.24
Chloride - dissolved	mg/L	250
Conductivity - laboratory	µS/cm	
Conductivity - in situ	µS/cm	
Fluoride	mg/L	0.12
Hardness - Total	mg/L as $CaCO_3$	
Nitrate	mg/L	13
Nitrite	mg/L	0.06
Nitrate plus nitrite	mg/L	
pH - Laboratory	pH units	6.5-9.0
pH - in situ	pH units	6.5-9.0
Phosphorus - nutrient analysis	mg/L	0.03
Sulphate	mg/L	50
Temperature - in situ	˚C	

[a] Benchmarks were selected from relevant water quality criteria as shown in Table A.1

APPENDIX B

Asbestos Toxicity Data

Table B.1: Summary of information on the toxicity of chrysotile asbestos in water from scientific literature.

Common Name	Scientific Name	Life Stage at Study Initiation	Effect exposure conditions	Minimum Effect Concentration	Observed Toxic Effects	Statistically Significant	Qualitative Observation	Reference
Planktonic algae	*Cryptomonas erosa*	-	48 hours	1-1.5 x 10^6 fibers/L	clumping of *Cryptomona cells* with intertwining asbestos fibers, fibers clinging to cell surface		x	Lauth and Schurr 1983
Duckweed	*Lemna gibba*	-	14 days	1.0 ug/mL (<30 um length fibers)	biochemical changes to glutathione indicate possible shift toward oxidative cellular environment	x		Trivedi et al. 2007
			21 days	0.5 ug/mL (<30 um length fibers)	biochemical changes to glutathione indicate possible shift toward oxidative cellular environment	x		
			7 days	5.0 ug/mL (< 30 um length fibers)	biochemical changes to glutathione indicate possible shift toward oxidative cellular environment	x		
			7 days	5.0 ug/mL (< 30 um length fibers)	biochemical changes to ascorbate indicate possible shift toward oxidative cellular environment	x		
			14 days	2.0 ug/mL (<30 um length fibers)	biochemical changes to ascorbate indicate possible shift toward oxidative cellular environment	x		
			21 days	0.5 ug/mL (<30 um length fibers)	biochemical changes to ascorbate indicate possible shift toward oxidative cellular environment	x		
Brine shrimp	*Artemia* sp.	3- day old	24 hours, with turbulence	2 x 10^2 mg/L (short fiber)	increased mortality	x		Stewart and Schurr 1980
		2-day old	22 - 26 hours, with turbulence	2 x 10^2 mg/L (short fiber)	increased mortality	x		
		3-day old	24 hours, with turbulence	2 x 10^2 mg/L (short fiber)	increased mortality in short fiber exposure versus long fiber. Since the same concentration was used, the difference between the two exposures was in the number of fibers.			
Asiatic clam	*Corbicula* sp.	adult	48 hours, no food	10^2 fibers/L	depressed siphoning	x		Belanger et al. 1986a
			30 days	10^2 fibers/L	depressed siphoning	x		
			30 days	10^4 fibers/L	reduced growth (shell length)	x		
			30 days	10^8 fibers/L	changes to gill microstructure (more and larger lamellar locules)			
			14 days	10^2 fibers/L	less larvae released and increased larval mortality,	x		
Clam	*Corbicula fluminea*	juvenile	30 days (collected in winter)	10^2 fibers/L	depressed siphoning	x		Belanger et al. 1986b
			30 days (collected in summer)	10^4 fibers/L	depressed siphoning	x		
			30 days (collected in summer)	10^4 fibers/L	reduced shell and tissue growth	x		
			30 days (collected in winter)	10^4 fibers/L	reduced shell and weight growth	x		
			30 days (collected in summer)	10^4 fibers/L	greater percent of water content in body tissue	x		
			30 days (collected in winter)	10^5 fibers/L	greater percent of water content in body tissue	x		
			30 days (collected in summer and winter)	10^8 fibers/L	increase in size and surface area of gill locules	x		
Amazon molly	*Poecilia formosa*	2 mos. Old	6 months	0.1 mg/L coarse fibers	kidney damage (e.g., necrosis of hemopoietic tissue, dilation of renal tubule)		x	Woodhead et al. 1983
			6 months	0.1 mg/L fine fibers (~0.2-2.0 um long)	kidney damage (e.g., necrosis of hemopoietic tissue, dilation of renal tubule)			
			6 months	0.1 mg/L coarse fibers	gill damage (e.g., ruptured pilaster cells causing lamellar telangiectasia, cell hypertrophy and hyperplasia)			
			6 months	0.1 mg/L fine fibers (~0.2-2.0 um long)	gill damage (e.g., ruptured pilaster cells causing lamellar telangiectasia, cell hypertrophy and hyperplasia)			
			6 months	1 mg/L coarse fibers	heart damage (e.g., small areas of vacuolation and necrosis)			
Coho salmon	*Oncorhynchus kisutch*	larvae	40 days	3.0 x 10^6 fibers/L	tumerous swelling under opercle, enlarged coelomic cavity, mortality		x	Belanger et al. 1986c
			40 days	3.0 x 10^6 fibers/L	distorted lateral line region, lateral nerve rested in a constricted channel, epidermis in region of lateral line severely eroded, vacuolated cells along the ventrum and near the lateral line organ, hyperplasia and hypertrophy of epidermal tissue		x	
			13 days	3.0 x 10^6 fibers/L	abnormal swimming behaviour (lack of positive rheotaxi, lying on bottom of tank)			
				1.5 x 10^6 fibers/L + TMS	time to loss of equilibrium and ataxia	x		
Green sunfish	*Lepomis cyanellus*	juvenile	52 days	3.0 x 10^6 fibers/L	loss of scales and skin surface tissues		x	Belanger et al. 1986c
			67 days	1.5 x 10^6 fibers/L	abnormal swimming behaviour		x	
			52 days	3.0 x 10^6 fibers/L	abnormal swimming behaviour			
Japanese Medaka	*Oryzias latipes*	egg	13-21 days	10^4 fibers/L	increased days to hatch	x		Belanger et al. 1990
		larvae	14 days	10^6 fibers/L	decreased growth	x		
		larvae	time to reach sig. diff. not clear	10^6 fibers/L	increased mortality	not known		
		larvae or juvenile	13 weeks	10^6 fibers/L	thickened epidermal tissue	x		
		larvae or juvenile	13 weeks	10^4 fibers/L	irregular outer epidermal layer		x	
		larvae or juvenile	28 - 56 days	10^{10} fibers/L	ventral non-invasive epidermal hyperplastic plaques (5% of fish)		x	
		adult	20 weeks (exposure), 4 weeks recovery	10^8 fibers/L	lower spawning frequency	x		

APPENDIX C

Supporting Site Chemistry and Biology Data

Table C.1 Site concordance for available water quality data.

Water body	Description	Station ID	Source	Parameters
Hudgeon L.	near Clinton Creek inlet	CLCR-7	RR 1999	asbestos, ions, nutrients, metals, physical
	near East Creek inlet	CLCR-4	RR 1999	metals, physical
		HL-03-04	Senes 2003	ions, nutrients, hardness
		HL-04	YG 2003-2004	metals
		HL-03-05	Senes 2003	ions, nutrients, hardness
		HL-05	YG 2003	metals
	middle	CLCR-6	RR 1999	asbestos, ions, nutrients, metals, physical
	near Bear Creek inlet	CLCR-8	RR 1999	asbestos, ions, nutrients, metals, physical
	adjacent waste rock (SE)	CLCR-1	RR 1999	metals
		HL-03-01,	Senes 2003	ions, nutrients, hardness
		HL-01	YG 2003	metals
	adjacent waste rock near outlet	HL-03-02	Senes 2003	ions, nutrients, hardness
		HL-02	YG 2003	metals
	by pumphouse for mine water supply	no station ID just description	Landucci 1978	asbestos
	outlet	CLCR-2	RR 1999	asbestos, ions, nutrients, metals, physical
		HL-03-06	Senes 2003	ions, nutrients, hardness
		HL-06	YG 2003, 2005-2008	metals
East Creek (reference)	near mouth at Hudgeon L. (reference)	CLCR-5	RR 1999	asbestos, metals, ions, nutrients, physical
		HL-03-03	Senes 2003	ions, nutrients, hardness
		HL-03 (WQ data also labelled	YG 2003-2006	metals
Clinton Creek	upstream Hudgeon L. (reference)	station 1	Landucci 1978	physical, metals, non-metals
	Zone 1 d/s Hudgeon L., u/s Porcupine Cr.	CLWR-13	RR 1999	metals
		CC-03-03	Senes 2003	ions, nutrients, hardness
		CC-03	YG 2003	metals
	Zone 2a u/s Wolverine Creek	station 2	Landucci 1978	physical, metals, non-metals
		CC-03-01,	Senes 2003	ions, nutrients, hardness
		CC-01	YG 2003, 2005-2008	metals
	Zone 2b at or d/s Wolverine Cr	station 5	Landucci 1978	physical, metals, non-metals
		CLCR-Z2	RR 1999	physical, metals
		CLCR-3	RR 1999	metals
		CC-03-02	Senes 2003	ions, nutrients, hardness
		CC-02	YG 2003-2004	metals
	Zone 3b at or d/s Eagle Creek (reference)	station 6	Landucci 1978	physical, metals, non-metals
		CLCR-Z3	RR 1999	physical
		CC-03-04	Senes 2003	ions, nutrients, hardness
		CC-04	YG 2003-2007	metals
		CC-05	YG 2003	metals
	Zone 4 middle Clinton Creek	CLCR-Z4	RR 1999	physical
		CC-03-05	Senes 2003	ions, nutrients, hardness
	Zone 5	CLCR-Z5	RR 1999	physical
	Zone 6 lower Clinton Creek	station 7	Landucci 1978	physical, metals, non-metals
		CLCR-Z6	RR 1999	asbestos, ions, nutrients, metals, physical
		CC-03-06,	Senes 2003	ions, nutrients, hardness
		CC-03-07	Senes 2003	ions, nutrients, hardness
		CC-06	YG 2003-2007	metals
Porcupine Creek	upper adjacent waste rock	PC-03-01	Senes 2003	ions, nutrients, hardness
		PC-01	YG 2003	metals
	middle near waste rock	CLWR-7	RR 1999	ions, nutrients, metals
		PC-03-02	Senes 2003	ions, nutrients, hardness
		PC-02	YG 2003	metals
		PC-03-03	Senes 2003	ions, nutrients, hardness
		PC-03	YG 2003	metals
	near mouth at Clinton Creek	PC-03-04	Senes 2003	ions, nutrients, hardness
		PC-04	YG 2003-2008	metals
Wolverine Creek	u/s of tailings pile (reference)	station 3	Landucci 1978	physical, metals, non-metals
		CLWC-1	RR 1999	metals, ions, nutrients, physical
		WC-03-01	Senes 2003	ions, nutrients, hardness
	adjacent tailings	CLWC-2	RR 1999	asbestos, ions, nutrients, metals, physical
		CLWC-3	RR 1999	asbestos, anions
		WC-03-02	Senes 2003	ions, nutrients, hardness
		WC-02	YG 2003	metals
		WC-03-03	Senes 2003	ions, nutrients, hardness
		WC-03	YG 2003	metals
		WC-03-04	Senes 2003	ions, nutrients, hardness
		WC-04	YG 2003	metals
	d/s tailings	Station 4	Landucci 1978	physical, metals, non-metals
		WC-03-05	Senes 2003	ions, nutrients, hardness
		WC-05	YG 2003-2008	metals
Eagle Creek (reference)	near mouth at Clinton Creek (reference)	CLCR-Z3B	RR 1999	asbestos, physical, metals
		EC-03-01	Senes 2003	ions, nutrients, hardness
		EC-01	YG 2003-2008	metals
Mickey Creek	no description	MC-01	YG 2003	metals
Fortymile River	Zone 8 u/s Clinton Creek (reference)	station 9	Landucci 1978	physical, metals, non-metals
		no station ID in the report, just	Landucci 1978	asbestos
		CLCR-Z8	RR 1999	asbestos, metals
		FM-03-01, FM-03-02	Senes 2003	ions, nutrients, hardness
		FM-01, FM-02	YG 2003, 2005-2007	metals
	Zone 7 d/s Clinton Creek	station 8	Landucci 1978	physical, metals, non-metals

YG - Yukon Government excel spreadsheets of water quality data (there are associated maps and GPS coordinates but no report)
RR - Royal Roads University (1999) report
SENES 2003 station data but not indicated on map: FM-03-03
Reference Areas
Locations that were the focus of the water quality evaluation

Table C.2: Grey highlighting shows values below detection where the method detection limit exceeded the water quality benchmark (method detection limits were not provided for data collected in 2003)

Station ID	Guideline[a]	CLCR-Z3B	CLCR-5	EC-01	HL-03	HL-06				CC-01			
Station Description		Eagle Creek	East Creek	Eagle Creek	East Creek	Hudgeon Lake Outlet				Clinton Creek d/s Wolverine Creek			
Source		Royal Roads		YG/SENES		YG/SENES	YG	YG	YG	YG/SENES	YG	YG	YG
Sample Date		11-Sep-98	10-Sep-98	24-Sep-03	23-Sep-03	23-Sep-03	20-Sep-05	5-Oct-05	3-Oct-06	24-Sep-03	20-Sep-05	5-Oct-05	3-Oct-06
Aluminum	0.1	0.98	0.066	0.023	0.014	0.148	< 0.20	< 0.20	< 0.20	0.081	< 0.20	< 0.20	< 0.20
Antimony	0.02	<0.2	<0.2	0.0005	0.0006	0.0005	< 0.20	< 0.20	< 0.20	0.0005	< 0.20	< 0.20	< 0.20
Arsenic	0.005	<0.2	<0.2	0.0006	0.0007	0.0007	< 0.20	< 0.20	< 0.20	0.001	< 0.20	< 0.20	< 0.20
Barium	1.0	0.08	0.03	0.06	0.05	0.05	0.054	0.051	0.063	0.05	0.063	0.048	0.059
Beryllium	1.1	<0.005	<0.005	0.001	0.001	0.001	< 0.0050	< 0.0050	< 0.0050	0.001	< 0.0050	< 0.0050	< 0.0050
Bismuth	0.26					-	< 0.20	< 0.20	< 0.20	-	< 0.20	< 0.20	< 0.20
Boron	1.2	<0.1	<0.1	0.1	0.1	0.1	< 0.10	< 0.10	< 0.10	0.1	< 0.10	< 0.10	< 0.10
Cadmium	0.00006	<0.0002	<0.0002	0.00005	0.00005	0.00006	< 0.010	< 0.010	< 0.010	0.00006	< 0.010	< 0.010	< 0.010
Calcium	116	41.8	32.1	60.4	60.5	45.3	72.6	65.4	65.6	59.1	70.5	68.3	71.2
Chromium	0.001	<0.01	<0.01	0.001	0.001	0.001	< 0.010	< 0.010	< 0.010	0.001	< 0.010	< 0.010	< 0.010
Cobalt	0.004	<0.01	<0.01	0.0003	0.0003	0.0005	< 0.010	< 0.010	< 0.010	0.0005	< 0.010	< 0.010	< 0.010
Copper	0.004	<0.01	<0.01	0.002	0.001	0.003	< 0.010	< 0.010	< 0.010	0.003	< 0.010	< 0.010	< 0.010
Iron	0.3	0.66	0.17	0.05	0.17	0.41	0.085	0.181	0.154	0.31	0.086	0.231	0.176
Lead	0.007	<0.001	<0.001	0.0005	0.0005	0.0005	< 0.050	< 0.050	< 0.050	0.0005	< 0.050	< 0.050	< 0.050
Lithium	0.65			0.005	0.007	0.005	< 0.010	< 0.010	< 0.010	0.005	< 0.010	< 0.010	< 0.010
Magnesium	82	14.8	21.9	25.8	41.4	24.5	55	42.4	38.0	37.1	33.4	44.7	44.4
Manganese	1.5	0.040	0.010	0.006	0.0786	0.161	0.0584	0.2090	0.120	0.113	0.0193	0.116	0.0836
Mercury	0.000026	<0.00005	<0.00005	0.00005	0.00005	0.00005				0.00005			
Molybdenum	0.073	<0.03	<0.03	0.001	0.001	0.001	< 0.030	< 0.030	< 0.030	0.001	< 0.030	< 0.030	< 0.030
Nickel	0.150	<0.05	<0.05	0.004	0.002	0.005	< 0.050	< 0.050	< 0.050	0.01	< 0.050	< 0.050	< 0.050
Phosphorus	0.03						< 0.30	< 0.30	< 0.30		< 0.30	< 0.30	< 0.30
Potassium	53			2	2	2	< 2.0	< 2.0	< 2.0	2	< 2.0	< 2.0	< 2.0
Selenium	0.001	0.0023	<0.001	0.003	0.001	0.001	< 0.20	< 0.20	< 0.20	0.001	< 0.20	< 0.20	< 0.20
Silicon	-					-	4.64	4.4	4.37	-	4.74	4.35	4.30
Silver	0.0001	<0.0001	<0.0001	0.00002	0.00002	0.00002	< 0.010	< 0.010	< 0.010	0.00002	< 0.010	< 0.010	< 0.010
Sodium	200			3	3	2	3.5	3.4	3.2	3	3.8	3.4	3.3
Strontium	9.3					-	0.405	0.354	0.317	-	0.298	0.38	0.360
Thallium	0.0008	<0.0001	<0.0001	0.0002	0.0002	0.0002	< 0.20	< 0.20	< 0.20	0.0002	< 0.20	< 0.20	< 0.20
Tin	0.35			0.0005	0.0005	0.0005	< 0.030	< 0.030	< 0.030	0.0005	< 0.030	< 0.030	< 0.030
Titanium	1.83			0.01	0.01	0.01	< 0.010	< 0.010	< 0.010	0.01	< 0.010	< 0.010	< 0.010
Uranium	0.015	0.00078	0.00159	0.0019	0.0049	0.0018			-	0.002			
Vanadium	0.006			0.03	0.03	0.03	< 0.030	< 0.030	< 0.030	0.03	< 0.030	< 0.030	< 0.030
Zinc	0.030	<0.005	<0.005	0.005	0.005	0.005	< 0.0050	< 0.0050	0.0085	0.005	< 0.0050	< 0.0050	< 0.0050
Hardness[b]	-			257	322	214	408	338	320	300	314	355	361
Bromide	-			<0.05	<0.05								
Chlroride	250			<0.5	<0.5								
Fluoride	0.12			0.13	0.19								
Sulphate	50			115	144								
Nitrate as N	13			0.178	0.048	0.161				0.154			
Nitrite as N	0.06			<0.001	<0.001	0.002				0.002			
Ammonia as N	0.24			<0.02	<0.005	0.014				< 0.02			

value exceeds guideline (yellow)

method detection limit exceeds guideline (grey)

[a] see table A.2 for sources

[b] 2003, 2005 and 2006 hardness values were calculated based on calcium and magnesium

YG - Yukon Government

SENES - SENES Consultants Limited

Note: values less than the detection limit were not indicated for 2003 and 2005 metals data.

For 2005, values equal to the detection limit were assumed to be less than detection while detection limits were not provided for 2003

Table C.2: Grey highlighting shows values below detection where the method detection limit exceeded the water quality benchmark (method detection limits were not provided for data collected in 2003)

Station ID	Guideline[a]	PC-04				CC-04			
Station Description		Porcupine Creek near mouth of Clinton Creek				Clinton Creek d/s of Eagle Creek			
Source		YG/SENES	YG	YG	YG	YG/SENES	YG	YG	YG
Sample Date		23-Sep-03	20-Sep-05	5-Oct-05	3-Oct-06	24-Sep-03	20-Sep-05	5-Oct-05	3-Oct-06
Aluminum	0.1	0.03	< 0.20	< 0.20	< 0.20	0.048	< 0.20	< 0.20	< 0.20
Antimony	0.02	0.003	< 0.20	< 0.20	< 0.20	0.0005	< 0.20	< 0.20	< 0.20
Arsenic	0.005	0.003	< 0.20	< 0.20	< 0.20	0.0007	< 0.20	< 0.20	< 0.20
Barium	1.0	0.03	0.02	0.02	0.052	0.06	0.058	0.048	0.023
Beryllium	1.1	0.005	< 0.0050	< 0.0050	< 0.0050	0.001	< 0.0050	< 0.0050	< 0.0050
Bismuth	0.26		< 0.20	< 0.20	< 0.20		< 0.20	< 0.20	< 0.20
Boron	1.2	0.1	0.16	0.16	< 0.10	0.1	0.13	< 0.10	0.23
Cadmium	0.00006	0.0003	< 0.010	< 0.010	< 0.010	0.00007	< 0.010	< 0.010	< 0.010
Calcium	116	231	212	207	77.1	59.4	112	81.7	230
Chromium	0.001	0.005	< 0.010	< 0.010	< 0.010	0.001	< 0.010	< 0.010	< 0.010
Cobalt	0.004	0.002	< 0.010	< 0.010	< 0.010	0.0003	< 0.010	< 0.010	< 0.010
Copper	0.004	0.005	< 0.010	< 0.010	< 0.010	0.003	< 0.010	< 0.010	< 0.010
Iron	0.3	0.03	0.03	0.03	0.245	0.17	0.395	0.275	< 0.030
Lead	0.007	0.003	< 0.050	< 0.050	< 0.050	0.0005	< 0.050	< 0.050	< 0.050
Lithium	0.65	0.04	0.038	0.032	< 0.010	0.005	0.022	0.017	0.101
Magnesium	82	257	283	265	59.3	32.4	109	64.3	316
Manganese	1.5	0.002	< 0.0050	< 0.0050	0.138	0.0519	0.282	0.188	< 0.0050
Mercury	0.000026	0.00005				0.00005			
Molybdenum	0.073	0.005	< 0.030	< 0.030	< 0.030	0.001	< 0.030	< 0.030	< 0.030
Nickel	0.150	0.092	0.077	0.076	< 0.050	0.008	< 0.050	< 0.050	0.102
Phosphorus	0.03		< 0.30	< 0.30	< 0.30		< 0.30	< 0.30	< 0.30
Potassium	53	2	2.2	< 2.0	< 2.0	2	< 2.0	< 2.0	2.8
Selenium	0.001	0.005	< 0.20	< 0.20	< 0.20	0.002	< 0.20	< 0.20	< 0.20
Silicon	-		5.19	5.2	4.32		4.64	4.71	5.74
Silver	0.0001	0.0001	0.02	< 0.010	< 0.010	0.00002	< 0.010	< 0.010	< 0.010
Sodium	200	11	12.0	11.2	4.4	4	6.8	5	26.5
Strontium	9.3		1.21	1.19	0.448		0.68	0.509	1.82
Thallium	0.0008	0.001	< 0.20	< 0.20	< 0.20	0.0002	< 0.20	< 0.20	< 0.20
Tin	0.35	0.003	< 0.030	< 0.030	< 0.030	0.0005	< 0.030	< 0.030	0.126
Titanium	1.83	0.01	< 0.010	< 0.010	< 0.010	0.01	< 0.010	< 0.010	< 0.010
Uranium	0.015	0.006				0.0021			
Vanadium	0.006	0.03	< 0.030	< 0.030	< 0.030	0.03	< 0.030	< 0.030	< 0.030
Zinc	0.030	0.03	0.0053	0.0063	< 0.0050	0.005	< 0.0050	< 0.0050	0.0087
Hardness[b]	-	1635	1695	1608	437	282	729	469	1876
Bromide	-								
Chlroride	250								
Fluoride	0.12								
Sulphate	50								
Nitrate as N	13	0.379				0.158			
Nitrite as N	0.06	0.002				0.002			
Ammonia as N	0.24	< 0.005				< 0.02			

value exceeds guideline (yellow)

method detection limit exceeds guideline (grey)

[a] see table A.2 for sources

[b] 2003, 2005 and 2006 hardness values were calculated based on calcium and magnesium

YG - Yukon Government

SENES - SENES Consultants Limited

Note: values less than the detection limit were not indicated for 2003 and 2005 metals data.

For 2005, values equal to the detection limit were assumed to be less than detection while detection limits were not provided for 2003

Table C.2: Grey highlighting shows values below detection where the method detection limit exceeded the water quality benchmark (method detection limits were not provided for data collected in 2003)

Station ID	Guideline[a]	WC-05				CC-06			
Station Description		Wolverine Creek d/s of tailings				Clinton Creek d/s of Eagle Creek			
Source		YG/SENES	YG	YG	YG	YG/SENES	YG	YG	YG
Sample Date		24-Sep-03	20-Sep-05	5-Oct-05	3-Oct-06	24-Sep-03	20-Sep-05	5-Oct-05	3-Oct-06
Aluminum	0.1	0.031	< 0.20	< 0.20	< 0.20	0.07	< 0.20	< 0.20	< 0.20
Antimony	0.02	0.0014	< 0.20	< 0.20	< 0.20	0.001	< 0.20	< 0.20	< 0.20
Arsenic	0.005	0.0008	< 0.20	< 0.20	< 0.20	0.001	< 0.20	< 0.20	< 0.20
Barium	1.0	0.05	0.063	0.06	0.052	0.04	0.066	0.048	0.049
Beryllium	1.1	0.001	< 0.0050	< 0.0050	< 0.0050	0.002	< 0.0050	< 0.0050	< 0.0050
Bismuth	0.26		< 0.20	< 0.20	< 0.20		< 0.20	< 0.20	< 0.20
Boron	1.2	0.1	0.16	0.15	< 0.10	0.1	< 0.10	< 0.10	< 0.10
Cadmium	0.00006	0.00005	< 0.010	< 0.010	< 0.010	0.0001	< 0.010	< 0.010	< 0.010
Calcium	116	54.6	78.7	71.3	63.3	72.5	116	82.5	72.1
Chromium	0.001	0.001	< 0.010	< 0.010	< 0.010	0.002	< 0.010	< 0.010	< 0.010
Cobalt	0.004	0.0003	< 0.010	< 0.010	< 0.010	0.0007	< 0.010	< 0.010	< 0.010
Copper	0.004	0.002	< 0.010	< 0.010	< 0.010	0.002	< 0.010	< 0.010	< 0.010
Iron	0.3	0.09	0.04	0.057	0.162	0.33	0.286	0.359	0.271
Lead	0.007	0.0005	< 0.050	< 0.050	< 0.050	0.001	< 0.050	< 0.050	< 0.050
Lithium	0.65	0.008	< 0.010	0.012	< 0.010	0.02	0.023	0.018	< 0.010
Magnesium	82	55.2	85.3	71.3	56.7	57.7	109	65.3	52.4
Manganese	1.5	0.0336	0.0222	0.0272	0.0296	0.201	0.246	0.237	0.136
Mercury	0.000026	0.00005				0.00005			
Molybdenum	0.073	0.001	< 0.030	< 0.030	< 0.030	0.002	< 0.030	< 0.030	< 0.030
Nickel	0.150	0.014	< 0.050	< 0.050	< 0.050	0.02	< 0.050	< 0.050	< 0.050
Phosphorus	0.03		< 0.30	< 0.30	< 0.30		< 0.30	< 0.30	< 0.30
Potassium	53	2	< 2.0	< 2.0	< 2.0	2	< 2.0	< 2.0	< 2.0
Selenium	0.001	0.001	< 0.20	< 0.20	< 0.20	0.002	< 0.20	< 0.20	< 0.20
Silicon	-		4.54	5.44	5.39		4.5	4.72	4.42
Silver	0.0001	0.00004	< 0.010	< 0.010	< 0.010	0.00004	0.02	< 0.010	< 0.010
Sodium	200	4	5.2	5.2	4.1	5	7.2	5.2	4.1
Strontium	9.3		0.437	0.43	0.327		0.699	0.524	0.400
Thallium	0.0008	0.0002	< 0.20	< 0.20	< 0.20	0.0004	< 0.20	< 0.20	< 0.20
Tin	0.35	0.0005	< 0.030	< 0.030	< 0.030	0.001	< 0.030	< 0.030	< 0.030
Titanium	1.83	0.01	< 0.010	0.01	< 0.010	0.01	< 0.010	< 0.010	< 0.010
Uranium	0.015	0.0021				0.0024			
Vanadium	0.006	0.03	< 0.030	< 0.030	< 0.030	0.03	< 0.030	< 0.030	< 0.030
Zinc	0.030	0.005	< 0.0050	< 0.0050	< 0.0050	0.01	< 0.0050	< 0.0050	< 0.0050
Hardness[b]	-	364	548	472	392	419	739	475	396
Bromide	-								
Chlroride	250								
Fluoride	0.12								
Sulphate	50								
Nitrate as N	13	0.098				0.122			
Nitrite as N	0.06	0.005				0.002			
Ammonia as N	0.24	< 0.02				< 0.02			

(yellow) value exceeds guideline

(grey) method detection limit exceeds guideline

[a] see table A.2 for sources

[b] 2003, 2005 and 2006 hardness values were calculated based on calcium and magnesium

YG - Yukon Government

SENES - SENES Consultants Limited

Note: values less than the detection limit were not indicated for 2003 and 2005 metals data.

For 2005, values equal to the detection limit were assumed to be less than detection while detection limits were not provided for 2003

Appendix Table C.3: Water quality data for Clinton Creek mine (Landucci 1978).

Station	Description (from report)	Sample Date	Temp C	Cond umho/cm	DO ppm	pH Field	pH Lab	NFR mg/L	Alkalinity-Total mg/L	Colour CU	Hardness-Total mg/L	Turbidity JTU or FTU
1	Clinton Creek above Hudgeon Lake	7-Aug-74	5.5	145	9.5	7.4	7.7	2.5	210.0	70	230	<0.5
		26-Jun-75	6.0	550	2.5	7.4						
		8-Aug-75	4.0	172	10.3	7.7		6.0	93.5	97	150	0.8
2	Clinton Creek d/s of waste rock pile, u/s of confluence with Wolverine Creek	7-Aug-74	11.0	455	6.0	7.8	7.7	25.0	170.0	45	1200	75.0
		26-Jun-75	14.0	580	8.0	7.8						
		8-Aug-75	13.9	130	8.2	7.6		36.0	96.8	126	180	4.7
3	Wolverine Creek u/s of Wolverine Lake	7-Aug-74	8.0	252	7.2	7.0	7.6	35.0	150.0	60	100	<.5
		26-Jun-75	6.0	400	9.5	8.1						
		8-Aug-75	5.8	195	10.2	7.8		3.0	86.9	125	160	0.7
4	Wolverine Creek just u/s of confluence with Clinton Creek	7-Aug-74	15.0	300	8.3	9.5	9.7	15.0	240.0	30	1100	46.0
		26-Jun-75	7.0	500	6.5	9.2						
		8-Aug-75	6.0	315	9.6	8.8		61.0	131.0	93	360	10.0
5	Clinton Creek ~300m d/s of confluence with Wolverine Creek	7-Aug-74	14.0	385	7.4	8.3	9.0	4.0	220.0	35	1400	48.0
		26-Jun-75	13.5	590	8.4	8.9						
		8-Aug-75	14.0	230	8.1	7.3		28.0	99.0	112	250	3.5
6	Clinton Creek ~5km d/s of station 5	7-Aug-74	13.0	375	4.3	7.0	7.2	<2.5	320.0	25	1200	9.7
		26-Jun-75	13.5	700	7.5	7.2						
		8-Aug-75	13.5	380	8.0	7.8		29.0	125.0	115	290	13.0
7	Clinton Creek 100m u/s of road leading to town site	7-Aug-74	9.5	280	9.3	7.5	7.9	2.5	210.0	60	380	1.2
		26-Jun-75	13.5	600	9.5	8.0						
		8-Aug-75	8.7	285	9.1	7.8		62.0	93.5	122	290	12.0
8	Fortymile River 300m d/s of Clinton Creek mouth	7-Aug-74	13.8	220		7.9	7.7	<2.5	110.0	55	140	0.7
		26-Jun-75	13.0	300	9.0	8.1						
		8-Aug-75	12.8	240	8.7	7.8		52.0	129.0	131	190	20.0
9	Fortymile River 100m u/s of Clinton Creek mouth	7-Aug-74	15.0	132		7.8	7.2	2.8	59.0	25	34	0.5
		26-Jun-75	12.5	130	8.2	8.1						
		8-Aug-75	12.0	80	8.7	7.6		17.0	40.7	109	48	2.2

NFR - non filterable residue
FTU - Formazin turbidity units
JTU - Jackson turbidity units

Appendix Table C.3: Water quality data for Clinton Creek mine (Landucci 1978).

Station	Calcium ppm	Magnesium ppm	Cadmium ppm	Copper ppm	Iron ppm	Lead ppm	Molybdenum ppm	Nickel ppm	Manganese ppm	Potassium ppm	Silver ppm	Zinc ppm	Mercury ppm
1		37.0	<0.1	<0.1	0.15	<0.1	<0.3		<0.03	0.40		<0.01	
	32.0	16.0	<0.1	<0.1	0.23	<0.2	<0.3	<0.05			<0.03	<0.01	<0.15
2	110.0	220.0	<0.1	<0.1	1.30	<0.2	<0.3		0.59	2.50		<0.01	
	37.0	21.5	<0.1	<0.1	1.30	<0.2	<0.3	<0.05			<0.03	<0.01	<0.15
3	39.0	2.7	<0.1	<0.1	0.28	<0.1	<0.3		<0.03	0.71		<0.01	
	28.0	22.5	<0.1	<0.1	0.25	<0.2	<0.3	<0.05			<0.03	<0.01	<0.15
4	5.0	270.0	<0.1	<0.1	2	<0.1	<0.3		0.14	1.90		<0.01	
	46.0	60.5	<0.1	<0.1	1.60	<0.2	<0.3	0.16			<0.03	<0.01	<0.15
5		210.0	<0.1	<0.1	1.90	<0.1	<0.3		0.39	2.20		<0.01	
	48.0	31.5	<0.1	<0.1	0.90	<0.2	<0.3	<0.05			<0.03	<0.01	<0.15
6	5.9	280.0	<0.1	<0.1	0.66	<0.1	<0.3		0.29	2.20		<0.01	
	48.0	42.0	<0.1	<0.1	1.40	<0.2	<0.3	0.07			<0.03	<0.01	<0.15
7	40.0	70.0	<0.1	<0.1	0.14	<0.1	<0.3		0.17	1		<0.01	
	46.0	42.5	<0.1	<0.1	1.50	<0.2	<0.3	0.09			<0.03	<0.01	<0.15
8	16.0	24.0	<0.1	<0.1	0.12	<0.1	<0.3		0.12	1.30		<0.01	
	31.0	27.0	<0.1	<0.1	1	<0.2	<0.3				<0.03	<0.01	<0.15
9	12.0	0.7	<0.1	<0.1	0.07	<0.1	<0.3		0.08	0.97		<0.01	
	27.0	4.3	<0.1	<0.1	0.6	<0.2	<0.3	<0.05			<0.03	<0.01	<0.15

NFR - non filterable residue
FTU - Formazin turbidity units
JTU - Jackson turbidity units

Appendix Table C.4: Water quality data for Clinton Creek mine (Royal Roads University 1999).

Station ID	CLCR-1	CLCR-2	CLCR-3	CLCR-4	CLCR-5	CLCR-6	CLCR-6A	CLCR-7
Station Description	Hudgeon Lake	Hudgeon Lake	Clinton Creek	Hudgeon Lake	Creek into Hudgeon L (reference)	Hudgeon Lake	field duplicate of CLCR-6	Hudgeon Lake
Parameters	13-Sep-98	10-Sep-98	11-Sep-98	10-Sep-98	10-Sep-98	10-Sep-98	11-Sep-98	10-Sep-98
pH		7.66		7.36	7.43	7.05		7.44
Temperature (°C)		8.5		9.9	5.0	8.4		8.2
Conductivity (uS)		307		310	212	312		289
Dissolved anions (mg/L)								
Alkalinity-Total		105			101	102	337	98
Bromide		<0.5			<0.5	<0.5	<0.5	<0.5
Chlroride		<0.5			<0.5	<0.5	2.2	<0.5
Fluoride		0.13			0.19	0.14	0.26	0.17
Sulphate		110			61	111	307	106
Nutrients (mg/L)								
Nitrate as N		0.2			<0.1	0.2	<0.1	0.2
Nitrite as N		<0.1			<0.1	<0.1	<0.1	<0.1
Total Metals (mg/L)								
Aluminum	0.059	0.067	0.061	0.063	0.066	0.062	0.08	0.123
Antimony	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Arsenic	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Barium	0.05	0.05	0.05	0.05	0.03	0.05	0.11	0.05
Beryllium	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Boron	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cadmium	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0004	<0.0002
Calcium	46.8	46.7	48.3	45.4	32.1	45.0	122	45.7
Chromium	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cobalt	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Copper	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Iron	0.23	0.25	0.27	0.24	0.17	0.24	0.94	0.26
Lead	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.002	<0.001
Magnesium	26.0	27.1	27.7	26.3	21.9	26.3	67.7	25.8
Manganese	0.110	0.118	0.108	0.107	0.010	0.117	2.70	0.112
Mercury	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Molybdenum	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Nickel	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Selenium	0.0014	<0.001	0.0012	0.0009	<0.001	<0.001	<0.002	0.0011
Silver	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0002	<0.0001
Thallium	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0002	<0.0001
Uranium	0.00141	0.00151	0.00149	0.00150	0.00159	0.00148	0.00231	0.00145
Zinc	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005

Appendix Table C.4: Water quality data for Clinton Creek mine (Royal Roads University 1999).

Station ID	**CLCR-9**	**CLCR-Z3B**	**CLCR-Z2**	**CLCR-Z3**	**CLCR-Z4**	**CLCR-Z5**	**CLCR-Z6**	**CLCR-Z8**
Station Description	field duplicate of CLCR-1	Eagle Creek (reference)	Clinton Creek	Clinton Creek	Clinton Creek	Clinton Creek	Clinton Creek	Fortymile River (reference)
Parameters	13-Sep-98	11-Sep-98					11-Sep-98	11-Sep-98
pH		7.23	7.53	7.44	7.39	7.27	7.46	
Temperature (°C)		2.6	7.7	4.3	6.9	6.9	6.3	
Conductivity (uS)		175	300	244	322	342	133	
Dissolved anions (mg/L)								
Alkalinity-Total							120	
Bromide							<0.5	
Chlroride							0.7	
Fluoride							0.18	
Sulphate							148	
Nutrients (mg/L)								
Nitrate as N							0.2	
Nitrite as N							<0.1	
Total Metals (mg/L)								
Aluminum	0.059	0.98	0.061				0.220	0.28
Antimony	<0.2	<0.2	<0.2				<0.2	<0.2
Arsenic	<0.2	<0.2	<0.2				<0.2	<0.2
Barium	0.05	0.08	0.05				0.05	0.04
Beryllium	<0.005	<0.005	<0.005				<0.005	<0.005
Boron	<0.1	<0.1	<0.1				<0.1	<0.1
Cadmium	<0.0002	<0.0002	<0.0002				<0.0002	<0.0002
Calcium	44.9	41.8	48.3				53.5	21.4
Chromium	<0.01	<0.01	<0.01				<0.01	<0.01
Cobalt	<0.01	<0.01	<0.01				<0.01	<0.01
Copper	<0.01	<0.01	<0.01				<0.01	<0.01
Iron	0.21	0.66	0.27				0.42	0.36
Lead	<0.001	<0.001	<0.001				<0.001	<0.001
Magnesium	25.7	14.8	27.7				35.8	6.6
Manganese	0.111	0.040	0.108				0.149	0.017
Mercury	<0.00005	<0.00005	<0.00005				<0.00005	<0.00005
Molybdenum	<0.03	<0.03	<0.03				<0.03	<0.03
Nickel	<0.05	<0.05	<0.05				<0.05	<0.05
Selenium	0.0013	0.0023	0.0012				0.0011	<0.001
Silver	<0.0001	<0.0001	<0.0001				<0.0001	<0.0001
Thallium	<0.0001	<0.0001	<0.0001				<0.0001	<0.0001
Uranium	0.00141	0.00078	0.00149				0.00142	0.00059
Zinc	<0.005	<0.005	<0.005				<0.005	<0.005

Appendix Table C.4: Water quality data for Clinton Creek mine (Royal Roads University 1999).

Station ID	CLMS-1	CLWC-1	CLWC-2	CLWC-3	CLWR-13	CLWR-7
Station Description	top of tailings site	Wolverine Creek	Wolverine Creek	field duplicate of CLWC-2	spring near Clinton Creek	Porcupine Creek
Parameters	12-Sep-98	12-Sep-98	12-Sep-98	12-Sep-98	13-Sep-98	13-Sep-98
pH	9.12	7.3	7.23	7.23		7.9
Temperature (°C)	5.3	5.0	5.0	5.0		
Conductivity (uS)	780					
Dissolved anions (mg/L)						
Alkalinity-Total		87	88	86		223
Bromide		<0.5	<0.5	<0.5		<0.5
Chlroride		0.6	0.6	0.6		0.7
Fluoride		0.14	0.14	0.14		0.30
Sulphate		124	128	127		900
Nutrients (mg/L)						
Nitrate as N		<0.1	<0.1	<0.1		0.5
Nitrite as N		<0.1	<0.1	<0.1		<0.1
Total Metals (mg/L)						
Aluminum	0.006	0.246	0.193		0.010	0.006
Antimony	<0.2	<0.2	<0.2		<0.2	<0.2
Arsenic	<0.2	<0.2	<0.2		<0.2	<0.2
Barium	0.04	0.05	0.05		0.06	0.02
Beryllium	<0.005	<0.005	<0.005		<0.005	<0.005
Boron	0.6	<0.1	<0.1		<0.1	<0.1
Cadmium	<0.0004	<0.0002	<0.0002		<0.001	<0.001
Calcium	6.69	45.2	41.7		141	270
Chromium	<0.01	<0.01	<0.01		<0.01	<0.01
Cobalt	<0.01	<0.01	<0.01		<0.01	<0.01
Copper	<0.01	<0.01	<0.01		<0.01	<0.01
Iron	<0.03	0.39	0.34		1.21	<0.03
Lead	<0.002	<0.001	<0.001		<0.005	<0.005
Magnesium	150	29.0	28.3		130	123
Manganese	<0.005	0.091	0.070		1.18	<0.005
Mercury	<0.00005	<0.00005	<0.00005		<0.00005	<0.00005
Molybdenum	<0.03	<0.03	<0.03		<0.03	<0.03
Nickel	<0.05	<0.05	<0.05		<0.05	<0.05
Selenium	0.0024	<0.001	<0.001		<0.005	0.0081
Silver	<0.0002	<0.0001	<0.0001		<0.0005	<0.0005
Thallium	<0.0002	<0.0001	<0.0001		<0.0005	<0.0005
Uranium	<0.00002	0.00184	0.00176		0.00040	0.00467
Zinc	<0.005	<0.005	<0.005		<0.005	<0.005

Appendix Table C.5: Water quality data for Clinton Creek mine (SENES 2003).

Station	PC-03-01	PC-03-02	PC-03-03	PP-03-01	HL-03-01	HL-03-02	HL-03-04	HL-03-05	WC-03-01	WC-03-02
Area	Porcupine Creek	Porcupine Creek	Porcupine Creek	Porcupine Creek	Hudgeon Lake	Hudgeon Lake	Hudgeon Lake	Hudgeon Lake	Wolverine Creek	Wolverine Creek
Date	23-Sep-03	23-Sep-03	23-Sep-03	23-Sep-03	23-Sep-03	23-Sep-03	23-Sep-03	23-Sep-03	24-Sep-03	24-Sep-03
Physical tests										
Hardness	1440	1410	1250	2630	209	206	220	212	362	364
Dissolved anion										
Bromide	<0.05	<0.05	<0.05	0.14	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Chloride	0.8	0.8	0.7	40	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Fluoride	0.3	0.29	0.28	0.07	0.11	0.1	0.1	0.1	0.15	0.15
Sulphate	1090	1070	966	2290	111	112	112	110	235	221
Nutrients										
Ammonia as N	<0.005	<0.005	0.011	<0.005	0.017	0.016	0.017	0.016	<0.02	<0.02
Nitrate as N	0.313	0.319	0.35	0.499	0.161	0.162	0.16	0.164	0.079	0.066
Nitrite as N	<0.001	<0.001	0.001	0.023	0.002	0.002	0.002	0.002	0.001	0.001

Station	WC-03-03	WC-03-04	CC-03-02	CC-03-03	CC-03-04	CC-03-05	FM-03-01	FM-03-02	FM-03-03
Area	Wolverine Creek	Wolverine Creek	Clinton Creek	Clinton Creek	Clinton Creek	Clinton Creek	Fortymile River	Fortymile River	Fortymile River
Date	24-Sep-03	24-Sep-03	24-Sep-03	24-Sep-03	24-Sep-03	24-Sep-03	24-Sep-03	24-Sep-03	24-Sep-03
Physical tests									
Hardness	346	342	305	254	282	405	113	299	131
Dissolved anion									
Bromide	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Chloride	0.8	0.8	0.6	<0.5	0.8	1.4	1.1	1.4	<0.5
Fluoride	0.12	0.12	0.12	0.11	0.12	0.13	0.11	0.12	0.08
Sulphate	206	208	169	133	161	237	43	150	45
Nutrients									
Ammonia as N	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Nitrate as N	0.11	0.122	0.14	0.159	0.158	0.129	0.136	0.123	0.32
Nitrite as N	0.008	0.012	0.002	0.002	0.002	0.002	0.001	0.001	<0.001

Table C.6: Summary of fish surveys conducted at Clinton Creek, 1975 - 2008.

Area	Arctic grayling	Chinook salmon	Lake Whitefish	Round Whitefish	Slimy sculpin	Longnose sucker	Lake chub	Source	Sampling Year	Sampling Dates	Gear type	Effort	Station ID	Description
Tributary to upper Clinton Ck.	0	0	0	0	0	0	0	White Mountain Environmental Consulting, 2008	2007	July	minnow trap	5 traps	-	small unnamed tributary flowing into side channel of upper Clinton C. ~100 m u/s of Hudgeon Lake
	0	0	0	0	0	0	0	White Mountain Environmental Consulting, 2008	2007	August	minnow trap	5 traps	-	small unnamed tributary flowing into side channel of upper Clinton C. ~100 m u/s of Hudgeon Lake
	0	0	0	0	0	0	0	White Mountain Environmental Consulting, 2008	2007	July	electrofishing	168 seconds	-	small unnamed tributary flowing into side channel of upper Clinton C. ~100 m u/s of Hudgeon Lake
	0	0	0	0	0	0	0	White Mountain Environmental Consulting, 2008	2007	August	electrofishing	70 seconds	-	small unnamed tributary flowing into side channel of upper Clinton C. ~100 m u/s of Hudgeon Lake
Clinton Ck. upstream of Hudgeon Lake	0	0	0	0	0	0	0	Landucci, 1978	1975	August 6-7	electrofishing	30 m with barrier nets	1	Clinton Cr above Hudgeon Lk
	0	0	0	0	0	0	0	White Mountain Environmental Consulting, 2008	2007	July	minnow trap	14 traps	-	up to 500 m upstream of lake investigated
	0	0	0	0	0	0	0	White Mountain Environmental Consulting, 2008	2007	August	minnow trap	14 traps	-	up to 500 m upstream of lake investigated
	0	0	0	0	0	0	0	White Mountain Environmental Consulting, 2008	2007	July	electrofishing	852 seconds	-	up to 500 m upstream of lake investigated
	0	0	0	0	0	0	0	White Mountain Environmental Consulting, 2008	2007	August	electrofishing	620 seconds	-	up to 500 m upstream of lake investigated
	0	0	0	0	0	0	0	White Mountain Environmental Consulting, 2008	2007	July	seine	9 seines	-	up to 500 m upstream of lake investigated
Hudgeon Lake	0	0	0	0	0	0	0	EVS 1980 data	1980	September	gill net	66 hours	-	Hudgeon L. above the mouth of Clinton Creek
	3	0	0	0	0	0	0	Royal Roads University, 1999	1998	September 9-14	gill net (2.5 and 10 cm)	2 x 20 m, ~48 hours	-	Hudgeon L. above the mouth of Clinton Creek
	1	0	0	0	0	0	0	DFO Dec 6, 2005	2005	September 2-3	gill net	14.5 m	-	u/s end of Hudgeon lake
	0	0	0	0	0	0	0	DFO Dec 6, 2005	2005	September 2-3	gill net	13 m	-	u/s end of lake in drowned forest
	0	0	0	0	0	0	0	DFO Oct 31, 2006	2006	August 8-10	gill net	15 x 2 m	-	Eastern end of Hudgeon lake
	0	0	0	0	0	0	0	DFO Oct 31, 2006	2006	August 8-10	gill net	7.5 x 2m+15 x 2m	-	Western end of Hudgeon lake
	0	0	0	0	0	0	0	White Mountain Environmental Consulting, 2008	2007	July	gill net (1", 1.5", 2", 2.5")	~300 hours	-	-
	0	0	0	0	0	0	0	White Mountain Environmental Consulting, 2008	2007	August	gill net (1", 1.5", 2", 2.5")	~300 hours	-	-
	0	0	0	0	0	0	0	White Mountain Environmental Consulting, 2008	2007	summer	minnow trap	not specified	-	outlet
	0	0	0	0	0	0	0	White Mountain Environmental Consulting, 2008	2007	summer	seine	not specified	-	near boat launch and north east corner of lake
Bear Ck.	0	0	0	0	0	0	0	White Mountain Environmental Consulting, 2008	2007	July	minnow trap	9 traps	-	flows into Hudgeon Lake
	0	0	0	0	0	0	0	White Mountain Environmental Consulting, 2008	2007	July	electrofishing	186 seconds	-	flows into Hudgeon Lake
	0	0	0	0	0	0	0	White Mountain Environmental Consulting, 2008	2007	August	electrofishing	100 seconds	-	flows into Hudgeon Lake
East (or Easter) Ck.	0	0	0	0	0	0	0	White Mountain Environmental Consulting, 2008	2007	July	minnow trap	9 traps	-	-
	0	0	0	0	0	0	0	White Mountain Environmental Consulting, 2008	2007	August	minnow trap	9 traps	-	-
	0	0	0	0	0	0	0	White Mountain Environmental Consulting, 2008	2007	July	electrofishing	400 seconds	-	-
	0	0	0	0	0	0	0	White Mountain Environmental Consulting, 2008	2007	August	electrofishing	740 seconds	-	-
Clinton Ck. upstream and within gabion baskets[a]	0	0	0	0	0	0	0	Roach and Ricks, 2003	2003	June 20-21	minnow trap	overnight set	1	above gabion structures at the lake mouth
	0	0	0	0	0	0	0	Roach and Ricks, 2003	2003	June 20-21	minnow trap	overnight set	2	above gabion structures in channel
	0	0	0	0	0	0	0	Roach and Ricks, 2003	2003	June 20-21	minnow trap	overnight set	3	immediately above gabion structure
	0	0	0	0	0	0	0	Roach and Ricks, 2003	2003	June 20-21	minnow trap	overnight set	4	in gabions
	70	0	0	0	0	1	0	Roach et al., 2003	2003	July 31	electrofishing with barrier nets	-	gabion structure	Clinton Creek in gabions
	0	0	0	0	0	0	0	Roach et al., 2003	2003	2 August	electrofishing with barrier nets	-	below dam	Clinton Creek above gabion structures in channel
	70	0	0	0	0	0	0	Roach et al., 2003	2003	2 August	electrofishing with barrier nets	-	gabion structure	Clinton Creek in gabions
	0	0	0	0	0	0	0	DFO Dec 6, 2005	2005	September 2-3	minnow trap	2 traps	-	outlet of Hudgeon Lake
	0	0	0	0	0	0	0	DFO Dec 6, 2005	2005	September 2-3	gill net	17m+16m+16m+15m+13m+13m	-	near outlet of Lake
	1	0	0	0	0	0	0	DFO Oct 31, 2006	2006	August 8-10	minnow trap	6 traps	Station 1	outlet of Hudgeon Lake (sets u/s, within, d/s of gabions)
	0	0	0	0	0	0	0	White Mountain Environmental Consulting, 2008	2007	July	minnow trap	9 traps	-	at outlet of Hudgeon Lake u/s and d/s of 1st gabion
	0	0	0	0	0	0	0	White Mountain Environmental Consulting, 2008	2007	August	minnow trap	9 traps	-	at outlet of Hudgeon Lake u/s and d/s of 1st gabion
	0	0	0	0	0	0	0	White Mountain Environmental Consulting, 2008	2007	July	electrofishing	> 500 seconds	-	at outlet of Hudgeon Lake u/s and d/s of 1st gabion
	0	0	0	0	0	0	0	White Mountain Environmental Consulting, 2008	2007	August	electrofishing	> 500 seconds	-	at outlet of Hudgeon Lake u/s and d/s of 1st gabion
	0	3	0	0	0	0	0	DFO Dec 23, 2007	2007	September 14-15	minnow trap	2 traps	Station G-1	At base of first (from the bottom) gabion structure
	0	0	0	0	0	0	0	DFO Dec 23, 2007	2007	September 14-15	minnow trap	2 traps	Station G-2	At base of second (from the bottom) gabion structure
	3	0	0	0	0	0	0	DFO Jan 16, 2009	2008	August 11-12	angling	-	-	between two most downstream gabions (structures 3 & 4)
	0	0	0	0	0	0	0	DFO Jan 16, 2009	2008	August 11-12	angling	-	-	between gabions 1&2, 2&3, and u/s of gabion 1
	1	0	0	0	0	0	0	DFO Jan 16, 2009	2008	September 18-19	angling	-	-	between two most downstream gabions (structures 3 & 4)
	0	0	0	0	0	0	0	DFO Jan 16, 2009	2008	September 18-19	angling	-	-	between gabions 1&2, 2&3, and u/s of gabion 1
	0	0	0	0	0	0	0	DFO Jan 16, 2009	2008	September 18-19	minnow trap	2 traps, ≥22 hours	Station G2	near bottom end of gabion 2
	0	0	0	0	0	0	0	DFO Jan 16, 2009	2008	September 18-19	minnow trap	2 traps, ≥22 hours	Station G3	near bottom end of gabion 3

[a] August 8 - 10, 2006 DFO sampling at Station 1 took place downstream as well as upstream and within the gabion baskets.
u/s - upstream; d/s - downstream

Table C.6: Summary of fish surveys conducted at Clinton Creek, 1975 - 2008.

Area	Arctic grayling	Chinook salmon	Lake Whitefish	Round Whitefish	Slimy sculpin	Longnose sucker	Lake chub	Source	Sampling Year	Sampling Dates	Gear type	Effort	Station ID	Description
Clinton Creek downstream of gabions and within/near gabion areas prior to their construction	14	0	0	2	1	1	0	Landucci, 1978	1975	August 6-7	electrofishing	31 m with barrier nets	2	Clinton Cr blw waste rock, u/s wolverine
	0	0	0	0	0	0	0	EVS 1980 data	1980	September	minnow trap	-	Zone 1	Clinton Cr blw Hudeon Lk
	0	0	0	0	0	0	0	Royal Roads University, 1999	1998	September 9-14	minnow trap	2 traps, ~24 hours	Zone 1	Clinton Cr blw Hudeon Lk/ u/s wolverine
	0	0	0	0	0	0	0	Roach and Ricks, 2003	2003	June 20-21	minnow trap	overnight set	5	immediately below gabion structure
	0	0	0	0	0	0	0	Roach and Ricks, 2003	2003	June 20-21	minnow trap	overnight set	6	downstream of gabion structure
	1	0	0	0	16	0	0	Roach and Ricks, 2003	2003	June 20-21	minnow trap	overnight set	7	bottom of canyon area
	0	0	0	0	9	0	0	Roach and Ricks, 2003	2003	June 20-21	minnow trap	overnight set	8	bottom of canyon
	30	1	0	0	0	0	0	Roach et al., 2003	2003	July 31	electrofishing with barrier nets	-	plunge pool	Clinton Creek immediately below gabion structure
	80	0	0	0	0	0	0	Roach et al., 2003	2003	2 August	electrofishing with barrier nets	-	plunge pool	Clinton Creek immediately below gabion structure
	60	0	0	0	0	0	0	Roach et al., 2003	2003	2 August	electrofishing with barrier nets	-	above canyon	Clinton Creek downstream of gabion structure
	900	0	0	0	200	50	0	Roach et al., 2003	2003	2 August	electrofishing with barrier nets	-	in canyon	Clinton Creek canyon area
	60	2	0	0	40	0	0	Roach et al., 2003	2003	2 August	electrofishing with barrier nets	-	above ford	Clinton Creek - spring area above the ford
	2	0	0	0	0	0	0	DFO July 14, 2005	2005	July 6-7	minnow trap	2 traps	Station 1	Immediately d/s of the bottom of the gabions
	5	0	0	0	0	0	0	DFO Aug 2, 2005	2005	July 26-27	minnow trap	4 traps	Station 1	Immediately d/s of the bottom of the gabions
	0	0	0	0	0	0	0	DFO Oct 31, 2006	2006	September 13-14	gill net	2 traps	Station 1	d/s of gabions
	0	1	0	0	0	0	0	DFO Dec 23, 2007	2007	August 8-9	minnow trap	2 traps	Station C-1	Immediately d/s of the bottom of the gabions
	0	2	0	0	0	0	0	DFO Dec 23, 2007	2007	August 8-9	minnow trap	2 traps	Station C-2	Stations C-1 to C-5 located approximately equidistant between the u/s end of the canyon (C1) and the d/s end of the canyon (C5)
	0	4	0	0	0	0	0	DFO Dec 23, 2007	2007	August 8-9	minnow trap	2 traps	Station C-3	
	0	4	0	0	0	0	0	DFO Dec 23, 2007	2007	August 8-9	minnow trap	2 traps	Station C-4	
	0	12	0	0	10	3	0	DFO Dec 23, 2007	2007	August 8-9	minnow trap	2 traps	Station C-5	
	0	13	0	0	0	0	0	DFO Dec 23, 2007	2007	September 14-15	minnow trap	2 traps	Station 1	Immediately d/s of the bottom of the gabions
	2	5	0	0	0	0	0	White Mountain Environmental Consulting, 2008	2007	August	electrofishing and visual	255 seconds	-	d/s of gabion structures and into native channel for 15 m
	6	0	0	0	0	0	0	DFO Jan 16, 2009	2008	August 11-12	angling	-	-	d/s of gabion 4
	0	0	0	0	0	0	0	DFO Jan 16, 2009	2008	May 30-31	minnow trap	3 traps, ≥22 hours	Station 1	d/s of gabion structures
	0	0	0	0	1	0	0	DFO Jan 16, 2009	2008	July 10-11	minnow trap	2 traps, ≥22 hours	Station 1	d/s of gabion structures
	2	0	0	0	0	0	0	DFO Jan 16, 2009	2008	August 11-12	minnow trap	2 traps, ≥22 hours	Station 1	d/s of gabion structures
	6	0	0	0	0	0	0	DFO Jan 16, 2009	2008	September 18-19	minnow trap	4 traps, ≥22 hours	Station 1	d/s of gabion structures
Clinton Ck. near Wolverine Ck. (including road crossing)	2	0	0	0	0	4	0	Landucci, 1978	1975	August 6-7	electrofishing	34 m with barrier nets	5	Clinton Cr blw Wolverine Cr
	3	10	0	0	1	0	0	EVS 1980 data	1980	September	minnow trap	-	Zone 2	Clinton Cr 1.5-3km blw Hudgeon Lk
	0	13	0	0	3	0	0	Royal Roads University, 1999	1998	September 9-14	minnow trap	3 traps, ~18 hours	Zone 2	Clinton Cr 1.5-3km blw Hudgeon Lk
	0	0	0	0	8	0	0	Roach and Ricks, 2003	2003	June 20-21	minnow trap	overnight set	9	above creek ford
	0	0	0	0	2	0	0	Roach and Ricks, 2003	2003	June 20-21	minnow trap	overnight set	10	above creek ford
	0	0	0	0	0	0	0	Roach and Ricks, 2003	2003	June 20-21	minnow trap	overnight set	11	immediately below ford
	0	0	0	0	5	0	0	Roach and Ricks, 2003	2003	June 20-21	minnow trap	overnight set	12	above wolverine Cr
	0	0	0	0	2	0	0	Roach and Ricks, 2003	2003	June 20-21	minnow trap	overnight set	13	above wolverine Cr
	0	0	0	0	0	0	0	Roach and Ricks, 2003	2003	June 20-21	minnow trap	overnight set	14	above wolverine Cr
	0	0	0	0	2	0	0	Roach and Ricks, 2003	2003	June 20-21	minnow trap	overnight set	15	above wolverine Cr
	0	0	0	0	3	0	0	Roach and Ricks, 2003	2003	June 20-21	minnow trap	overnight set	16	above wolverine Cr
	0	0	0	0	3	0	0	Roach and Ricks, 2003	2003	June 20-21	minnow trap	overnight set	17	above wolverine Cr
	0	0	0	0	2	0	0	Roach and Ricks, 2003	2003	June 20-21	minnow trap	overnight set	18	above wolverine Cr
	0	0	0	0	9	0	0	DFO July 14, 2005	2005	July 6-7	minnow trap	2 traps	Station 2	At road crossing near the d/s end of the waste dump
	7	0	0	0	7	0	0	DFO Aug 2, 2005	2005	July 26-27	minnow trap	4 traps	Station 2	At road crossing near the d/s end of the waste dump
	2	7	0	0	15	0	0	DFO Aug 2, 2005	2005	July 26-27	minnow trap	4 traps	Station 2a	Extending d/s of Wolverine mouth ~100m
	15	0	0	0	4	0	0	Roach et al., 2003	2003	July 31	electrofishing with barrier nets	-	clinton channel	Clinton Creek immediately below ford
	60	0	0	0	20	50	0	Roach et al., 2003	2003	July 31	electrofishing with barrier nets	-	clinton channel	Clinton Creek above beaver ponds
	2	10	0	0	5	0	0	DFO Dec 6, 2005	2005	September 2-3	minnow trap		Station 2a	Extending d/s of Wolverine mouth ~100m (extensively modified by beaver dams since last sampling)
	1	0	0	0	14	0	0	DFO Oct 31, 2006	2006	June 19-20	minnow trap	set from June 19 - 20	Station 2a	Clinton Creek near the mouth of Wolverine Creek
	1	43	0	0	8	0	0	DFO Oct 31, 2006	2006	August 8-10	minnow trap	3 traps	Station 2a	Clinton Creek near the mouth of Wolverine Creek
	0	11	0	0	5	0	0	DFO Oct 31, 2006	2006	September 13-14	gill net	2 traps	Station 2a	Clinton Creek near the mouth of Wolverine Creek; d/s of beaver dam constructed since early August
	0	18	0	0	2	0	0	DFO Dec 23, 2007	2007	September 14-15	minnow trap	2 traps	Station 2	At road crossing near the d/s end of the waste dump

[a] August 8 - 10, 2006 DFO sampling at Station 1 took place downstream as well as upstream and within the gabion baskets.
u/s - upstream; d/s - downstream

Table C.6: Summary of fish surveys conducted at Clinton Creek, 1975 - 2008.

Area	Arctic grayling	Chinook salmon	Lake Whitefish	Round Whitefish	Slimy sculpin	Longnose sucker	Lake chub	Source	Sampling Year	Sampling Dates	Gear type	Effort	Station ID	Description
Clinton Ck. near Wolverine Ck. (including road crossing)	0	0	0	0	12	4	0	DFO Dec 23, 2007	2007	July 10-11	minnow trap	4 traps	Station 2a	Clinton Creek near the mouth of Wolverine Creek
	0	126	0	0	2	0	0	DFO Dec 23, 2007	2007	September 14-15	minnow trap	2 traps	Station 2A	Extending d/s of Wolverine mouth ~100m
	0	0	0	0	1	0	0	DFO Jan 16, 2009	2008	May 30-31	minnow trap	3 traps, ≥22 hours	Station 2	at mine site ford
	0	0	0	0	9	0	0	DFO Jan 16, 2009	2008	July 10-11	minnow trap	2 traps, ≥22 hours	Station 2	at mine site ford
	0	2	0	0	2	0	0	DFO Jan 16, 2009	2008	August 11-12	minnow trap	4 traps, ≥22 hours	Station 2	at mine site ford
	3	1	0	0	4	0	0	DFO Jan 16, 2009	2008	September 18-19	minnow trap	4 traps, ≥22 hours	Station 2	at mine site ford
	0	0	0	0	14	0	0	DFO Jan 16, 2009	2008	May 30-31	minnow trap	8 traps, ≥22 hours	Station 2A	near mouth of Wolverine Creek
	1	0	0	0	38	0	1	DFO Jan 16, 2009	2008	July 10-11	minnow trap	4 traps, ≥22 hours	Station 2A	near mouth of Wolverine Creek
	0	49	0	0	1	0	0	DFO Jan 16, 2009	2008	August 11-12	minnow trap	2 traps, ≥22 hours	Station 2A	near mouth of Wolverine Creek
	0	33	0	0	20	0	0	DFO Jan 16, 2009	2008	September 18-19	minnow trap	4 traps, ≥22 hours	Station 2a	near mouth of Wolverine Creek
	0	0	0	0	0	0	0	DFO Jan 16, 2009	2008	May 30-31	minnow trap	3 traps, ≥22 hours	Station 2B	d/s end of canyon
Clinton Ck. near confluence of Eagle Ck.	1	0	0	0	1	2	0	Landucci, 1978	1975	August 6-7	electrofishing	35 m with barrier nets	6	Clinton Cr 5 km d/s of 5
	1	4	0	0	0	0	0	EVS 1980 data	1980	September	minnow trap	-	Zone 3	Clinton Cr 3.5-6 km blw Hudgeon Lk
	1	0	0	0	0	0	0	EVS 1980 data	1980	September	minnow trap	-	Zone 4	Clinton Cr 6-7 km blw Hudgeon Lk
	0	19	0	0	4	0	0	Royal Roads University, 1999	1998	September 9-14	minnow trap	3 traps, ~47 hours	Zone 3	Clinton Cr 3.5-6 km blw Hudgeon Lk
	0	6	0	0	0	0	0	Royal Roads University, 1999	1998	September 9-14	minnow trap	3 traps, ~18 hours	Zone 4	Clinton Cr 6-7 km blw Hudgeon Lk
	3	4	0	0	3	0	0	DFO July 14, 2005	2005	July 6-7	minnow trap	2 traps	Station 3	Along Clinton Creek access road
	3	10	0	0	1	0	0	DFO Aug 2, 2005	2005	July 26-27	minnow trap	4 traps	Station 3	Along Clinton Creek access road
	0	11	0	0	2	0	0	DFO Jan 16, 2009	2008	August 11-12	minnow trap	2 traps, ≥22 hours	Station 3	approximately half-way between Forty-Mile confluence and Lake outlet
	1	4	0	0	5	0	0	DFO Jan 16, 2009	2008	September 18-19	minnow trap	2 traps, ≥22 hours	Station 3	approximately half-way between Forty-Mile confluence and Lake outlet
Clinton Ck. near confluence of Fortymile River	2	0	1	1	3	3	0	Landucci, 1978	1975	August 6-7	electrofishing	36 m with barrier nets	7	Clinton Cr above road
	0	0	0	0	0	0	0	EVS 1980 data	1980	September	minnow trap	-	Zone 5	Clinton Cr 7-8 km blw Hudgeon Lk
	1	4	0	0	0	0	0	EVS 1980 data	1980	September	minnow trap	-	Zone 6	Clinton Cr 8-9.2 km blw Hudgeon Lk
	0	12	0	0	1	0	0	Royal Roads University, 1999	1998	September 9-14	minnow trap	3 traps, ~45 hours	Zone 5	Clinton Cr 7-8 km blw Hudgeon Lk
	0	17	0	0	0	0	0	Royal Roads University, 1999	1998	September 9-14	minnow trap	3 traps, ~18 hours	Zone 6	Clinton Cr 8-9.2 km blw Hudgeon Lk
	0	2	0	0	1	0	0	Royal Roads University, 1999	1998	September 9-14	electrofishing (no stop nets)	-	Zone 6	Clinton Cr 8-9.2 km blw Hudgeon Lk (near the weir at DS-2)
	0	33	0	0	0	0	0	DFO Dec 6, 2005	2005	September 2-3	minnow trap	"	Station 4	Near mouth of Clinton Ck d/s of all beaver dams
	0	11	0	0	5	0	0	DFO Oct 31, 2006	2006	June 19-20	minnow trap	set from June 19 - 20	Station 4	d/s of 1st beaver dam near mouth into Fortymile River
	0	175	0	0	1	5	0	DFO Oct 31, 2006	2006	August 8-10	minnow trap	3 traps	Station 4	d/s of 1st beaver dam near mouth into Fortymile River
	0	120	0	0	0	0	0	DFO Oct 31, 2006	2006	September 13-14	gill net	2 traps	Station 4	d/s of 1st beaver dam near mouth into Fortymile River
	0	53	0	0	0	3	0	DFO Dec 23, 2007	2007	July 10-11	minnow trap	3 traps	Station 4	lowest reach, d/s of all beaver dams
	0	58	0	0	0	0	0	DFO Dec 23, 2007	2007	September 14-15	minnow trap	3 traps	Station 4	Near mouth of Clinton Ck d/s of all beaver dams
	7	2070	0	0	47	76	0	Smart 2007	2007	July 12-August 9	minnow trap	29 traps	-	immediately u/s of confluence with Forty-Mile River
	0	1	0	0	1	0	0	DFO Jan 16, 2009	2008	May 30-31	minnow trap	4 traps, ≥22 hours	Station 4	immediately u/s of confluence with Forty-Mile River
	0	1	0	0	0	0	0	DFO Jan 16, 2009	2008	July 10-11	minnow trap	4 traps, ≥22 hours	Station 4	immediately u/s of confluence with Forty-Mile River
	0	0	0	0	0	21	0	DFO Jan 16, 2009	2008	August 11-12	minnow trap	4 traps, ≥22 hours	Station 4	immediately u/s of confluence with Forty-Mile River
	1	33	0	0	0	1	0	DFO Jan 16, 2009	2008	September 18-19	minnow trap	4 traps, ≥22 hours	Station 4	immediately u/s of confluence with Forty-Mile River
	0	12	0	0	1	0	0	DFO Jan 16, 2009	2008	August 11-12	minnow trap	≥22 hours	Station 4a	townsite ford (used as Fortymile River had backed up into lower Clinton Creek)
Wolverine Ck.	0	0	0	0	0	0	0	Landucci, 1978	1975	August 6-7	electrofishing	32 m with barrier nets	3	Wolverine Cr above Wolverine Lk
	0	0	0	0	0	0	0	Landucci, 1978	1975	August 6-7	electrofishing	33 m with barrier nets	4	Wolverine Cr above Clinton Cr
	0	0	0	0	0	0	0	White Mountain Environmental Consulting, 2008	2007	summer	minnow trap	9 traps	-	180 m reach u/s of culvert
	0	0	0	0	0	0	0	White Mountain Environmental Consulting, 2008	2007	summer	electrofishing	429 seconds	-	180 m reach u/s of culvert
Fortymile R.	2	0	0	0	1	5	0	Landucci, 1978	1975	August 6-7	electrofishing	37 m with barrier nets	8	Fortymile R blw Clinton Cr.
	2	2	0	0	2	5	0	Landucci, 1978	1975	August 6-7	electrofishing	38 m with barrier nets	9	Fortymile R above Clinton Cr.

[a] August 8 - 10, 2006 DFO sampling at Station 1 took place downstream as well as upstream and within the gabion baskets.
u/s - upstream; d/s - downstream