

Appendices

Appendix A

Groundwater Data

Table A.1

Groundwater Quality Monitoring Results
Groundwater Monitoring Study
Sporting Mountain Quarry, Seaview, Nova Scotia

SAMPLE LOCATIONS			Criteria			MW1	MW2		MW3	MW4
BV Labs ID			2021 NSE PSSs for GW; Groundwater Discharge to Surface Water (>10 m from a freshwater body)	CDWQG; MAC	CDWQG; AO	RRK042	RRK043	RRK046	RRK044	RRK045
Date Sampled (dd-mmm-yy)						21-Jan-22	21-Jan-22	21-Jan-22	21-Jan-22	21-Jan-22
PARAMETERS	UNITS	RDL								
Anion Sum	me/L	N/A	-	-	-	7.31	2.83	2.92	2.26	2.92
Bicarb. Alkalinity (calc. as CaCO3)	mg/L	1	-	-	-	330	110	120	92	120
Calculated TDS	mg/L	1	-	-	500	380	160	160	120	160
Carb. Alkalinity (calc. as CaCO3)	mg/L	1	-	-	-	1.5	1.2	1.3	<1.0	1.3
Cation Sum	me/L	N/A	-	-	-	6.93	2.74	2.77	2.11	2.77
Hardness (CaCO3)	mg/L	1	-	-	-	250	110	120	92	120
Ion Balance (% Difference)	%	N/A	-	-	-	2.67	1.62	2.64	3.43	2.64
Langelier Index (@ 20C)	N/A		-	-	-	0.691	0.333	0.384	0.0690	0.384
Langelier Index (@ 4C)	N/A		-	-	-	0.442	0.0830	0.133	-0.182	0.133
Nitrate (N)	mg/L	0.05	-	10	-	<0.050	<0.050	<0.050	0.31	<0.050
Saturation pH (@ 20C)	N/A		-	-	-	6.98	7.71	7.69	7.86	7.69
Saturation pH (@ 4C)	N/A		-	-	-	7.23	7.96	7.94	8.11	7.94
Inorganics										
Total Alkalinity (Total as CaCO3)	mg/L	5.0	-	-	-	340	110	120	93	120
Dissolved Chloride (Cl-)	mg/L	1.0	1,500	-	250	12	9.2	9.4	7.9	9.4
Colour	TCU	5.0	-	-	15	<5.0	<5.0	<5.0	<5.0	<5.0
Nitrate + Nitrite (N)	mg/L	0.050	-	-	-	<0.050	<0.050	<0.050	0.33	<0.050
Nitrite (N)	mg/L	0.010	-	1	-	<0.010	<0.010	<0.010	0.010	<0.010
Nitrogen (Ammonia Nitrogen)	mg/L	0.050	-	-	-	0.11	0.051	<0.050	<0.050	<0.050
Total Organic Carbon (C)	mg/L	5.0	-	-	-	6.6	0.88	0.83	3.8	0.83
Orthophosphate (P)	mg/L	0.010	-	-	-	<0.010	<0.010	<0.010	<0.010	<0.010
pH	pH		-	-	7.0 : 10.5	7.67	8.05	8.07	7.93	8.07
Reactive Silica (SiO2)	mg/L	0.50	-	-	-	11	13	13	3.9	13
Dissolved Sulphate (SO4)	mg/L	2.0	-	-	500	13	15	14	7.7	14
Turbidity	NTU	0.10	-	-	0.3	6.6	25	24	42	24
Conductivity	uS/cm	1.0	-	-	-	640	260	270	210	270

Table A.1

Groundwater Quality Monitoring Results
Groundwater Monitoring Study
Sporting Mountain Quarry, Seaview, Nova Scotia

SAMPLE LOCATIONS			Criteria			MW1	MW2		MW3	MW4
BV Labs ID			2021 NSE PSSs for GW; Groundwater Discharge to Surface Water (>10 m from a freshwater body)	CDWQG; MAC	CDWQG; AO	RRK042	RRK043	RRK046	RRK044	RRK045
Date Sampled (dd-mmm-yy)						21-Jan-22	21-Jan-22	21-Jan-22	21-Jan-22	21-Jan-22
PARAMETERS	UNITS	RDL								
Metals										
Dissolved Aluminum (Al)	ug/L	5.0	50	-	100	7.9	<5.0	<5.0	40	<5.0
Dissolved Antimony (Sb)	ug/L	1.0	90	6	-	<1.0	<1.0	<1.0	<1.0	<1.0
Dissolved Arsenic (As)	ug/L	1.0	50	10	-	1.7	2.0	2.0	<1.0	2.0
Dissolved Barium (Ba)	ug/L	1.0	10000	2000	-	26	53	52	6.4	52
Dissolved Beryllium (Be)	ug/L	0.10	1.5	-	-	<0.10	<0.10	<0.10	<0.10	<0.10
Dissolved Bismuth (Bi)	ug/L	2.0	-	-	-	<2.0	<2.0	<2.0	<2.0	<2.0
Dissolved Boron (B)	ug/L	50	15000	5000	-	<50	<50	<50	<50	<50
Dissolved Cadmium (Cd)	ug/L	0.010	0.9	7	-	0.017	<0.010	<0.010	0.012	<0.010
Dissolved Calcium (Ca)	ug/L	100	-	-	-	86000	41000	41000	34000	41000
Dissolved Chromium (Cr)	ug/L	1.0	89	50	-	<1.0	<1.0	<1.0	<1.0	<1.0
Dissolved Cobalt (Co)	ug/L	0.40	10	-	-	0.90	<0.40	<0.40	<0.40	<0.40
Dissolved Copper (Cu)	ug/L	0.50	20	2000	1000	7.6	<0.50	<0.50	1.7	<0.50
Dissolved Iron (Fe)	ug/L	50	3000	-	300	<50	<50	<50	<50	<50
Dissolved Lead (Pb)	ug/L	0.50	10	5	-	<0.50	<0.50	<0.50	<0.50	<0.50
Dissolved Magnesium (Mg)	ug/L	100	-	-	-	7800	3100	3100	1900	3100
Dissolved Manganese (Mn)	ug/L	2.0	4300	120	20	1800	<u>98</u>	<u>100</u>	<u>110</u>	<u>100</u>
Dissolved Molybdenum (Mo)	ug/L	2.0	730	-	-	10	2.3	2.4	<2.0	2.4
Dissolved Nickel (Ni)	ug/L	2.0	250	-	-	5.5	7.8	8.0	<2.0	8.0
Dissolved Phosphorus (P)	ug/L	100	-	-	-	<100	<100	<100	<100	<100
Dissolved Potassium (K)	ug/L	100	-	-	-	9000	600	600	1800	600
Dissolved Selenium (Se)	ug/L	0.50	10	50	-	0.79	<0.50	<0.50	<0.50	<0.50
Dissolved Silver (Ag)	ug/L	0.10	2.5	-	-	<0.10	<0.10	<0.10	<0.10	<0.10
Dissolved Sodium (Na)	ug/L	100	-	-	200000	40000	9900	10000	5300	10000
Dissolved Strontium (Sr)	ug/L	2.0	210000	7000	-	370	220	220	48	220
Dissolved Thallium (Tl)	ug/L	0.10	8	-	-	<0.10	<0.10	<0.10	<0.10	<0.10
Dissolved Tin (Sn)	ug/L	2.0	-	-	-	<2.0	<2.0	<2.0	<2.0	<2.0
Dissolved Titanium (Ti)	ug/L	2.0	-	-	-	<2.0	<2.0	<2.0	<2.0	<2.0
Dissolved Uranium (U)	ug/L	0.10	150	20	-	8.3	11	11	1.7	11
Dissolved Vanadium (V)	ug/L	2.0	1200	-	-	<2.0	<2.0	<2.0	<2.0	<2.0
Dissolved Zinc (Zn)	ug/L	5.0	70	-	5000	6.9	<5.0	<5.0	<5.0	<5.0



Your P.O. #: 735001928
 Your Project #: 11194492-01
 Site Location: SPORTING MOUNTAIN QUARRY
 Your C.O.C. #: N/A

Attention: Sherman Jackson

GHD Contractors Limited
 120 Western Parkway
 Bedford, NS
 CANADA B4B 0V2

Report Date: 2022/02/01
 Report #: R6985201
 Version: 1 - Final

CERTIFICATE OF ANALYSIS

BV LABS JOB #: C218357

Received: 2022/01/21, 16:40

Sample Matrix: Ground Water
 # Samples Received: 5

Analyses	Quantity	Date	Date	Laboratory Method	Analytical Method
		Extracted	Analyzed		
Carbonate, Bicarbonate and Hydroxide	5	N/A	2022/01/27	N/A	SM 23 4500-CO2 D
Alkalinity	5	N/A	2022/01/31	ATL SOP 00013	EPA 310.2 R1974 m
Chloride	5	N/A	2022/01/31	ATL SOP 00014	SM 23 4500-Cl- E m
Colour	5	N/A	2022/01/31	ATL SOP 00020	SM 23 2120C m
Conductance - water	5	N/A	2022/01/27	ATL SOP 00004	SM 23 2510B m
Hardness (calculated as CaCO3)	5	N/A	2022/01/27	ATL SOP 00048	Auto Calc
Metals Water Diss. MS (as rec'd)	5	N/A	2022/01/26	ATL SOP 00058	EPA 6020B R2 m
Ion Balance (% Difference)	5	N/A	2022/02/01	N/A	Auto Calc.
Anion and Cation Sum	5	N/A	2022/01/28	N/A	Auto Calc.
Nitrogen Ammonia - water	5	N/A	2022/01/27	ATL SOP 00015	EPA 350.1 R2 m
Nitrogen - Nitrate + Nitrite	5	N/A	2022/01/31	ATL SOP 00016	USGS I-2547-11m
Nitrogen - Nitrite	5	N/A	2022/01/31	ATL SOP 00017	SM 23 4500-NO2- B m
Nitrogen - Nitrate (as N)	5	N/A	2022/01/31	ATL SOP 00018	ASTM D3867-16
pH (1)	5	N/A	2022/01/27	ATL SOP 00003	SM 23 4500-H+ B m
Phosphorus - ortho	5	N/A	2022/01/31	ATL SOP 00021	SM 23 4500-P E m
Sat. pH and Langelier Index (@ 20C)	5	N/A	2022/02/01	ATL SOP 00049	Auto Calc.
Sat. pH and Langelier Index (@ 4C)	5	N/A	2022/02/01	ATL SOP 00049	Auto Calc.
Reactive Silica	5	N/A	2022/01/31	ATL SOP 00022	EPA 366.0 m
Sulphate	5	N/A	2022/01/31	ATL SOP 00023	ASTM D516-16 m
Total Dissolved Solids (TDS calc)	5	N/A	2022/02/01	N/A	Auto Calc.
Organic carbon - Total (TOC) (2)	2	N/A	2022/01/26	ATL SOP 00203	SM 23 5310B m
Organic carbon - Total (TOC) (2)	3	N/A	2022/01/27	ATL SOP 00203	SM 23 5310B m
Turbidity	5	N/A	2022/01/28	ATL SOP 00011	EPA 180.1 R2 m

Remarks:

Bureau Veritas is accredited to ISO/IEC 17025 for specific parameters on scopes of accreditation. Unless otherwise noted, procedures used by Bureau Veritas are based upon recognized Provincial, Federal or US method compendia such as CCME, MELCC, EPA, APHA.

All work recorded herein has been done in accordance with procedures and practices ordinarily exercised by professionals in Bureau Veritas' profession using accepted testing methodologies, quality assurance and quality control procedures (except where otherwise agreed by the client and Bureau Veritas in writing). All data is in statistical control and has met quality control and method performance criteria unless otherwise noted. All method blanks are reported; unless indicated otherwise, associated sample data are not blank corrected. Where applicable, unless otherwise noted, Measurement Uncertainty has not been accounted for when stating conformity to the referenced standard.



Your P.O. #: 735001928
Your Project #: 11194492-01
Site Location: SPORTING MOUNTAIN QUARRY
Your C.O.C. #: N/A

Attention: Sherman Jackson

GHD Contractors Limited
120 Western Parkway
Bedford, NS
CANADA B4B 0V2

Report Date: 2022/02/01
Report #: R6985201
Version: 1 - Final

CERTIFICATE OF ANALYSIS

BV LABS JOB #: C218357

Received: 2022/01/21, 16:40

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Reference Method suffix "m" indicates test methods incorporate validated modifications from specific reference methods to improve performance.

* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.

(1) The APHA Standard Method require pH to be analyzed within 15 minutes of sampling and therefore field analysis is required for compliance. All Laboratory pH analyses in this report are reported past the APHA Standard Method holding time.

(2) TOC / DOC present in the sample should be considered as non-purgeable TOC / DOC.

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.

Marie Muise, Key Account Specialist
Email: Marie.MUISE@bureauveritas.com
Phone# (902)420-0203 Ext:253

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AT. RCAP-MS DISSOLVED (FIELDFIL) IN W

Bureau Veritas ID		RRK042	RRK043		RRK044		RRK045		
Sampling Date		2022/01/21 10:05	2022/01/21 09:15		2022/01/21 10:30		2022/01/21 09:40		
COC Number		N/A	N/A		N/A		N/A		
	UNITS	MW 1	MW 2	RDL	MW 3	QC Batch	MW 4	RDL	QC Batch
Calculated Parameters									
Anion Sum	me/L	7.31	2.83	N/A	2.26	7796141	2.01	N/A	7796141
Bicarb. Alkalinity (calc. as CaCO3)	mg/L	330	110	1.0	92	7796137	80	1.0	7796137
Calculated TDS	mg/L	380	160	1.0	120	7796146	110	1.0	7796146
Carb. Alkalinity (calc. as CaCO3)	mg/L	1.5	1.2	1.0	<1.0	7796137	<1.0	1.0	7796137
Cation Sum	me/L	6.93	2.74	N/A	2.11	7796141	1.85	N/A	7796141
Hardness (CaCO3)	mg/L	250	110	1.0	92	7796139	79	1.0	7796139
Ion Balance (% Difference)	%	2.67	1.62	N/A	3.43	7796140	4.15	N/A	7796140
Langelier Index (@ 20C)	N/A	0.691	0.333		0.0690	7796144	-0.272		7796144
Langelier Index (@ 4C)	N/A	0.442	0.0830		-0.182	7796145	-0.523		7796145
Nitrate (N)	mg/L	<0.050	<0.050	0.050	0.31	7796142	0.37	0.050	7796142
Saturation pH (@ 20C)	N/A	6.98	7.71		7.86	7796144	8.00		7796144
Saturation pH (@ 4C)	N/A	7.23	7.96		8.11	7796145	8.25		7796145
Inorganics									
Total Alkalinity (Total as CaCO3)	mg/L	340	110	25	93	7805036	81	5.0	7805036
Dissolved Chloride (Cl-)	mg/L	12	9.2	1.0	7.9	7805040	7.0	1.0	7805040
Colour	TCU	<5.0	<5.0	5.0	<5.0	7805048	<5.0	5.0	7805048
Nitrate + Nitrite (N)	mg/L	<0.050	<0.050	0.050	0.33	7805052	0.37	0.050	7805052
Nitrite (N)	mg/L	<0.010	<0.010	0.010	0.010	7805053	<0.010	0.010	7805053
Nitrogen (Ammonia Nitrogen)	mg/L	0.11	0.051	0.050	<0.050	7802824	<0.050	0.050	7802824
Total Organic Carbon (C)	mg/L	6.6	0.88	0.50	3.8	7801073	4.7	0.50	7800723
Orthophosphate (P)	mg/L	<0.010	<0.010	0.010	<0.010	7805050	<0.010	0.010	7805050
pH	pH	7.67	8.05		7.93	7803116	7.73		7803116
Reactive Silica (SiO2)	mg/L	11	13	0.50	3.9	7805047	4.6	0.50	7805047
Dissolved Sulphate (SO4)	mg/L	13	15	2.0	7.7	7805045	8.1	2.0	7805045
Turbidity	NTU	6.6	25	0.10	42	7805071	43	0.10	7805071
Conductivity	uS/cm	640	260	1.0	210	7803109	180	1.0	7803109
Metals									
Dissolved Aluminum (Al)	ug/L	7.9	<5.0	5.0	40	7800682	22	5.0	7800682
Dissolved Antimony (Sb)	ug/L	<1.0	<1.0	1.0	<1.0	7800682	<1.0	1.0	7800682
Dissolved Arsenic (As)	ug/L	1.7	2.0	1.0	<1.0	7800682	<1.0	1.0	7800682
Dissolved Barium (Ba)	ug/L	26	53	1.0	6.4	7800682	9.5	1.0	7800682
RDL = Reportable Detection Limit QC Batch = Quality Control Batch N/A = Not Applicable									



AT. RCAP-MS DISSOLVED (FIELDFIL) IN W

Bureau Veritas ID		RRK042	RRK043		RRK044		RRK045		
Sampling Date		2022/01/21 10:05	2022/01/21 09:15		2022/01/21 10:30		2022/01/21 09:40		
COC Number		N/A	N/A		N/A		N/A		
	UNITS	MW 1	MW 2	RDL	MW 3	QC Batch	MW 4	RDL	QC Batch
Dissolved Beryllium (Be)	ug/L	<0.10	<0.10	0.10	<0.10	7800682	<0.10	0.10	7800682
Dissolved Bismuth (Bi)	ug/L	<2.0	<2.0	2.0	<2.0	7800682	<2.0	2.0	7800682
Dissolved Boron (B)	ug/L	<50	<50	50	<50	7800682	<50	50	7800682
Dissolved Cadmium (Cd)	ug/L	0.017	<0.010	0.010	0.012	7800682	0.019	0.010	7800682
Dissolved Calcium (Ca)	ug/L	86000	41000	100	34000	7800682	28000	100	7800682
Dissolved Chromium (Cr)	ug/L	<1.0	<1.0	1.0	<1.0	7800682	<1.0	1.0	7800682
Dissolved Cobalt (Co)	ug/L	0.90	<0.40	0.40	<0.40	7800682	0.41	0.40	7800682
Dissolved Copper (Cu)	ug/L	7.6	<0.50	0.50	1.7	7800682	2.1	0.50	7800682
Dissolved Iron (Fe)	ug/L	<50	<50	50	<50	7800682	<50	50	7800682
Dissolved Lead (Pb)	ug/L	<0.50	<0.50	0.50	<0.50	7800682	<0.50	0.50	7800682
Dissolved Magnesium (Mg)	ug/L	7800	3100	100	1900	7800682	2300	100	7800682
Dissolved Manganese (Mn)	ug/L	1800	98	2.0	110	7800682	120	2.0	7800682
Dissolved Molybdenum (Mo)	ug/L	10	2.3	2.0	<2.0	7800682	4.2	2.0	7800682
Dissolved Nickel (Ni)	ug/L	5.5	7.8	2.0	<2.0	7800682	6.0	2.0	7800682
Dissolved Phosphorus (P)	ug/L	<100	<100	100	<100	7800682	<100	100	7800682
Dissolved Potassium (K)	ug/L	9000	600	100	1800	7800682	800	100	7800682
Dissolved Selenium (Se)	ug/L	0.79	<0.50	0.50	<0.50	7800682	<0.50	0.50	7800682
Dissolved Silver (Ag)	ug/L	<0.10	<0.10	0.10	<0.10	7800682	<0.10	0.10	7800682
Dissolved Sodium (Na)	ug/L	40000	9900	100	5300	7800682	6000	100	7800682
Dissolved Strontium (Sr)	ug/L	370	220	2.0	48	7800682	40	2.0	7800682
Dissolved Thallium (Tl)	ug/L	<0.10	<0.10	0.10	<0.10	7800682	<0.10	0.10	7800682
Dissolved Tin (Sn)	ug/L	<2.0	<2.0	2.0	<2.0	7800682	<2.0	2.0	7800682
Dissolved Titanium (Ti)	ug/L	<2.0	<2.0	2.0	<2.0	7800682	<2.0	2.0	7800682
Dissolved Uranium (U)	ug/L	8.3	11	0.10	1.7	7800682	1.1	0.10	7800682
Dissolved Vanadium (V)	ug/L	<2.0	<2.0	2.0	<2.0	7800682	<2.0	2.0	7800682
Dissolved Zinc (Zn)	ug/L	6.9	<5.0	5.0	<5.0	7800682	5.1	5.0	7800682
RDL = Reportable Detection Limit QC Batch = Quality Control Batch									



AT. RCAP-MS DISSOLVED (FIELDFIL) IN W

Bureau Veritas ID		RRK046			RRK046		
Sampling Date		2022/01/21			2022/01/21		
COC Number		N/A			N/A		
	UNITS	MW - DUP	RDL	QC Batch	MW - DUP Lab-Dup	RDL	QC Batch
Calculated Parameters							
Anion Sum	me/L	2.92	N/A	7796141			
Bicarb. Alkalinity (calc. as CaCO3)	mg/L	120	1.0	7796137			
Calculated TDS	mg/L	160	1.0	7796146			
Carb. Alkalinity (calc. as CaCO3)	mg/L	1.3	1.0	7796137			
Cation Sum	me/L	2.77	N/A	7796141			
Hardness (CaCO3)	mg/L	120	1.0	7796139			
Ion Balance (% Difference)	%	2.64	N/A	7796140			
Langelier Index (@ 20C)	N/A	0.384		7796144			
Langelier Index (@ 4C)	N/A	0.133		7796145			
Nitrate (N)	mg/L	<0.050	0.050	7796142			
Saturation pH (@ 20C)	N/A	7.69		7796144			
Saturation pH (@ 4C)	N/A	7.94		7796145			
Inorganics							
Total Alkalinity (Total as CaCO3)	mg/L	120	25	7805058	120	25	7805058
Dissolved Chloride (Cl-)	mg/L	9.4	1.0	7805061	8.0	1.0	7805061
Colour	TCU	<5.0	5.0	7805065	<5.0	5.0	7805065
Nitrate + Nitrite (N)	mg/L	<0.050	0.050	7805069	<0.050	0.050	7805069
Nitrite (N)	mg/L	<0.010	0.010	7805070	<0.010	0.010	7805070
Nitrogen (Ammonia Nitrogen)	mg/L	<0.050	0.050	7802824			
Total Organic Carbon (C)	mg/L	0.83	0.50	7800723			
Orthophosphate (P)	mg/L	<0.010	0.010	7805067	<0.010	0.010	7805067
pH	pH	8.07		7803116			
Reactive Silica (SiO2)	mg/L	13	0.50	7805063	13	0.50	7805063
Dissolved Sulphate (SO4)	mg/L	14	2.0	7805062	14	2.0	7805062
Turbidity	NTU	24	0.10	7805071	23	0.10	7805071
Conductivity	uS/cm	270	1.0	7803109			
Metals							
Dissolved Aluminum (Al)	ug/L	<5.0	5.0	7800682			
Dissolved Antimony (Sb)	ug/L	<1.0	1.0	7800682			
Dissolved Arsenic (As)	ug/L	2.0	1.0	7800682			
RDL = Reportable Detection Limit QC Batch = Quality Control Batch Lab-Dup = Laboratory Initiated Duplicate N/A = Not Applicable							



AT. RCAP-MS DISSOLVED (FIELDFILT) IN W

Bureau Veritas ID		RRK046			RRK046		
Sampling Date		2022/01/21			2022/01/21		
COC Number		N/A			N/A		
	UNITS	MW - DUP	RDL	QC Batch	MW - DUP Lab-Dup	RDL	QC Batch
Dissolved Barium (Ba)	ug/L	52	1.0	7800682			
Dissolved Beryllium (Be)	ug/L	<0.10	0.10	7800682			
Dissolved Bismuth (Bi)	ug/L	<2.0	2.0	7800682			
Dissolved Boron (B)	ug/L	<50	50	7800682			
Dissolved Cadmium (Cd)	ug/L	<0.010	0.010	7800682			
Dissolved Calcium (Ca)	ug/L	41000	100	7800682			
Dissolved Chromium (Cr)	ug/L	<1.0	1.0	7800682			
Dissolved Cobalt (Co)	ug/L	<0.40	0.40	7800682			
Dissolved Copper (Cu)	ug/L	<0.50	0.50	7800682			
Dissolved Iron (Fe)	ug/L	<50	50	7800682			
Dissolved Lead (Pb)	ug/L	<0.50	0.50	7800682			
Dissolved Magnesium (Mg)	ug/L	3100	100	7800682			
Dissolved Manganese (Mn)	ug/L	100	2.0	7800682			
Dissolved Molybdenum (Mo)	ug/L	2.4	2.0	7800682			
Dissolved Nickel (Ni)	ug/L	8.0	2.0	7800682			
Dissolved Phosphorus (P)	ug/L	<100	100	7800682			
Dissolved Potassium (K)	ug/L	600	100	7800682			
Dissolved Selenium (Se)	ug/L	<0.50	0.50	7800682			
Dissolved Silver (Ag)	ug/L	<0.10	0.10	7800682			
Dissolved Sodium (Na)	ug/L	10000	100	7800682			
Dissolved Strontium (Sr)	ug/L	220	2.0	7800682			
Dissolved Thallium (Tl)	ug/L	<0.10	0.10	7800682			
Dissolved Tin (Sn)	ug/L	<2.0	2.0	7800682			
Dissolved Titanium (Ti)	ug/L	<2.0	2.0	7800682			
Dissolved Uranium (U)	ug/L	11	0.10	7800682			
Dissolved Vanadium (V)	ug/L	<2.0	2.0	7800682			
Dissolved Zinc (Zn)	ug/L	<5.0	5.0	7800682			
RDL = Reportable Detection Limit QC Batch = Quality Control Batch Lab-Dup = Laboratory Initiated Duplicate							



Bureau Veritas Job #: C218357
Report Date: 2022/02/01

GHD Contractors Limited
Client Project #: 11194492-01
Site Location: SPORTING MOUNTAIN QUARRY
Your P.O. #: 735001928

GENERAL COMMENTS

Each temperature is the average of up to three cooler temperatures taken at receipt

Package 1	4.0°C
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Results relate only to the items tested.



Bureau Veritas Job #: C218357
 Report Date: 2022/02/01

QUALITY ASSURANCE REPORT

GHD Contractors Limited
 Client Project #: 11194492-01
 Site Location: SPORTING MOUNTAIN QUARRY
 Your P.O. #: 735001928

QC Batch	Parameter	Date	Matrix Spike		SPIKED BLANK		Method Blank		RPD		QC Standard	
			% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits	% Recovery	QC Limits
7800682	Dissolved Aluminum (Al)	2022/01/26	104	80 - 120	106	80 - 120	<5.0	ug/L				
7800682	Dissolved Antimony (Sb)	2022/01/26	104	80 - 120	99	80 - 120	<1.0	ug/L				
7800682	Dissolved Arsenic (As)	2022/01/26	94	80 - 120	92	80 - 120	<1.0	ug/L				
7800682	Dissolved Barium (Ba)	2022/01/26	96	80 - 120	97	80 - 120	<1.0	ug/L				
7800682	Dissolved Beryllium (Be)	2022/01/26	97	80 - 120	100	80 - 120	<0.10	ug/L				
7800682	Dissolved Bismuth (Bi)	2022/01/26	95	80 - 120	96	80 - 120	<2.0	ug/L				
7800682	Dissolved Boron (B)	2022/01/26	96	80 - 120	99	80 - 120	<50	ug/L				
7800682	Dissolved Cadmium (Cd)	2022/01/26	97	80 - 120	99	80 - 120	<0.010	ug/L				
7800682	Dissolved Calcium (Ca)	2022/01/26	NC	80 - 120	95	80 - 120	<100	ug/L				
7800682	Dissolved Chromium (Cr)	2022/01/26	96	80 - 120	95	80 - 120	<1.0	ug/L				
7800682	Dissolved Cobalt (Co)	2022/01/26	95	80 - 120	95	80 - 120	<0.40	ug/L				
7800682	Dissolved Copper (Cu)	2022/01/26	94	80 - 120	96	80 - 120	<0.50	ug/L				
7800682	Dissolved Iron (Fe)	2022/01/26	NC	80 - 120	98	80 - 120	<50	ug/L	1.8 (1)	20		
7800682	Dissolved Lead (Pb)	2022/01/26	98	80 - 120	97	80 - 120	<0.50	ug/L				
7800682	Dissolved Magnesium (Mg)	2022/01/26	99	80 - 120	102	80 - 120	<100	ug/L				
7800682	Dissolved Manganese (Mn)	2022/01/26	NC	80 - 120	98	80 - 120	<2.0	ug/L	0.76 (1)	20		
7800682	Dissolved Molybdenum (Mo)	2022/01/26	103	80 - 120	98	80 - 120	<2.0	ug/L				
7800682	Dissolved Nickel (Ni)	2022/01/26	96	80 - 120	96	80 - 120	<2.0	ug/L				
7800682	Dissolved Phosphorus (P)	2022/01/26	105	80 - 120	102	80 - 120	<100	ug/L				
7800682	Dissolved Potassium (K)	2022/01/26	101	80 - 120	100	80 - 120	<100	ug/L				
7800682	Dissolved Selenium (Se)	2022/01/26	97	80 - 120	95	80 - 120	<0.50	ug/L				
7800682	Dissolved Silver (Ag)	2022/01/26	91	80 - 120	94	80 - 120	<0.10	ug/L				
7800682	Dissolved Sodium (Na)	2022/01/26	93	80 - 120	98	80 - 120	<100	ug/L				
7800682	Dissolved Strontium (Sr)	2022/01/26	NC	80 - 120	96	80 - 120	<2.0	ug/L				
7800682	Dissolved Thallium (Tl)	2022/01/26	98	80 - 120	98	80 - 120	<0.10	ug/L				
7800682	Dissolved Tin (Sn)	2022/01/26	102	80 - 120	99	80 - 120	<2.0	ug/L				
7800682	Dissolved Titanium (Ti)	2022/01/26	99	80 - 120	97	80 - 120	<2.0	ug/L				
7800682	Dissolved Uranium (U)	2022/01/26	102	80 - 120	100	80 - 120	<0.10	ug/L				
7800682	Dissolved Vanadium (V)	2022/01/26	99	80 - 120	98	80 - 120	<2.0	ug/L				
7800682	Dissolved Zinc (Zn)	2022/01/26	97	80 - 120	97	80 - 120	<5.0	ug/L				
7800723	Total Organic Carbon (C)	2022/01/26	96	85 - 115	99	80 - 120	<0.50	mg/L	9.5 (1)	15		
7801073	Total Organic Carbon (C)	2022/01/27	99	85 - 115	103	80 - 120	<0.50	mg/L	6.4 (1)	15		



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Bureau Veritas Job #: C218357

Report Date: 2022/02/01

QUALITY ASSURANCE REPORT(CONT'D)

GHD Contractors Limited

Client Project #: 11194492-01

Site Location: SPORTING MOUNTAIN QUARRY

Your P.O. #: 735001928

QC Batch	Parameter	Date	Matrix Spike		SPIKED BLANK		Method Blank		RPD		QC Standard	
			% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits	% Recovery	QC Limits
7802824	Nitrogen (Ammonia Nitrogen)	2022/01/27	101	80 - 120	106	80 - 120	<0.050	mg/L	0.82 (1)	20		
7803109	Conductivity	2022/01/27			100	80 - 120	<1.0	uS/cm	4.7 (1)	10		
7803116	pH	2022/01/27			100	97 - 103			0.49 (1)	N/A		
7805036	Total Alkalinity (Total as CaCO3)	2022/01/31	92	80 - 120	110	80 - 120	<5.0	mg/L	7.0 (1)	20		
7805040	Dissolved Chloride (Cl-)	2022/01/31	93	80 - 120	97	80 - 120	<1.0	mg/L	0.049 (1)	20		
7805045	Dissolved Sulphate (SO4)	2022/01/31	92	80 - 120	95	80 - 120	<2.0	mg/L	1.7 (1)	20		
7805047	Reactive Silica (SiO2)	2022/01/31	NC	80 - 120	95	80 - 120	<0.50	mg/L	2.5 (1)	20		
7805048	Colour	2022/01/31			106	80 - 120	<5.0	TCU	NC (1)	20		
7805050	Orthophosphate (P)	2022/01/31	89	80 - 120	95	80 - 120	<0.010	mg/L	2.2 (1)	20		
7805052	Nitrate + Nitrite (N)	2022/01/31	NC	80 - 120	92	80 - 120	<0.050	mg/L	0.19 (1)	20		
7805053	Nitrite (N)	2022/01/31	97	80 - 120	96	80 - 120	<0.010	mg/L	NC (1)	20		
7805058	Total Alkalinity (Total as CaCO3)	2022/01/31	NC (2)	80 - 120	104	80 - 120	<5.0	mg/L	4.2 (3)	20		
7805061	Dissolved Chloride (Cl-)	2022/01/31	95 (2)	80 - 120	96	80 - 120	<1.0	mg/L	15 (3)	20		
7805062	Dissolved Sulphate (SO4)	2022/01/31	92 (2)	80 - 120	95	80 - 120	<2.0	mg/L	5.4 (3)	20		
7805063	Reactive Silica (SiO2)	2022/01/31	NC (2)	80 - 120	96	80 - 120	<0.50	mg/L	2.4 (3)	20		
7805065	Colour	2022/01/31			102	80 - 120	<5.0	TCU	NC (3)	20		
7805067	Orthophosphate (P)	2022/01/31	90 (2)	80 - 120	93	80 - 120	<0.010	mg/L	NC (3)	20		
7805069	Nitrate + Nitrite (N)	2022/01/31	92 (2)	80 - 120	95	80 - 120	<0.050	mg/L	NC (3)	20		
7805070	Nitrite (N)	2022/01/31	97 (2)	80 - 120	99	80 - 120	<0.010	mg/L	NC (3)	20		



BUREAU
VERITAS

Bureau Veritas Job #: C218357

Report Date: 2022/02/01

QUALITY ASSURANCE REPORT(CONT'D)

GHD Contractors Limited

Client Project #: 11194492-01

Site Location: SPORTING MOUNTAIN QUARRY

Your P.O. #: 735001928

QC Batch	Parameter	Date	Matrix Spike		SPIKED BLANK		Method Blank		RPD		QC Standard	
			% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits	% Recovery	QC Limits
7805071	Turbidity	2022/01/28			103	80 - 120	<0.10	NTU	3.9 (3)	20	101	80 - 120

N/A = Not Applicable

Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.

Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.

QC Standard: A sample of known concentration prepared by an external agency under stringent conditions. Used as an independent check of method accuracy.

Spiked Blank: A blank matrix sample to which a known amount of the analyte, usually from a second source, has been added. Used to evaluate method accuracy.

Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.

NC (Matrix Spike): The recovery in the matrix spike was not calculated. The relative difference between the concentration in the parent sample and the spike amount was too small to permit a reliable recovery calculation (matrix spike concentration was less than the native sample concentration)

NC (Duplicate RPD): The duplicate RPD was not calculated. The concentration in the sample and/or duplicate was too low to permit a reliable RPD calculation (absolute difference <= 2x RDL).

(1) Duplicate Parent ID

(2) Matrix Spike Parent ID [RRK046-01]

(3) Duplicate Parent ID [RRK046-01]



Bureau Veritas Job #: C218357
Report Date: 2022/02/01

GHD Contractors Limited
Client Project #: 11194492-01
Site Location: SPORTING MOUNTAIN QUARRY
Your P.O. #: 735001928

VALIDATION SIGNATURE PAGE

The analytical data and all QC contained in this report were reviewed and validated by:

Mike MacGillivray, Scientific Specialist (Inorganics)



Automated Statchk

BV Labs has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per ISO/IEC 17025, signing the reports. For Service Group specific validation please refer to the Validation Signature Page.



200 Bluewater Road, Suite 105, Bedford, Nova Scotia B4B 1G9 Tel: 902-420-0203 Fax: 902-420-8612 Toll Free: 1-800-565-7227
 49-55 Elizabeth Avenue, St John's, NL A1A 1W9 Tel: 709-754-0203 Fax: 709-754-8612 Toll Free: 1-888-492-7227
 465 George Street, Unit G, Sydney, NS B1P 1K5 Tel: 902-567-1256 Fax: 902-539-8504 Toll Free: 1-888-535-7770

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CHAIN OF CUSTODY RECORD

COC #:

Page 1 of 1

Invoice Information	Report Information (If differs from Invoice)	Project Information (where applicable)	Turnaround Time (TAT) Required
Company Name: GHD Limited	Company Name: GHD Limited	Quotation #: _____	<input checked="" type="checkbox"/> Regular TAT (5 business days) Most analyses
Contact Name: _____	Contact Name: Sherman Jackson	Purchase Order#: 735 001928	PLEASE PROVIDE ADVANCE NOTICE FOR RUSH PROJECTS
Address: 455 Phillip St., Waterloo, ON	Address: 110-120 Western Parkway, Bedford, NS	Project #: 11194492-01	IF RUSH please specify date (Surcharges will be applied)
PC: N2L3X2	PC: B4B 0V2	Site Location: Sporting Mountain Quarry	DATE REQUIRED: _____
Phone: _____	Phone: 902-483 0767	Site Province: NS	
Email: Invoicing-Canada@ghd.com	Email: sherman.jackson@ghd.com	Site #: _____	
Report Copies: _____	Report Copies: jeff.parks@ghd.com	Sampled By: SJ	

Laboratory Use Only					Analysis Requested																														
CUSTODY SEAL		COOLER TEMPERATURES		COOLER TEMPERATURES	# OF CONTAINERS SUBMITTED	FIELD FILTERED & PRESERVED	LAB FILTRATION REQUIRED	PCAP-M5 (Total Metals) Well / Surface water	PCAP-M5 (Dissolved Metals) Ground waters	Metals (Water)		Metals (Soil)		Total Digest (Default Method) for well water & surface water	Dissolved for ground water	Mercury (CIRCLE) TOTAL / DISSOLVED	Metals & Mercury Default Acid Extractable (Available) Digest	Hot Water Soluble Boron (required for CCME Agriculture/ Landfill)	RBGA Hydrocarbons (BTEX, C6-C12)	CCME Hydrocarbons (CWS-PHC F1/BTEX, F2-F4)	PAHs (Default for water/soil)	PAHs (FWA)/CCME Sediment	PCBS - Select One: Default or CCME Sediment	VOCs	Total Coliform/E.coli (Presence/Absence)	Total Coliform/E.Coli (Count)	TSS	pH	HOLD-DO NOT ANALYZE	Regulatory Requirements (Specify)					
Present	Intact																																		
			2, 5, 5																																
COOLING MEDIA PRESENT Y / N					SAMPLES MUST BE KEPT COOL (< 10 °C) FROM TIME OF SAMPLING UNTIL DELIVERY TO BV LABS																														
SAMPLE IDENTIFICATION				DATE SAMPLED (YYYY/MM/DD)	TIME SAMPLED (HH:MM)	MATRIX																													
1	MW 1			2022-01-21	10:05	GW	4	X																											
2	MW 2			2022-01-21	9:15	GW	4	X																											
3	MW 3			2022-01-21	10:30	GW	4	X																											
4	MW 4			2022-01-21	9:40	GW	4	X																											
5	MW - Dup			2022-01-21		GW	4	X																											
6																																			
7																																			
8																																			
9																																			
10																																			

RELINQUISHED BY: (Signature/Print)	DATE: (YYYY/MM/DD)	TIME: (HH:MM)	RECEIVED BY: (Signature/Print)	DATE: (YYYY/MM/DD)	TIME: (HH:MM)	BV LABS JOB #
<i>Sherman Jackson</i> Sherman Jackson	21-Jan-22	16:40	<i>MATT GRACE</i> MATT GRACE			C218357

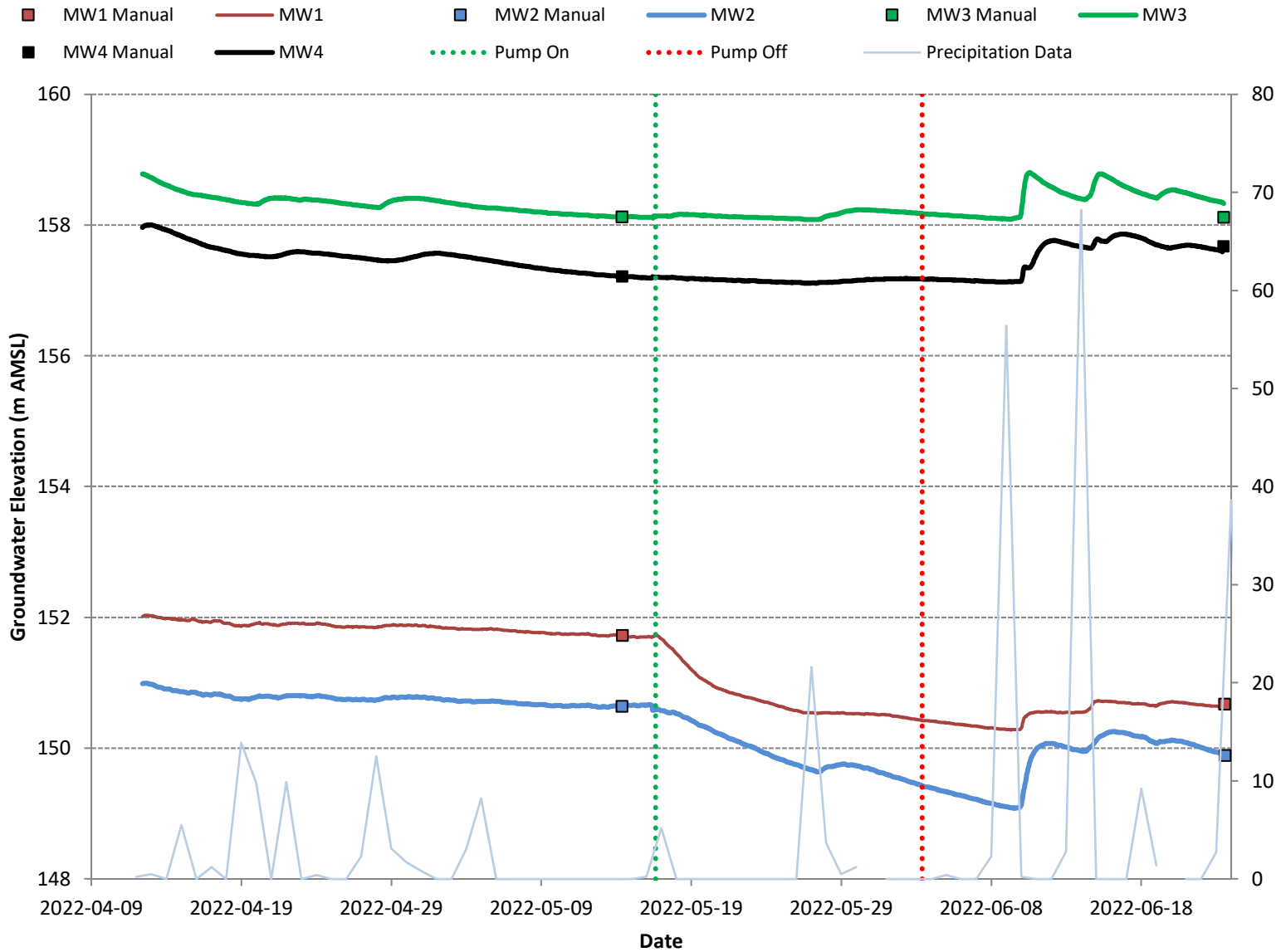
Unless otherwise agreed to in writing, work submitted on this Chain of Custody is subject to BV Labs standard Terms and Conditions. Signing of this Chain of Custody document is acknowledgment and acceptance of our terms which are available for viewing at www.bvlabs.com

2022 JAN 21 16:40

White: Maxxam

Pink: Client




Groundwater Elevations



Appendix B

General Visual Observations Data Sheets

General Observation Data Form - TEMPLATE

Location ID						Wetland Type			
Date of Assessment/Assessor						Wetland Observation Details			
Hydrological Indicator Present Y/N?		B:	PCM:	PCM:	PCM:	B:	PCM:	PCM:	PCM:
Surface water						Siltation/Sedimentation			
Dry season water table (30cm)						Flooding			
Saturated at surface						Drying			
Saturated within 20cm						Ground disturbance/rutting			
Water stained leaves						Artificial channelization			
H ₂ SO ₄						Invasive/Exotic Species			
Other						Dying Vegetation			
						NOTES: Describe all instances of Y noted above including coordinates, photos, potential cause.			
Photo Coordinates/Direction Facing									
Ph#									
Ph#									
Ph#									
Preceding Rainfall									
24 Hrs									
5 days prior									
									

Note: B=Baseline, PCM = Post Construction Monitoring

Appendix C

Water Balance Analysis

Memorandum

August 22, 2022

To	Bailee Williams		
Copy to	Jeff Parks, P. Geo., FGC		
From	Andrew Betts, M.A.Sc., P. Eng., Glen Merkley, P. Eng.	Tel	902 863-8689
Subject	Sporting Mountain Quarry – Water Balance Analysis	Project no.	11194492

1. Background

The following technical memorandum summarizes the water balance assessment completed for the proposed Nova Construction (Nova) Sporting Mountain Quarry Expansion (the Project) located in Seaview, Richmond County, Nova Scotia. Nova proposes to expand their existing quarry in Sporting Mountain from the approved <4 hectares (ha) to 10 ha to continue to extract and supply aggregate for road and local construction projects. There are no watercourses within the proposed expansion area, however, there are two unnamed watercourses (herein referred to as WC1 and WC2) located approximately 30 metres (m) west and east of the expansion area, respectively.

The water balance presented here is a preliminary assessment of the predicted effects on surrounding surface waterbodies caused by expansion of the quarry area. Four site conditions were analyzed, including: baseline conditions, operating conditions, dormant conditions, and reclamation conditions. Baseline conditions consider the site topography prior to extraction of the existing quarry. Operating conditions consider the quarry at full development and are expected to occur at approximately 30 years. Runoff in operating conditions will be discharged to two settling ponds located northeast and southeast of the quarry before entering WC2. The quarry floor was assumed to be dry during operating conditions. Dormant conditions consider the quarry between operating periods and before reclamation, with the quarry flooded to create a pit lake. Reclamation conditions are representative of the quarry after recontouring and revegetating disturbed areas of the property. As such these represent the “post-closure” condition as some degree of progressive reclamation will happen as site development occurs. Two overflow channels will be constructed to direct water from the pit lake to the two settling ponds located to the northeast and southeast during dormant and reclamation conditions.

1.1 Data Collection

1.1.1 Topographic Data

A 1 m digital elevation model (DEM) collected from the Nova Scotia Data Locator - Elevation Explorer was used to delineate the watershed areas for WC1 and WC2 (Nova Scotia, 2022). Watershed delineations were produced via the watershed delineation tool within PCSWMM, a hydrologic modelling software. Drainage areas were manually assessed and confirmed using 1 m contours generated from the DEM.

1.1.2 Climate Data

Precipitation totals were obtained from the Environment Canada 1981 to 2010 Climate Normals for the Baddeck Climate Station (Climate ID 8200300). This station was selected based on its proximity to the Project Site (approximately 48 kilometres [km] northeast of the Site) and relatively long record.

Monthly potential evapotranspiration normals were calculated using the Thornthwaite equation (1948). The Thornthwaite equation requires monthly average hours of daylight and monthly average temperature as inputs. Monthly average hours of daylight were calculated for the Site using the Sunrise and Sunset Calculator (Time and Date, 2022). Monthly average temperature values were obtained from the Environment Canada Baddeck Station.

Table 1 Climate Data

Parameter	January	February	March	April	May	June	July	August	September	October	November	December
Temperature ¹ (°C)	-5.4	-5.8	-2.3	3.2	9	13.9	18.1	18.5	14.6	8.9	3.8	-1.5
Precipitation ¹ (mm)	155	125.6	128.6	125.8	104	104.8	97.5	107.2	127.8	137.1	155	166.3
PET ² (mm/d)	0	0	0	0.6	1.9	3.1	3.8	3.5	2.6	1.3	0.5	0
Notes:												
¹ Values obtained from the Environment Canada 1981 to 2010 Climate Normals for the Baddeck Climate Station												
² Potential Evapotranspiration was calculated using the Thornthwaite equation (1948)												

2. Methodology

A preliminary water balance assessment was developed to assess the potential environmental impacts of the proposed Project at the operating, dormant, and reclamation conditions. The assessment was developed to determine the monthly changes to flow composition during an average year for the baseline, operating, dormant, and reclamation scenarios.

2.1 Watershed Delineation

Contributing drainage areas were delineated for two assessment points within WC1 and two assessment points within WC2. Pre-development drainage areas are as follows:

- WC1-US – 31.67 ha
- WC1-DS – 32.94 ha
- WC2-US – 6.55 ha
- WC2-DS – 19.06 ha

The WC1-US assessment point is located in the upstream reach of WC1. The WC1-DS assessment point is located at the downstream extent of the field delineated reach of WC1 and near the western property line. The WC2-US assessment point is located in WC2 at the predicted confluence with discharge from the northeast settling pond. The WC2-DS assessment point is located in WC2 at the predicted confluence with discharge from the southeast settling pond.

Drainage areas for WC1 and WC2 are subcatchments within the Long Lake drainage area. The Long Lake drainage area experiences no net loss in area due to the Project.

The contributing drainage areas were delineated using PCSWMM software and the 1 m DEM and were verified by manual methods within a GIS environment. Drainage delineations are presented based on four life-cycle phases of the proposed quarry: baseline drainage areas are shown on Figures 1 and 2, and operating, dormant, and reclamation drainage areas are shown in Figure 3. It should be noted the drainage in operating, dormant, and reclamation conditions is expected to remain constant. During operating, dormant, and reclamation conditions, water which falls on the quarry will be discharged to WC1.

2.2 Evaporation & Evapotranspiration Potential

Evaporation describes the process of the return of moisture to the atmosphere from open water and land surfaces. Evaporation from plant surfaces is called evapotranspiration. The magnitude of evaporation or evapotranspiration over time is a function of the climate, soil and the vegetation in the area. Evaporation rates tend to peak in the summer months when temperatures are highest, daylight hours are longest, sun intensity is greatest and the growing season is at its peak.

Evapotranspiration rates were calculated using the Thornthwaite equation (1948) as described in Section 1.1.2 based on average monthly temperature and daylight hours. Potential evapotranspiration rates for the five months of December to March were set to zero due to low temperatures resulting in minimal potential for evapotranspiration. The total potential evapotranspiration rate used for this water balance is 527 millimetre (mm) per year. July represents the month with the highest potential evaporation rate on average, at 3.8 mm/day or 116.6 mm per month. Table 1 provides a summary of the potential evaporation rates used as a water loss parameter in the water balance assessment.

2.3 Infiltration Factor

The water storage/infiltration has been estimated using the infiltration factors taken from Table 3.1 from the Ontario Ministry of Environment, Conservation and Parks (OMEC) SWM Planning and Design Manual (2003). Calculations using OMEC (2003) Table 3.1 accounts for slope, soil types, and vegetation cover when estimating water holding capacity for an area. Each watershed was individually analyzed to determine the slope, land use and soil type drainage factors. If multiple slope or land use segments existed within a watershed an area-ratio method was used to determine the appropriate infiltration factor. During baseline conditions the watersheds in the project site were determined to be hilly land (0.1 infiltration factor) with a combination of cultivated land (0.1) and woodland (0.2). Soil in the area is described in the Soil Survey of Cape Breton Island as having good drainage (Nova Scotia, 1981).

Due to the relatively shallow groundwater table observed at the site, minimal infiltration is expected through the quarry floor under dry conditions. An infiltration factor of 0.1 was applied to the quarry area in the operating conditions scenario. An area-ratio method was applied to determine the appropriate infiltration factor for drainage areas containing mixed land use.

Streamflow volumes were calculated as the sum of the surface runoff and baseflow volumes. Surface runoff volumes were assumed to equal the total precipitation less the evapotranspiration and infiltration. Baseflow volumes were assumed to equal infiltration volumes when the pit is flooded and the water table is at equilibrium. The basis for this assumption is that the groundwater flow divide follows the catchment boundaries and the water infiltrated within the catchment area appears as baseflow at the corresponding assessment point. It is assumed that there are no or minimal losses of groundwater to a deep aquifer system that crosses the catchment boundaries. In operating conditions, groundwater will be drawn into the pit, resulting in a reduction in baseflow in the adjacent watercourses.

2.4 Groundwater Contribution

The baseflow volume reductions in the watercourses adjacent to the pit were determined using the average estimated groundwater inflow rate to the pit and the zone of influence of the expanded pit on the surrounding water table. A pit inflow rate of 20 Liters per minute (L/min) was determined from the groundwater monitoring program. The pit inflow rate is estimated to increase to 30 L/min when the quarry is at full development.

The zone of influence radius was estimated to be approximately 200 m to the north of the pit and 40 m to the south of the pit. An average zone of influence was drawn around the pit and intersected with the adjacent catchment areas. Baseflow volume reductions were estimated as the percentage of the zone of influence that is comprised by the catchment multiplied by the groundwater inflow rate. The average approximate zone of influence is shown as the green outline on Figure 4.

3. Results

Tables 2 through 5 present the water balance analysis during baseline, operating, dormant, and reclamation conditions, respectively. Tables 6 through 8 display the percentage change in area and runoff from baseline conditions to operating, dormant, and reclamation conditions, respectively. A negative value in Tables 6 through 8 represents a decrease in the value compared to baseline conditions, and a positive value represents an increase in the value compared to baseline conditions. Monthly streamflow impacts are provided in Attachment 1.

Table 2 Water Balance - Baseline Conditions

Watershed	Area (ha)	Streamflow (cubic metre [m ³])	AET (m ³)	Infiltration (m ³)
WC1-US	31.67	319,061	166,977	177,334
WC1-DS	32.94	330,491	173,655	185,755
WC2-US	6.55	65,954	34,516	31,335
WC2-DS	19.06	192,055	100,510	101,431

Table 3 Water Balance - Operating Conditions

Watershed	Area (ha)	Streamflow (m ³)	AET (m ³)	Infiltration (m ³)
WC1-US	31.67	314,990	166,977	178,140
WC1-DS	32.94	326,199	173,655	186,964
WC2-US	8.32	85,616	43,846	31,449
WC2-DS	19.06	217,717	80,633	89,689

Table 4 Water Balance – Dormant Conditions

Watershed	Area (ha)	Streamflow (m ³)	AET (m ³)	Infiltration (m ³)
WC1-US	31.67	319,061	166,977	178,140
WC1-DS	32.94	330,120	173,655	186,964
WC2-US	8.32	83,781	43,846	29,450
WC2-DS	19.06	192,055	100,510	69,793

Table 5 Water Balance – Reclamation Conditions

Watershed	Area (ha)	Streamflow (m ³)	AET (m ³)	Infiltration (m ³)
WC1-US	31.67	319,061	166,977	178,462
WC1-DS	32.94	329,972	173,655	187,448
WC2-US	8.32	83,781	43,846	29,495
WC2-DS	19.06	192,055	100,510	70,357

Table 6 *Operating Conditions Comparison to Baseline Conditions*

Watershed	%Area Change	%Streamflow Change
WC1-US	0.00%	-1.28%
WC1-DS	0.00%	-1.30%
WC2-US	27.03%	29.81%
WC2-DS	0.00%	13.36%

Table 7 *Dormant Conditions Comparison to Baseline Conditions*

Watershed	%Area Change	%Streamflow Change
WC1-US	0.00%	0.00%
WC1-DS	0.00%	-0.11%
WC2-US	27.03%	27.03%
WC2-DS	0.00%	0.00%

Table 8 *Reclamation Conditions Comparison to Baseline Conditions*

Watershed	%Area Change	%Streamflow Change
WC1-US	0.00%	0.00%
WC1-DS	0.00%	-0.16%
WC2-US	27.03%	27.03%
WC2-DS	0.00%	0.00%

4. Conclusions

The results from the water balance analysis can be used to assess the potential impact of the proposed quarry development on the receiving environment in terms of the change in runoff volume discharged to WC1 and WC2. The results are analyzed for average annual conditions.

At full quarry development, WC1 will experience no change in drainage area at the WC1-US and WC1-DS assessment points compared to baseline conditions. WC2 will experience an increase in drainage area of 27.03 percent at full quarry development at the WC2-US assessment point compared to baseline conditions, however WC2-DS will experience no change in drainage area. The drainage area impacts are consistent between operating, dormant, and reclamation conditions.

In operating conditions, WC1-US will experience a reduction in streamflow of 1.28 percent compared to baseline conditions caused by water table drawdown into the empty pit. There are no impacts to streamflow's at this assessment point in dormant and reclamation conditions when the pit is flooded and the groundwater table is stabilized.

In operating, dormant, and reclamation conditions WC1-DS will experience reductions in streamflow of 1.30 percent, 0.11 percent, and 0.16 percent, respectively, compared to baseline conditions. These reductions are caused by water table drawdown into the empty pit during operating conditions and by slight changes in land cover during the dormant and reclamation scenarios.

In operating conditions there will be a 29.81 percent increase in streamflow at the WC2-US assessment point. In dormant and reclamation conditions there will be a 27.03 percent increase in streamflow compared to baseline conditions. These increase in streamflow are attributed to the overflow/pumped water from the expanded pit via the northeast settling pond that is outside of the baseline WC2-US catchment.

WC2 at the WC2-DS assessment point will experience an increase in streamflow of 13.36 percent under operating conditions due to groundwater inflows to the quarry discharged at the southeast settling pond. No changes in streamflow are predicted at this assessment point under dormant and reclamation conditions.

Impacts to WC2 resulting from increases in streamflow will be mitigated through use of the northeast and southeast settling ponds. Instantaneous peak flows will be attenuated as water is discharged more gradually through the pond outlets. Furthermore, increases in streamflow in the dormant and reclamation phases will be limited to the reach of WC2 upstream of WC-DS. Impacts to WC2 will gradually decrease in the downstream direction.

There will be a reduction in streamflow in WC2 when the quarry is dormant or in reclamation and the pit is filling with water. The impact will be greatest near the WC2-DS assessment point and will gradually decrease in the downstream direction.

When discussing the results of this water balance it should be noted that this quarry will be developed over the course of approximately 30 years. The lengthy duration of development will allow the surrounding environment to slowly adjust to changes in the hydrologic regime. In addition, reclamation will occur throughout the course of the quarry's life span. As such, the operating and dormant conditions represent the worst-case scenario in terms of overall development.

5. Closure

This technical memo was prepared by Glen Merkley and reviewed by Andrew Betts.

6. References

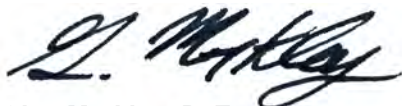
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All of which is respectfully submitted,



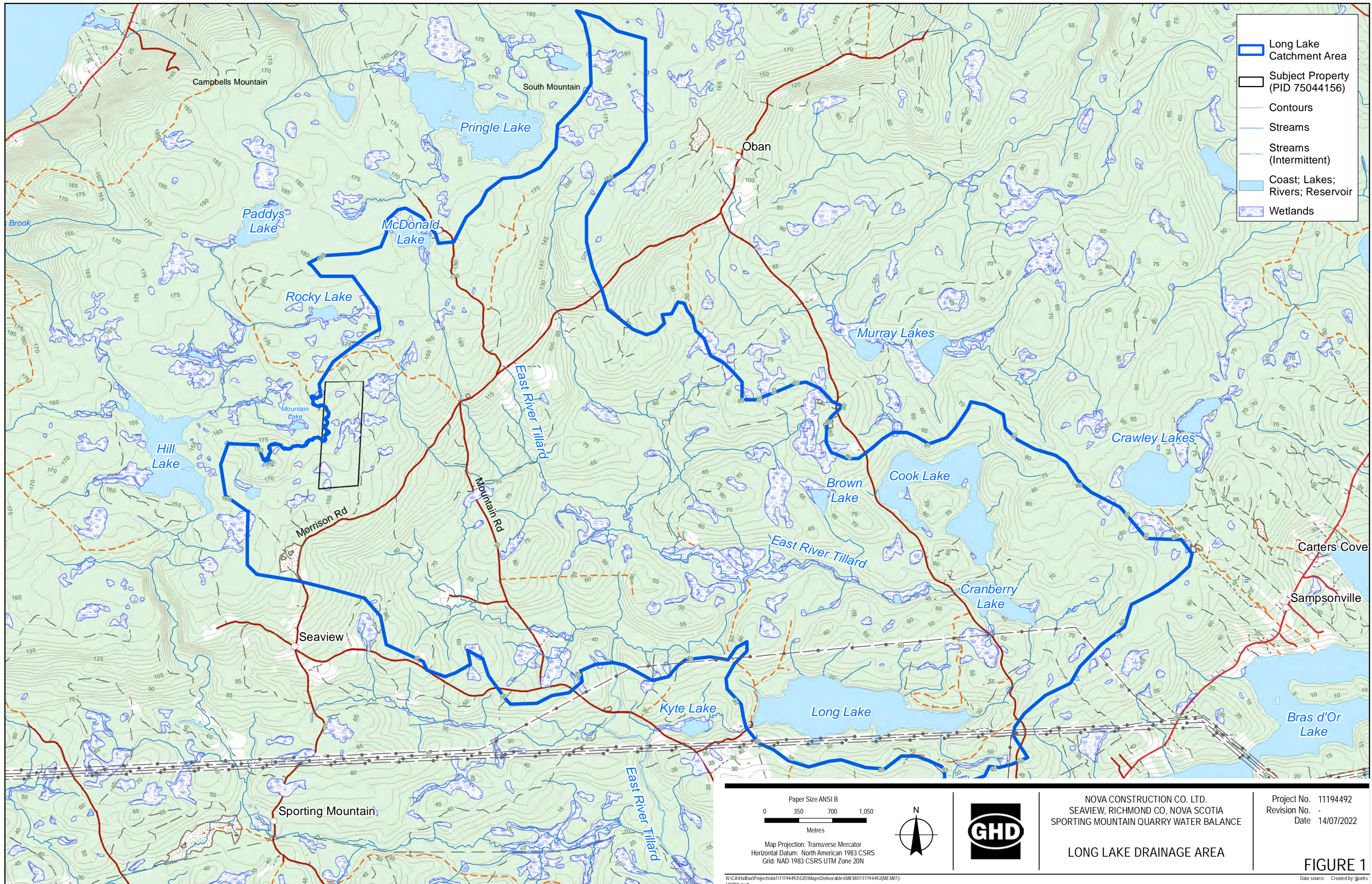
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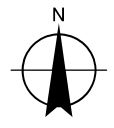
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- Long Lake Catchment Area
- Subject Property (PID 75044156)
- Contours
- Streams
- Streams (Intermittent)
- Coast; Lakes; Rivers; Reservoir
- Wetlands

Paper Size ANSI B
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 Horizontal Datum: North American 1983 CSRS
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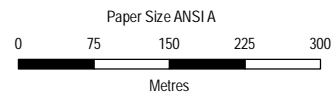
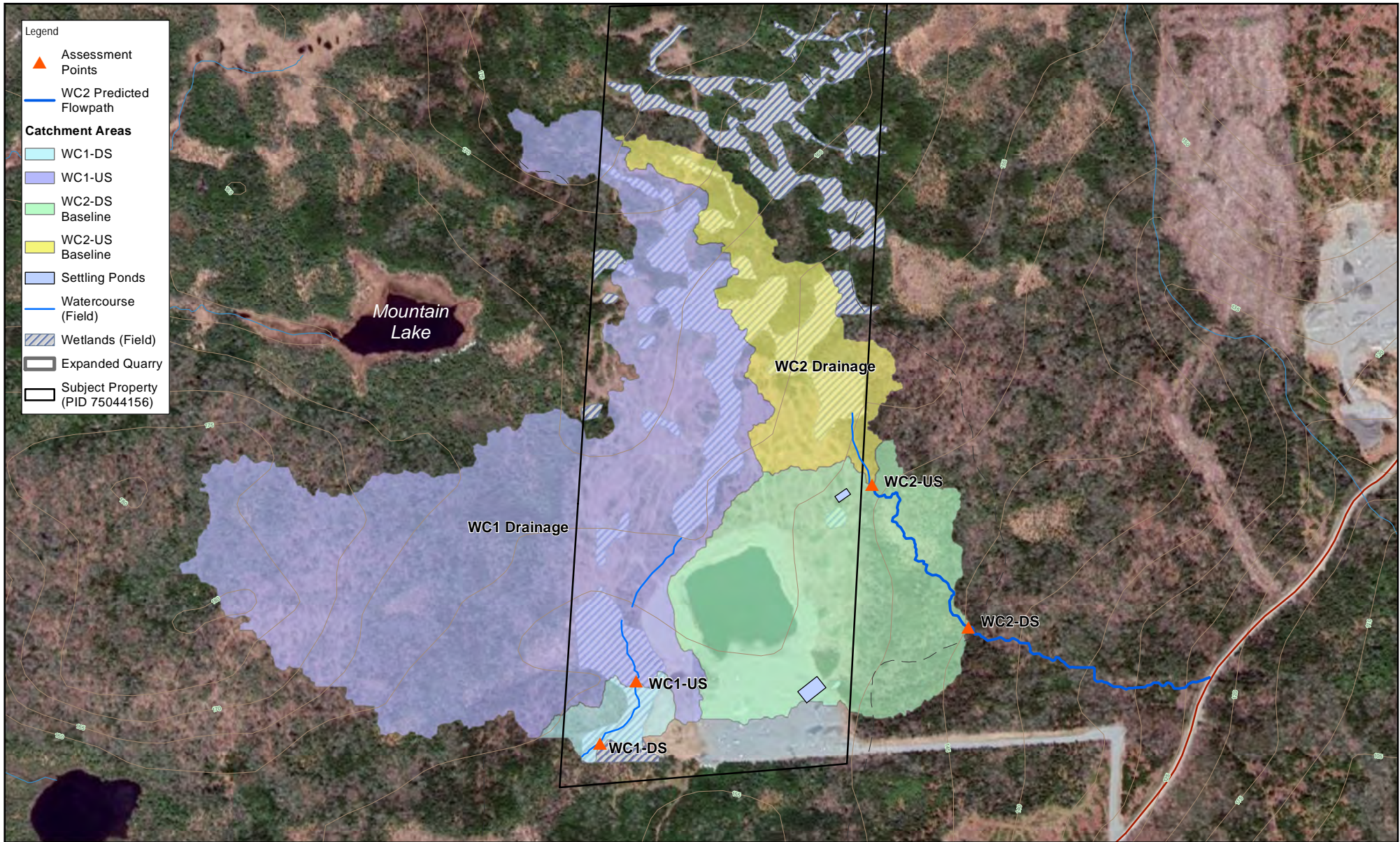
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 SEAVIEW, RICHMOND CO, NOVA SCOTIA
 SPORTING MOUNTAIN QUARRY WATER BALANCE
LONG LAKE DRAINAGE AREA

Project No. 11194492
 Revision No. -
 Date 14/07/2022

FIGURE 1

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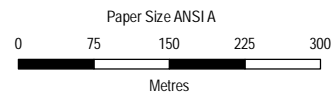
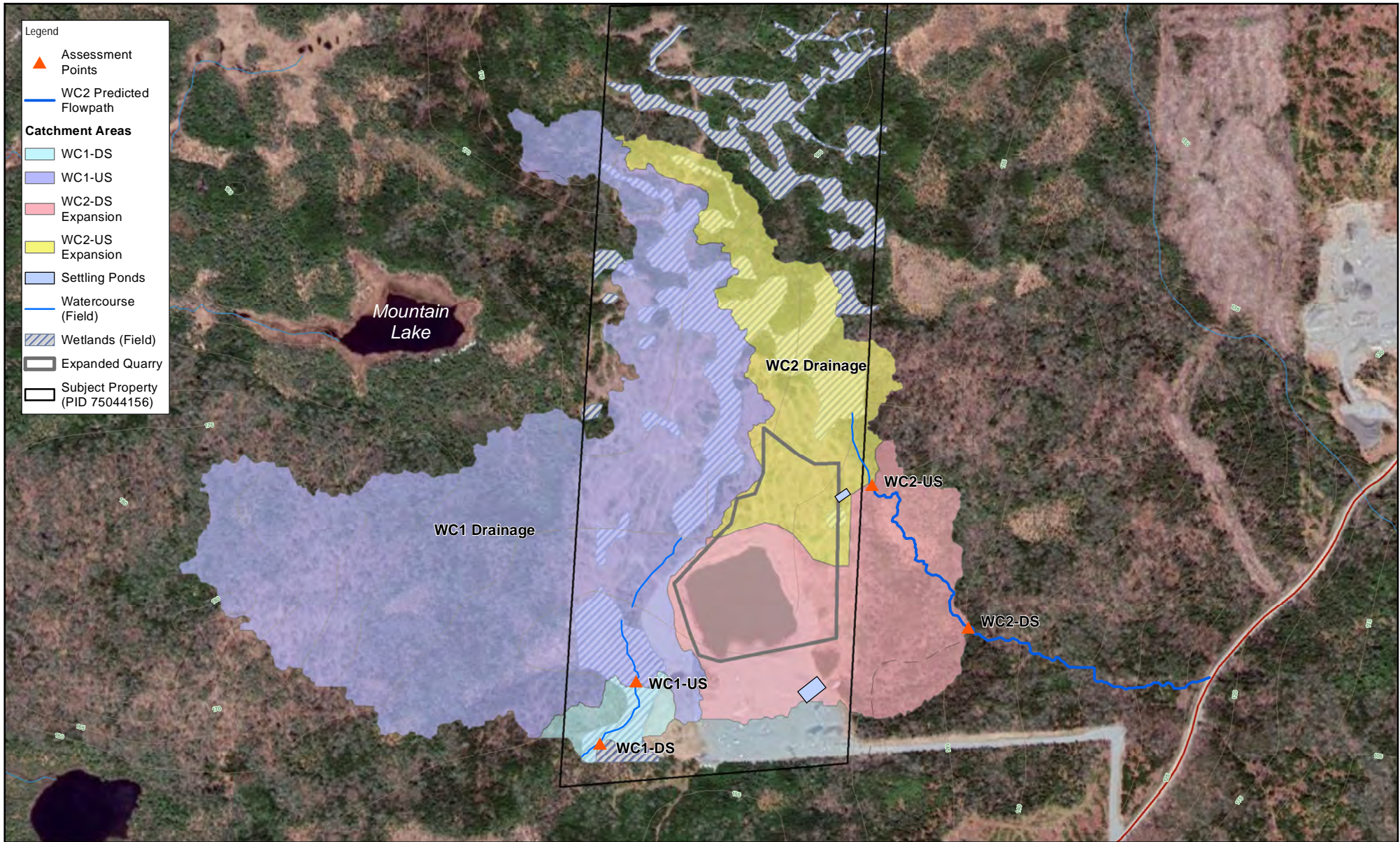
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 Date 01/08/2022

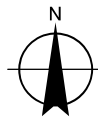
**BASELINE DRAINAGE
 AREAS DELINEATION**

FIGURE 2

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Map Projection: Transverse Mercator
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Grid: NAD 1983 CSRS UTM Zone 20N



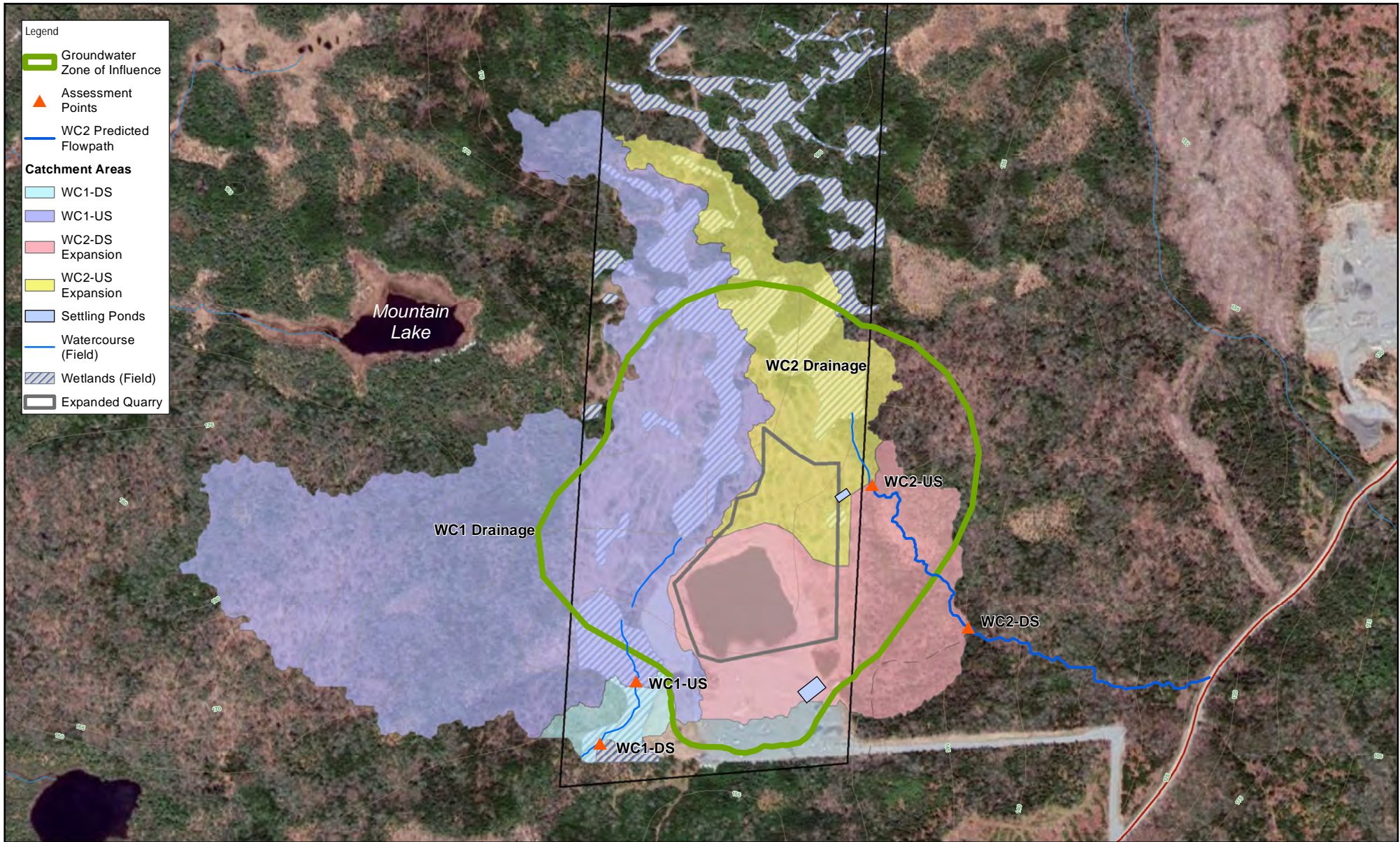
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SPORTING MOUNTAIN QUARRY WATER BALANCE

OPERATING, DORMANT &
RECLAMATION DRAINAGE
AREAS DELINEATION

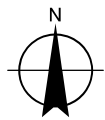
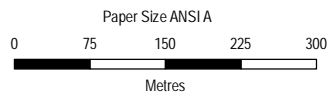
Project No. 11194492
Revision No. -
Date 01/08/2022

FIGURE 3

Data source: - Created by: jiparks



- Legend**
- Groundwater Zone of Influence
 - Assessment Points
 - WC2 Predicted Flowpath
- Catchment Areas**
- WC1-DS
 - WC1-US
 - WC2-DS Expansion
 - WC2-US Expansion
 - Settling Ponds
 - Watercourse (Field)
 - Wetlands (Field)
 - Expanded Quarry



Map Projection: Transverse Mercator
 Horizontal Datum: North American 1983 CSRS
 Grid: NAD 1983 CSRS UTM Zone 20N



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 Revision No. -
 Date 01/08/2022

**EXPANDED QUARRY
 ZONE OF INFLUENCE ON
 SURROUNDING WATER TABLE**

FIGURE 4

Attachments

Attachment 1

Monthly Streamflow Results

Table 1 *Change in Monthly Streamflow Values for the Development Stages for WC1-US*

Month	Operating	Dormant	Reclamation
Jan	-0.85%	0.00%	0.00%
Feb	-0.95%	0.00%	0.00%
Mar	-1.02%	0.00%	0.00%
Apr	-1.19%	0.00%	0.00%
May	-2.82%	0.00%	0.00%
Jun	-9.92%	0.00%	0.00%
Jul	0.00%	0.00%	0.00%
Aug	0.00%	0.00%	0.00%
Sep	-4.22%	0.00%	0.00%
Oct	-1.37%	0.00%	0.00%
Nov	-0.91%	0.00%	0.00%
Dec	-0.79%	0.00%	0.00%
Annual	-1.28%	0.00%	0.00%

Table 2 *Change in Monthly Streamflow Values for the Development Stages for WC1-DS*

Month	Operating	Dormant	Reclamation
Jan	-0.90%	-0.11%	-0.16%
Feb	-0.99%	-0.11%	-0.16%
Mar	-1.06%	-0.11%	-0.16%
Apr	-1.22%	-0.11%	-0.16%
May	-2.74%	-0.11%	-0.16%
Jun	-9.33%	-0.11%	-0.16%
Jul	0.00%	0.00%	0.00%
Aug	0.00%	0.00%	0.00%
Sep	-4.04%	-0.11%	-0.16%
Oct	-1.39%	-0.11%	-0.16%
Nov	-0.96%	-0.11%	-0.16%
Dec	-0.85%	-0.11%	-0.16%
Annual	-1.30%	-0.11%	-0.16%

Table 3 *Change in Monthly Streamflow Values for the Development Stages for WC2-US*

Month	Operating	Dormant	Reclamation
Jan	29.09%	27.03%	27.03%
Feb	29.33%	27.03%	27.03%
Mar	29.51%	27.03%	27.03%
Apr	29.92%	27.03%	27.03%
May	33.89%	27.03%	27.03%
Jun	26.12%	27.03%	27.03%
Jul	0.00%	0.00%	0.00%
Aug	0.00%	0.00%	0.00%
Sep	37.30%	27.03%	27.03%
Oct	30.36%	27.03%	27.03%
Nov	29.25%	27.03%	27.03%
Dec	28.95%	27.03%	27.03%
Annual	29.81%	27.03%	27.03%

Table 4 *Change in Monthly Streamflow Values for the Development Stages for WC2-DS*

Month	Operating	Dormant	Reclamation
Jan	12.11%	0.00%	0.00%
Feb	12.39%	0.00%	0.00%
Mar	12.62%	0.00%	0.00%
Apr	13.11%	0.00%	0.00%
May	17.90%	0.00%	0.00%
Jun	38.74%	0.00%	0.00%
Jul	0.00%	0.00%	0.00%
Aug	0.00%	0.00%	0.00%
Sep	22.02%	0.00%	0.00%
Oct	13.64%	0.00%	0.00%
Nov	12.30%	0.00%	0.00%
Dec	11.94%	0.00%	0.00%
Annual	13.36%	0.00%	0.00%

Appendix D

SOP for Fish Collection

STANDARD OPERATING PROCEDURE: FISH COLLECTION

1 PURPOSE

The purpose of this document is to provide standard methods for fish collection techniques performed by McCallum Environmental Ltd. (MEL) employees and subconsultants in freshwater habitats.

2 SCOPE

This document provides standards for data collection and measurements, and gives details on a limited range of fish collection methodologies/gear for linear watercourses and littoral habitats of open water areas (i.e. ponds, lakes), including:

- Electrofishing
- Minnow traps
- Eel pots
- Fyke nets
- Seine nets

Subject to study design, these sampling techniques can provide both qualitative information (i.e. species presence, community composition, and relative abundance) and quantitative information (i.e. population estimates) on fish species within freshwater habitats. A clear understanding of the purpose of the sampling program will help define the fish trapping methodology that is needed.

It is important to note that all gear types have certain limitations, including but not limited to catch selectivity and sampling efficacy. The best fish collection studies will employ variety of gear types to sample as many habitat types as possible, thus ensuring the widest possible range of fish species and sizes are collected. A summary of gear types (i.e. sampling methodologies) presented within this document and their limitations are provided in Section 5. There are several resources that provide greater detail and a wider range of procedures for fish collection - see Portt et al. (2006) for a comprehensive review of fish sampling methods in freshwater habitats.

It is also important that all field staff understand the habitat preferences of fish expected to be encountered within the study area. All field staff should have a general understanding of the biology and habitat preferences of anticipated fish species and age groups. This knowledge can greatly improve the sampling efficiency of the field crew and provides important information for gear selection. Detailed information on the biology of fishes in Nova Scotia can be found in Scott and Crossman (1973), McPhail and Lindsey (1970), and the Nova Scotia Adopt A Stream Manual (2005). Fact sheets for common freshwater fish species have been provided in Appendix C.

3 PERMITTING

Before engaging in any fish collection survey, MEL must apply for, and obtain a Licence to Fish Finfish for Scientific Purposes, issued by Fisheries and Oceans Canada (DFO). This is required under the provisions of the Fisheries Act, and any fishing completed without a permit can be subject to criminal charges under the Act. Project managers must ensure proper notification is provided to DFO as outlined in the licence, and must confirm that there are no variation orders in effect which may limit fish sampling methods.

All field staff must read and understand the conditions of the fishing licence and are required to have a hard copy of the licence on hand during all fish collection surveys.

4 SAFETY

The following documents provide important safety considerations and Personal Protective Equipment (PPE) for this type of work, and should be consulted before proceeding with any fish collection survey:

- MEL HSE Policy;
- MEL Remote Work Policy; and,
- Fisheries and Oceans Canada's Interim Policy for the Use of Backpack Electrofishing Units (2003)

The following sections provide important information pertaining to the prevention and avoidance of injury to personnel and fish during fish collection surveys. Unique safety considerations that apply to each fishing method are outlined in Sections 5.1 through 5.5, and procedures outlined in Section 6.0 contain safety checks and emergency response protocols to be followed by all field crew members.

5 FISH COLLECTION METHODS - THEORY

Gear types used for sampling can be divided into two categories: active and passive. Active gear includes those that are moved through the water either by machine or with human power (e.g. electrofishing). Passive gear is usually set and left stationary for a period of time (e.g. minnow traps).

Although gear will be selected prior to the field survey, the surveyors will exercise their judgment in using any combination of gear types to ensure that all habitat types are surveyed within the watercourse reaches or waterbodies of interest.

Certain criteria assist in selection of appropriate gear types. These criteria can include, for example, the overall objective of the fish collection survey, anticipated fish species to be encountered, and in-field limitations such as the physical characteristics of the watercourse/waterbody being surveyed. Fish mortality is also an issue that must be considered, with preference for non-lethal or low-mortality methods wherever possible. Gear types known to have high mortality rates (e.g. gill nets) are not proposed for use as part of MEL fish collection efforts at this time.

Certain limitations may restrict the use of a particular gear type to a lake, a stream, or a particular habitat type. For example, electrofishing is effective in shallow areas of with higher velocity but cannot be used efficiently in deep open waters. Site accessibility, substrate, vegetation, time constraints, size, and accessibility of the habitat of the lake or stream may further affect deployment of each gear type. The best results are obtained by using a variety of gear types to sample as many habitat types as possible, thus ensuring the widest possible range of fish species and sizes are collected.

Many factors affect fish sampling. These include water depth, conductivity, water clarity, water temperature, water velocity, fish size and behavior. The effects these factors have on sampling efficiency vary, and many of the factors are interrelated. Efficacy and limitations of specific gear types are summarized in Table 1.

5.1 Electrofishing

Electrofishing is the technique of passing electric current through the water to attract and stun fish, thus facilitating their capture. This SOP pertains to backpack electrofishing only. It is most useful in streams

and rivers, but can also be used to sample shallow littoral areas of lakes. The deeper and wider a sampling area, the more likely fish will be able to avoid capture.

The electrofishing unit is essentially a portable transformer carried on the back of the operator (like a backpack), with probes, controls, and gauges. An electrical current is produced by the unit and is passed through the water from the cathode (negatively (-) charged probe) to the anode (positively (+) charged probe). This current produces an electric field in the water that will affect any fish in a variety of ways depending on where the fish is situated in relation to the electrical field (flight, attraction, or stun). It is also influenced by environmental conditions such as flow rate and conductivity, and the size of the fish present.

Electrofishing is the preferred MEL method for fish collection. Ideally, electrofishing reaches will be free of safety or navigation hazards such as abundant woody debris, deep pools, unstable substrate, or high flow. Although larger fish are typically more easily stunned, electrofishing can be effective at capturing all species and sizes of fish.



Photo 1: Example of an electrofishing crew in action

Electrofishing can be used to determine both qualitative metrics (i.e. determining species presence, diversity, or relative abundance) and quantitative metrics (i.e. estimating population size, absolute abundance), depending on the characteristics of the habitat and the overall objective of the survey. Electrofishing procedures presented in Section 7.2 outline techniques for both qualitative and quantitative surveys. Quantitative surveys (i.e. the depletion method) is the preferred procedure and should be completed whenever site conditions allow.

The depletion method (also known as the “Zippin” method, see Zippin, 1958) is a suitable method for population estimates when the stream is very small, it is expedient to collect all data within a short time

period such as one day, and the population being estimated is relatively small (roughly less than 2,000 individuals). This type of freshwater habitat is typical of what MEL biologists encounter throughout Nova Scotia's landscape, especially within headwater inland systems.

The depletion method requires that an adequate number of fish be removed on each sampling pass so that measurably fewer fish are available for capture and removal on a subsequent pass. The number of passes required generally depends on the capture result of each pass; however, a minimum of three passes is generally recommended. Two passes may be sufficient if the second catch is < 10% of the first, and if catches have not declined in the first three sweeps then additional passes are required until catches are < 25% of that in the initial pass.

The following conditions must be met for accurate depletion method estimates:

1. Emigration and immigration by fish during the sampling period must be negligible. This is accomplished by installing barrier nets at both upstream and downstream ends of the electrofishing reach.
2. All fish within a specified sample group must be equally vulnerable to capture during a pass.
3. Vulnerability to capture of fish in a specified sample group must remain constant for each pass (e.g. fish do not become more wary of capture).
4. Collection effort and conditions which affect collection efficiency, such as water clarity, must remain constant. To minimize error, the amount of effort used on each pass should be as constant as possible.

The depletion method is ineffective when more individuals are caught in the second or third passes than were caught in previous passes. This may be particularly problematic for streams containing low numbers of fish. In addition, the depletion method can only be used when barrier nets can be effectively deployed to reduce fish movement. When sampling reaches where blocking nets are not practical (i.e. large rivers), a qualitative survey (single pass without the use of barrier nets) should be performed, which will allow an estimate of relative abundance (Catch Per Unit Effort, known as CPUE).

Electrofishing must be done with a minimum crew size of two people: a "crew leader" and the other "crew members". The crew leader must be a qualified person and be certified to conduct backpack electrofishing surveys. The crew leader is responsible for the instruction of all other crew members. At least one crew member must have up-to-date Standard First Aid and CPR training.

Unsafe working conditions that may cause one to halt electrofishing operations (this list is not exhaustive and the final decision is generally left to the crew leader):

- Temperature
 - Electrofishing cannot be conducted in water temperatures >22°C
- Weather conditions
 - Moderate rain (enough to soak through clothing)
 - thunder and lightning
 - extreme heat (above 30°C)
- Dark water, deep water, fast flowing waters
 - unsure footing
 - inability to properly see substrate and/or fish
 - difficult to net fish efficiently and safely

- Stream conditions
 - thick, hidden, difficult vegetation and other debris in site
 - in-stream or overhanging vegetation

If any of these situations arise, the team must stop to evaluate conditions, and determine whether it is safe to proceed with electrofishing surveys. All crew members will work as a group to discuss and evaluate options to proceed with the survey. The final decision to proceed, delay, or forego the survey will be left to the crew leader. The crew leader must contact the Project Manager within 24 hours if a survey is delayed or skipped due to safety concerns.

5.2 Minnow Traps

Minnow traps are small, wire or plastic enclosures used to trap live fish. They are typically circular and slightly tapered towards the ends, with inward facing funnels at each end. The opening size for most minnow traps is 3 – 5 cm in diameter, with a standard mesh size of 6 - 8 mm, giving it an effective catch range of body depths approximately 6 - 50 mm. Small fish can swim inside through funnels that guide them from the large opening near the outside of the trap to the narrow opening close to the centre of the trap. Once inside it is difficult for the animal to locate the opening and escape.

Minnow traps consist of two wire baskets held together by a clip. The baskets are interlocked and the clip is inserted to hold the two halves together. The trap is attached with rope to a fixed object to it can be retrieved, and is positioned either on the bottom or suspended at a particular depth. Minnow traps are set with bait, which is discussed further in Procedures (Section 7).



Photo 2: Typical metal minnow trap (Source: <https://dynamicaquasupply.com/products/minnow-trap-gee-style-1-8-mesh>)

Minnow traps are also size selective and are best suited for sampling juvenile fish or adults of small species. They are most commonly used in littoral habitat and low velocity streams, especially within areas that may be difficult to sample with nets or electrofishing, such as deep areas, or habitats with abundant aquatic vegetation or woody debris. Water depth must be sufficient to submerge the trap entrances. As for

all trap and net types, the length of set time for minnow traps should account for activity levels of fish at various times of the day (daylight, dusk, overnight, and dawn). Generally, traps should be set for approximately 24 hours (set on the first day and retrieved the following day). Traps may be re-deployed on successive days, provided they are checked once per 24 hours. If minnow trapping is completed to supplement electrofishing efforts, shorter set times may be suitable (to be determined on a project-by-project basis).

Minnow traps provide a qualitative metric of abundance (i.e. relative abundance), with effort expressed in terms of catch per trap per length of time set (CPUE).

5.3 Eel Pots

Eel pots are similar to minnow traps in that they allow fish into an opening in a rigid metal trap. MEL's eel pots are rectangular and are available in a variety of lengths (2-5 ft). A single, inward facing funnel (6.5 - 8 cm opening) is located at one end of the trap, through which small and medium sized fish can swim inside through. This longer funnel guides the fish from the large opening near the outside of the trap to the narrow opening situated closer to the opposite end of the trap. This end of the trap acts like a door which can be opened to retrieve trapped fish and to install bait. A bungee cord and hook keep this door closed when the trap is set. With a wire mesh size of 1-2 cm, the effective catch range of eel pots are fish with body depths of 10 - 80 mm. The trap is attached with rope to a fixed object to it can be retrieved, and is positioned on the bottom substrate.



Photo 3: Typical metal eel pot (Source: <https://ketchamsupply.com/product/eel-trap/>)

This sample method is selective towards small-medium sized fishes, and can be deployed wherever water depth allows the opening of the eel pot to be submerged. Eel pots target slightly larger fish which may be excluded from the minnow trap; however as a larger trap, it is typically deployed in larger, deeper pools or littoral zones without many obstructions, whereas minnow traps can be selected to sample small watercourses where other methods cannot be used. Pots should be set for approximately 24 hours (set on the first day and retrieved the following day). Traps may be re-deployed on successive days, provided they are checked once per 24 hours. If trapping is completed to supplement electrofishing efforts, shorter set times may be suitable (to be determined on a project-by-project basis). Eel pots can provide a qualitative metric of abundance (i.e. relative abundance), with effort expressed in terms of catch per trap per length of time set (CPUE).

5.4 Fyke Nets

A fyke net is a type of hoop net which traps fish inside mesh enclosures. The mesh is supported by a series of rigid hoops, which become smaller towards the back of the net. The opening of the trap contains a D-shaped hoop, and all subsequent hoops are round. The fyke net is characterized by “wings” which lead fish to the fyke net opening. The wings are short lengths of mesh with float (on the top, with buoys) and lead (on the bottom, weighted) lines that are attached to the lateral margins of the first hoop and extended at a 45° angle to the opening of the trap.

Fish that enter the fyke net pass through constrictions called tunnels. The tunnels are cones of mesh that are attached to the hoops, so that when the net is set and the hoops are separated the narrow end of the tunnel points to the rear. Usually there are multiple tunnels per net which get smaller towards the back of the net. Fyke nets are normally not baited, relying instead on the wings to guide fish into them. Fyke nets are accessed at the posterior end, where the mesh that extends beyond the last hoop is closed by a drawstring.

Fyke nets can be set in littoral and stream habitats in water that is deeper or shallower than the height of the hoops, as long as the tunnels are submerged. These nets are difficult to set where the bottom is



Photo 4: Example of a fyke net installation in an open waterbody

uneven, such as among boulders, and where there is dense vegetation or an abundance of other obstructions such as logs or stumps. In littoral habitats, fyke nets should be installed perpendicular to the shoreline, with the posterior end of the net positioned farthest offshore. In stream setting, the net is normally set with the opening facing upstream. One of the main drawbacks of a fyke net in stream environments is that debris can collect in or damage the net, reducing catch efficiency.

Fyke nets are size and species selected – they tend to target larger bodied fish as smaller fish like juvenile salmonids and forage fish may escape through the mesh (2 cm openings), and are more likely to capture roaming species than sedentary species. When deployed, fyke nets should remain in place for approximately 24 hours (set on the first day and retrieved the following day). Fyke nets may be re-deployed on successive days, provided they are checked once per 24 hours. If netting is completed to

supplement electrofishing efforts, shorter set times may be suitable (to be determined on a project-by-project basis). Nets can provide a qualitative metric of abundance (i.e. relative abundance), with effort expressed in terms of catch per trap per length of time set (CPUE).

5.5 Seines

Seine nets (which also double as barrier nets for use during electrofishing surveys) consist of a length of fine mesh strung between a positively buoyant line (the float line) and a negatively buoyant line (the lead line) that is pulled through the water to encircle fish. Typical seines used in research are made of a woven (also called knotless) nylon mesh with small (in our case, 1/8th inch) openings. This SOP pertains only to seines used through wading, though they may also be deployed from a boat.

Seines can be used in both littoral habitat and slackwater areas of larger rivers, but generally cannot be used in moderate-fast currents. Seines are normally only used in water depths that are less than two thirds the depth of the seine, so that the lead line remains on the bottom and the float line remains at the surface as the net is pulled forward. Seining is easiest over smooth bottoms with no debris or obstructions, which may cause the net to lift off the bottom substrate, causing a loss of fish.

The simplest deployment technique involves two people, one on each end of the seine. One person stays fixed at the shore, while the second person wades through the water with the seine in a smooth arc. The seine haul ends by bringing the two ends of the seine together and pulling the net forward so that the encircled fish end up in the mesh that is between the lead and float lines.



Photo 5. Example of seining within riverine habitat

(Source:

https://commons.wikimedia.org/wiki/File:Seining_for_wild_fish.jpg)

Efficiency varies widely among species, with benthic species being less susceptible to capture than mid-water species. Smaller individuals are more susceptible than large individuals, which may avoid capture by swimming out of the path of the seine. Qualitative abundance estimates can be expressed in terms of catch per haul if all hauls are similar, whereas more quantitative abundance estimates can be expressed as catch per unit area seined (e.g, catch per m²).

Table 1. Efficacy and limitations of gear types (adapted from Portt et al. 2006)

Gear	Limitations			Survey Objective			Units
	Depth	Habitat	Selectivity	Presence	Relative Abundance	Absolute Abundance	
Electrofishing	Limited to safe wading depths for backpack; <2 m for boat. Only requires enough water to submerge the anode ring and tail.	Cannot conduct in water >22°C, or in the rain. Currents must be low enough to safely wade. High turbidity, vegetation, woody debris, soft substrate, and low conductivity decreases efficiency. Efficiency lower in large streams than in small streams.	Capture efficiency greater for large individuals. Benthic species are easy to overlook.	✓	✓	✓	CPUE (effort = electrofishing seconds) or catch per square m
Minnow Traps	Requires depths sufficient to submerge trap (>15cm). Not suitable for extremely shallow water.	Limited to low velocity habitat.	Limited to small-bodied fish (6 - 50 mm).	✓	✓		CPUE (effort = trap time in hours)
Eel Pots	Requires depths sufficient to submerge interior funnel (>20cm) along the <u>entire</u> length of the trap. Not suitable for extremely shallow water.	Limited to low velocity habitat.	Limited to small/moderate bodied-fish (10 - 80 mm).	✓	✓		CPUE (effort = trap time in hours)

Gear	Limitations			Survey Objective			Units
	Depth	Habitat	Selectivity	Presence	Relative Abundance	Absolute Abundance	
Fyke Nets	Requires depths sufficient to submerge interior funnel (>20 cm). Not suitable for extremely shallow water.	Limited to low-moderate velocity habitats with limited amounts of debris.	High selectivity for roaming species (vs. sedentary). Good for intercepting fish during migration. Effective catch range 20 mm + body depth.	✓	✓		CPUE (effort = net time in hours)
Seines	Limited to safe wading depths. Ideal water depths are less than 1/2 – 2/3 depth of the seine, so that the lead line can rest on the substrate, while the float line remains above water.	Limited to stream or littoral habitat with small, rocky substrate and limited obstructions.	Benthic species less catchable than mid-water species. Smaller individuals more susceptible than large individuals.	✓	✓	✓	CPUE (effort = number of hauls) or catch per square m

6 MATERIALS

The materials and equipment required to safely perform fish capture surveys in the field are listed below. The list is inclusive of all materials required to perform any fish capture survey (electrofishing, trapping, and netting).

- Electrofishing Kit
 - backpack electrofisher in Pelican case
 - anode pole and ring
 - cathode tail
 - batteries and battery charger
 - gloves (long-armed, lineman's gloves)
 - polarized sunglasses
 - long-handled landing net
 - wader repair kit
- Traps and nets
 - minnow traps
 - eel pots
 - fyke nets
 - seine nets (i.e. barrier nets)
 - rope
 - rebar or stakes to aid in setup
- Fish Processing Kit
 - clear tupperware with ruler
 - plexiglass fish viewer
 - electronic balance scale (including calibration weights and extra batteries)
 - spring scale (and extra batteries)
 - live-well buckets (plastic, 5-gallon)
 - small dip net
- Additional Equipment
 - standard MEL PPE
 - Required PPE for electrofishing:
 - Leak-free chest waders with wading belt
 - Wide brimmed hat
 - Polarized sunglasses
 - Long-armed gloves/linesman gloves
 - first aid kit
 - personal flotation device if deemed necessary based on site characteristics
 - field sheets on write-in-the-rain paper ("Fish Collection Tracking Sheet", Appendix D)
 - fish ID books, identification key
 - pencils
 - multi-parameter water quality instrument (YSI or equivalent)
 - GPS
 - hand sanitizer
 - flagging tape
 - measuring tape

- meter stick
- phone or digital camera
- **hard copy of DFO fishing licence**

7 FISH COLLECTION METHODS – PROCEDURES

7.1 Planning: Before You Leave

1. Review detailed written scope provided to you by the Project Manager. This will identify priority deliverables, timelines, and budget allowed for each task. Detailed methods will be provided in this scope (i.e. # of traps required, set time required, etc).
2. Identify the crew supervisor/operator and crew members. The crew supervisor must have an Electrofishing Crew Leader Certification and proper training for the use of the electrofisher and safety procedures. The primary responsibility of the crew supervisor is to ensure the safety of all crew members. Their secondary responsibility is to direct the survey. A field team must consist of a minimum of 2 people, and all crew members are responsible for working in a safe manner, bearing mind that any action can affect the safety of other crew members.
3. Determine the location(s) of the survey, size of area to be surveyed and easiest access to the site based on the work scope provided by the Project Manager. Sample design should be verified by the Project Manager.
4. Prepare site maps and GPS units as required.
5. Ensure that all personal safety equipment and field gear are in good working order. Check the electrofisher unit and traps for any obvious signs of damage. Ensure all traps and nets have clear markings on them identifying the licence number, a contact person, and an emergency contact number.
6. Fill out a field tracking sheet. Have all crew members review and sign off on the field tracking sheet.

7.2 Electrofishing

7.2.1 Site Setup

1. Ensure that all personal safety equipment is in good working order and remove all jewelry including watches, necklaces or rings before commencing electrofishing.
2. Assign roles for the following:
 - electrofisher operator
 - primary netter
 - secondary netter (if third crew member is available)
3. Prepare the workstation for the survey by laying out the first aid kit(s) and other equipment to ensure fast and easy access. Set-up any equipment to be used for processing fish.
4. Measure a 100 m survey reach along the contours of the stream channel, marking the beginning and end of the survey reach with flagging tape and take GPS waypoints. For “closed” sites, install the barrier nets at the downstream extent, and then upstream extent of the reach, ensuring that the lead line is placed firmly against the bottom substrate and that the nets cover the entire channel width. This is not required for larger streams greater than the width of the barrier nets (on average > 7 m across); however, whenever possible, adjust the downstream and upstream extent locations of reaches to allow for use of barrier nets (try to find a narrow channel section). For

larger streams, a qualitative, single-pass survey using an open-site methodology should be employed.

5. Take representative photos of the following:
 - Looking upstream
 - Looking downstream
 - Right bank (downstream orientation)
 - Left bank (downstream orientation)
 - Substrate
 - Any distinct physical features
6. Sketch a rough drawing of the site on the Fish Collection Tracking Sheet, noting any distinct physical features of the site (barriers, pools, braiding etc.), and discuss any potential safety hazards with all crew members. Discuss how to proceed through the survey reach.
7. Record the site identifier information, general site conditions (air temperature, weather, previous precipitation), and physical characteristics of the reach (widths, depths, substrate, habitat types, etc) on the Fish Collection Tracking Sheet.
8. Measure and record temperature, conductivity (SPC, CON), total dissolved solids (TDS), pH, dissolved oxygen (DO), and salinity (SAL) on the Fish Collection Tracking Sheet.

*Note: If performing multi-pass surveys, water temperature must be recorded at the beginning of each pass. **Electrofishing cannot be conducted in water >22°C.***

9. Assemble the electrofishing unit.
 - With the main power switch in the OFF position, and emergency shut off switch pressed down, plug the anode and cathode into their proper connectors located on the bottom of the Pelican case and install the battery
 - Ensure the tilt switch is turned on
 - Reset the 'elapsed time' counter
 - Check that emergency releases are in good working order
 - Set a low output voltage (100 or 150V) and frequency (40 or 60Hz) to start
 - Ensure that the audible safety tone and light are working
 - Keep the emergency shut off switch pressed down when entering the stream
10. Outside of the closed survey reach, test the voltage and frequency settings and adjust if necessary. Voltage and frequency may need to be changed to get a desired response. In general, lower frequencies are safer for larger fish than higher frequencies. If the unit is not producing satisfactory results, try increasing the frequency a few levels before increasing the output voltage. Only increase the output voltage one-step at a time, releasing the anode pole switch to change the electrofisher output frequency and/or voltage levels.

Note: Observe fish closely. In general, if it takes more than 5 seconds for a fish to recover it may have been shocked too much. If it takes more than 15 seconds for a fish to recover it was definitely shocked too much; therefore reduce the frequency or output voltage. Another common indication of an excessive voltage setting is "burn marks" on fish caused by the triggering of pigment cells in the flesh and visible as dark discolorations. Burn marks are temporary, but when observed the voltage should be decreased. The voltage should only be increased if fish are consistently in the fright zone and are not completely stunned.

7.2.2 Surveying

1. The survey should be completed in an upstream direction. Start at the most downstream point of the sampling site and work your way upstream. Once in the reach, the backpack operator will release the emergency shut off switch on the electrofishing unit. The operator must always give a verbal indication to, and receive a verbal acknowledgement from, all crew before commencing each sweep.
2. The electrofisher operator must say aloud “Power On” each time they begin electrofishing. Begin the first sweep by shocking water at the designated starting point.
3. The netter should be positioned downstream of the operator, approximately 2-3 m apart. The netter should set the pole net flush with the bed of the stream and perpendicular to flow.
4. Continue sweeping the anode ring wading from one bank to the other, always in line with the pole net, thus sampling a “lane” of the stream. When fishing undercut banks or log jams, fish can be drawn out by inserting the uncharged anode, switching it on and then pulling the anode out and away. Creating currents using the anode ring or dip-nets can often assist with pulling stunned fish out of complex structure when using this technique. When the opposite bank is reached, both the machine operator and pole netter move upstream 2–3 m and begin fishing again. Continue fishing until the entire sample reach has been fished.

*Note: If you get water in waders or gloves, or it begins to rain hard enough to saturate clothing, **STOP WORK** immediately and get dry clothing. Never reach into the water in vicinity of an electrode, even if rubber gloves are being worn. To further prevent electrical shock, never touch an electrode while the circuit is energized, even while wearing rubber gloves and waders.*

5. Transfer captured fish to live wells where they can be held until the completion of the electrofishing pass. Keep the live well in a shaded area. When fish are held for a longer period of time, particularly during warm conditions, regularly change the water maintain water quality.
6. Record pass details (seconds of electrofishing, voltage, and frequency) on the Fish Collection Tracking Sheet. Reset the elapsed time counter for each pass.
7. Process the captured fish (refer to Section 8). Once processed, return captured fish to watercourse/ waterbody, outside of the barricaded reach (if using barrier nets).
8. Repeat steps 1-8 until the required number of passes have been completed. The number of passes required will depend on the type of survey (qualitative or quantitative) being employed.
 - a. For a **qualitative, open-site survey**, one pass should be sufficient, unless crew members note a high number of fish that evaded capture. In that case, perform a second or third pass to obtain greater species representation. For all qualitative electrofishing surveys, crews should aim for at least 300 seconds of effort (i.e. minimum effort).
 - b. In **quantitative, closed-site surveys**, a minimum of three passes should be performed. The requirement for additional passes is determined by the total catch on the last run. If the catch on the last run is <20% of the catch on the first pass and <50% of the catch of the previous pass, no additional passes are required. If no fish are captured or observed on the first two passes, the third pass is not necessary.
9. At the conclusion of all electrofishing surveys, inspect all equipment and note any problems requiring correction. Disconnect the battery and all attachments. Batteries must be charged at the

end of each day's use to maintain the life expectancy and all equipment must be thoroughly dried and stored in the appropriate manner.

7.3 Trapping and Netting

As previously stated, fish collection surveys are most effective when using a variety of gear types to sample as many habitat types as possible. Efforts should be made to supplement electrofishing surveys with other fishing techniques (trapping and netting) when the watercourse reach or portions of the reach being surveyed are not suitable for electrofishing (i.e. non-wadeable, deeper pools, high concentration of woody debris). Trapping and netting are also the preferred method for the open water habitats (e.g. ponded wetlands) and littoral habitats of lakes, where electrofishing tends to be inefficient. The types of traps and nets suitable for each survey depends largely on physical habitat characteristics of the watercourse or waterbody and the fish species anticipated to inhabit them. However, the main objective for netting and trapping should be to set the most diverse combination of traps and nets possible. The habitat limitations and selectivity of each trap type are summarized in Table 1.

7.3.1 Site Setup

Note: if trapping/nettings occurs within the same survey reach as electrofishing, combine all data onto one Fish Collection Tracking Form. Trapping/netting completed within a watercourse/waterbody without electrofishing requires its own tracking form.

1. Ensure that all traps and nets are in good working order (no tears and holes). Ensure all passive traps that are to be left unattended have an identification tag (licence number, contact name and emergency contact number) attached.
2. Select suitable locations within the watercourse/waterbody for deployment that are accessible by wading. Consider the physical characteristics of the habitat being surveyed, the fish species anticipated to be present, and the likelihood of fish to congregate in certain areas based on the species and time of year. Plan to distribute traps so they will be independent of each other. Target in-stream habitats such as:
 - Areas with suitable water depths for trap deployment
 - Slack-water areas (particularly in rivers)
 - Potential refuge/cover areas, including snags, deep pools, highly vegetated areas, and undercut banks
 - Off-channel habitats, side channels, and backwaters
3. If considering seining, identify any possible snags, large substrate, deep areas, or other safety hazards which may impede the survey. Discuss and mitigate with all crew members. Only seine if it is safe and appropriate to do so.
4. When trap/net locations are confirmed, take a GPS waypoint and a water depth reading of each location. Record the UTM coordinates and water depth for each trap/net on the Fish Collection Tracking Sheet.
5. Sketch a rough drawing of the site on the Fish Collection Tracking Sheet, noting any distinct physical features of the site (barriers, pools, braiding etc.), and discuss any potential safety hazards with all crew members.

6. Record the site identifier information, general site conditions (air temperature, weather, previous precipitation), and physical characteristics of the watercourse/waterbody (when applicable) on the Fish Collection Tracking Sheet.
7. Measure and record temperature, conductivity (SPC, CON), total dissolved solids (TDS), pH, dissolved oxygen (DO), and salinity (SAL).
8. Proceed with trap/net deployment or seining (if conditions allow).

Note: As standard practice, all passive traps and nets (minnow traps, eel pots, and fyke nets) should be set for approximately 24 hours. This involves setting traps/nets on one day, and retrieving traps the following day then the following day. Traps may be re-deployed on successive days, provided they are checked once per 24 hours. If trapping is completed to supplement electrofishing efforts, shorter set times may be suitable (to be determined on a project-by-project basis).

7.3.2 Trap/Net Deployment (Day 1)

1. If deploying minnow traps or eel pots, place bait in inner compartment, bearing in mind various mesh sizes so the bait stays inside the traps. Possible bait includes dry or wet cat/dog food, or Cheetos. Ensure rope is attached to each minnow trap/eel pot and tie the other end to a stationary object. Identify the stationary object with flagging tape. This will assist in locating the traps and will also prevent the trap from floating away.
2. If deploying fyke nets, face the opening upstream if in riverine habitat, or perpendicular to the shoreline if in an open waterbody with the opening facing the shore. Fix the wings in place using stakes driven into the substrate, or rope attached to stationary objects to achieve a 45° angle to the opening of the trap. Ensure that the lead line lays flat on the bottom substrate – this can be ensured by placing rocks along the bottom edge of the wings. Ensure that each funnel is open and not twisted to allow for the passage of fish to the back of the net. Tie off the posterior drawstring and extend the traps back so that each segment is fully extended and the hoops are upright. To maintain this position, the posterior end of the trap may need to be fixed in place – this can be achieved with a stake, stick, rope, rock or other heavy object.
3. Ensure all entries into the traps and nets are submerged.
4. Record deployment time on the Fish Collection Tracking Sheet.
5. Take photos of each trap setup.

7.3.3 Trap/Net Retrieval (Day 2)

1. If multiple traps are used, retrieve in the order they are deployed, one at a time. Record retrieval time for each trap/net on the Fish Collection Tracking Sheet. Set times and retrieval times can be rounded to the closest 5-minute interval.
2. Deposit fish captured into a live well.
3. Process captured fish (refer to Section 8).
4. Rinse the traps/nets clean after all of the fish have been released. Allow the traps/nets to dry once the field survey is complete.
5. If re-deploying traps, follow outlines in Section 7.3.2.

7.3.4 Seining

1. Attach a pole (stake, rebar, etc.) to each end of the seine and used as a handle. The lead line should be attached to the bottom of the pole, which is kept on or at the substrate. An alternate method is to tie a loop in each end of the lead line and place it over the operators' feet that are

closest to the net, and to hold the float line in the hand closest to the net. The bottom line is pulled forward by the operator's leg.

2. With one crew member staying stationary on the shore/bank holding one end of the seine, the other crew member drags the other end of the net into the water by wading in a perpendicular line to the shore, keeping the lead line on the bottom substrate and the float line at the water's surface.
3. Once almost all of the net has been pulled into the water, the wading crew member arcs back to the shoreline/bank, creating an arc shape with the net. The wading operator then pulls their end of the net back to the shoreline, lining up parallel to the stationary operator.
4. To retrieve the net, pull the net to shore with one person on each end of the net. The float and lead lines should be pulled in together at a slow, even pace. Do not pull too quickly, as this could cause the float line to become submerged and possibly allow fish to escape over the net. If the float line is pulled in ahead of the lead line, the flow of water will be downward causing the lead line to lift off the bottom, allowing fish to escape underneath the net.
5. As the net approaches shore, the lead line should be kept on the bottom and the float line should be lifted slightly to stop fish from jumping out of the net. The entire net should be pulled onto the shore and the catch quickly transferred into live wells and processed.

8 FISH PROCESSING

Fish should be handled as little as possible and processed quickly. The water quality of the live wells should be maintained as close as possible to the fish's natural habitat, and should be kept out of direct sunlight. Monitor condition of fish on a regular basis to ensure the temperature and oxygen levels in the well are adequate, and replace water if fish show signs of stress (i.e. gasping at surface, frantic swimming, lethargy, rapid gill movements, etc.). Note that these processing procedures do not include anesthetic. Gentle pressure should be used to immobilize fish on the measuring board - ensure that this pressure remains slight and is not focused on the eye area or the operculum.

1. Prepare the onshore workstation to commence the processing of captured fish. Layout/assemble all equipment from the Fish Processing Kit. Level the electronic balance scale and calibrate prior to use.
2. If fish have been captured through multiple gear types, process fish from each gear type one at a time. This is necessary to infer qualitative abundance data for each method of fish collection.
3. Any crew member involved in fish handling procedures will ensure that hands are free of chemical contaminants (i.e. insect repellent, sunscreen) prior to any handling of fish. If additional surveys are to take place in the same day, crew members must sanitize hands prior to handling fish from different areas in order to minimize the risk of disease transfer.
4. Prepare the live well (fish captured during electrofishing should be actively placed in a live well during sampling), ensuring that water is refreshed regularly, especially on warm days. Prepare multiple live wells and separate fish species if predation within the well is likely to occur (i.e. American eel captured with other fish species).
5. On the Fish Collection Tracking Sheet under Individual Fish Measurements (Appendix D), assign each fish captured with a number starting from 1, and continue numbering for each fish (1, 2, 3...) captured within a particular survey site. Photograph each individual fish with the fish number in the photograph (or photograph the fish number prior to photographing the fish). Record the collection method - if electrofishing with multiple passes, record what pass the fish was captured during (e.g. Pass 1), or if captured with a trap or net, record the gear type and ID if using multiples of the same type (e.g. MT1). Gear type codes are presented on the Fish Collection

Tracking Sheet. Record the fish species using the 3-letter codes provided in Appendix B. If species is unknown, record with a “U”.

6. Measure and record the total length (TL, mm), fork length (FL, mm), weight (in grams), and life stage (if known). See Appendix B for terms and definitions:
 - Small fish (<500g) are to be weighed with the electronic balance scale, measuring to with +/- 0.01g.
 - Large fish (>500g) are to be weighed on a spring scale using a tared mesh net.
7. Note whether or not the adipose fin is clipped, as this will indicate that the fish is from a hatchery. Watch for burn marks and note any other pertinent observations. Note any mortalities, and overall condition. Appendix A provides anatomical features and morphological definitions for fish.
8. Return captured fish to the habitat area. In the case of multi-pass electrofishing surveys, captured fish may should be returned outside and downstream of the barrier nets so as to avoid being double counted.

9 REPORTING

Reporting and data management requirements will be communicated to the field crew by the Project Manager. At a minimum, the following parameters must be communicated to the Project Manager for submission to DFO under Appendix A of the License to Fish for Scientific Purposes:

- Dates of the fishing activity
- Fishing location (waterbody, county and province)
- Gear type used
- Number of fish caught by species
- Life stage of fish caught by species
- Number of fish sampled/tagged by species if applicable
- Fate of fish by species:
 - Number released alive
 - Number of incidental mortalities
 - Number retained alive
 - Number of retained mortalities.

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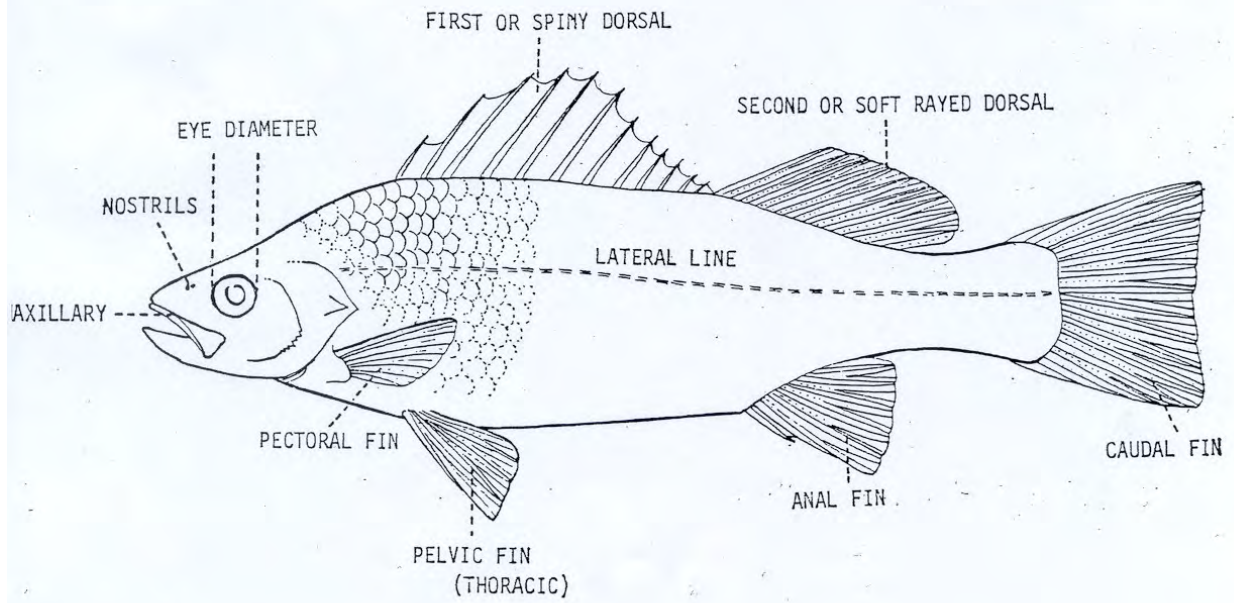
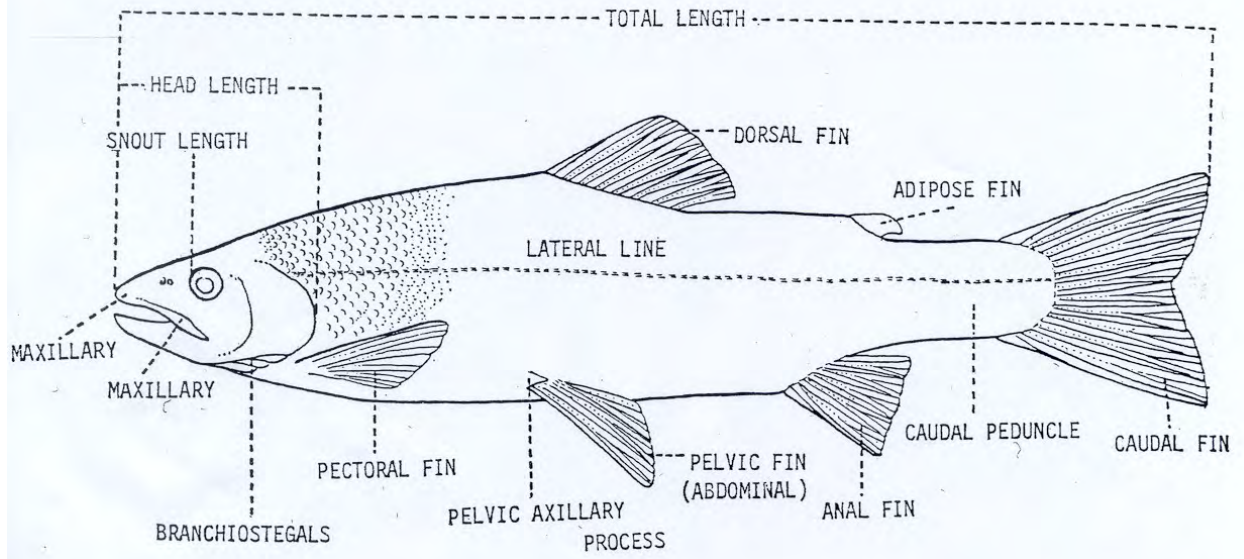
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Appendix A: Anatomical Features of Fish



Appendix B: Fish Species Codes & Definitions

Code	Species Name	Code	Species Name
ALE	Alewife (<i>Alosa pseudoharengus</i>)	LKC	Lake chub (<i>Couesius plumbeus</i>)
EEL	American eel (<i>Anguilla rostrata</i>)	LKT	Lake trout (<i>Salvelinus namaycush</i>)
AMS	American shad (<i>Alosa sapidissima</i>)	LWF	Lake whitefish (<i>Coregonus clupeaformis</i>)
ARC	Arctic char (<i>Salvelinus alpinus</i>)	LLS	Landlocked salmon (<i>Salmo salar</i>)
ATS	Atlantic salmon (<i>Salmo salar</i>)	LNS	Longnose sucker (<i>Catostomus catostomus</i>)
AST	Atlantic sturgeon (<i>Acipenser oxyrinchus</i>)	MUM	Mummichog (<i>Fundulus heteroclitus</i>)
ATC	Atlantic tomcod (<i>Microgadus tomcod</i>)	MUS	Muskellunge (<i>Esox masquinongy</i>)
BKF	Banded killifish (<i>Fundulus diaphanus</i>)	9SB	Ninespine stickleback (<i>Pungitius pungitius</i>)
BND	Blacknose dace (<i>Rhinichthys atratulus</i>)	NRD	Northern redbelly dace (<i>Chrosomus eos</i>)
BNS	Blacknose shiner (<i>Notropis heterolepis</i>)	PLD	Pearl dace (<i>Semotilus margarita</i>)
BSS	Blackspotted stickleback (<i>Gasterosteus wheatlandi</i>)	PSF	Pumpkinseed Sunfish (<i>Lepomis gibbosus</i>)
BLH	Blueback herring (<i>Alosa aestivalis</i>)	RBS	Rainbow smelt (<i>Osmerus mordax</i>)
BKS	Brook stickleback (<i>Culaea inconstans</i>)	RBT	Rainbow trout (<i>Salmo gairdneri</i>)
BKT	Brook trout (<i>Salvelinus fontinalis</i>)	RSF	Redbreast sunfish (<i>Lepomis auritus</i>)
BBH	Brown bullhead (<i>Ictalurus nebulosus</i>)	RWF	Round whitefish (<i>Prosopium cylindraceum</i>)
BNT	Brown trout (<i>Salmo trutta</i>)	SLP	Sea lamprey (<i>Petromyzon marinus</i>)
BUR	Burbot (<i>Lota lota</i>)	SST	Shortnose sturgeon (<i>Acipenser brevirostrum</i>)
CHP	Chain pickerel (<i>Esox niger</i>)	SLS	Slimy sculpin (<i>Cottus cognatus</i>)
CSH	Common shiner (<i>Notropis cornutus</i>)	SMB	Smallmouth bass (<i>Micropterus dolomieu</i>)
CRC	Creek chub (<i>Semotilus atromaculatus</i>)	SPL	Splake (<i>S. namaycush</i> x <i>S. fontinalis</i>)
FLF	Fallfish (<i>Semotilus corporalis</i>)	STB	Striped bass (<i>Morone saxatilis</i>)
FHM	Fathead minnow (<i>Pimephales promelas</i>)	3SB	Threespine stickleback (<i>Gasterosteus aculeatus</i>)
FSD	Finescale dace (<i>Chrosomus neogaeus</i>)	WHP	White perch (<i>Morone americana</i>)
4SB	Fourspine stickleback (<i>Apeltes quadracus</i>)	WHS	White sucker (<i>Catostomus commersoni</i>)
GSH	Golden shiner (<i>Notemigonus crysoleucas</i>)	YLP	Yellow perch (<i>Perca flavescens</i>)
GLF	Goldfish (<i>Carassius auratus</i>)		

Total Length: the distance from the most anterior part of the head to the tip of the tail when the fin lobes of the tail are pressed together. This is the only length measurement collected for fish without forked tails such as banded killifish.

Fork length: measured from the most anterior part of the head to the median caudal fin rays (fork of tail). This measurement is only appropriate for fork tailed fish such as trout and salmon.

CPUE: Catch per unit effort = catch (fish) / survey effort (time).

Appendix C: Fish Fact Sheets for Common Freshwater Species (Source: NSSA, 2005)

SECTION 6.0. FISH FACTS

THIS SECTION CONTAINS:

- Some notes on fish anatomy
- Habitat requirements of salmon and trout
- Fish facts on many Nova Scotia fish species

6.1. Understanding Fish

This first section contains information on the anatomy of fish. Although different species of fish vary, what is described here is a general description of a trout or salmon.

Eyes and Sight

As with the eyes of mammals, fish eyes serve a number of purposes: to find food, to watch for enemies and other dangers, and to navigate perhaps even during ocean migrations. The pupil bulges outward to take in a wider field of vision, and although the eyes are set on the side of the head, they have all-around vision, giving the fish stereoscopic vision in a forward direction. The lens of the fish eye can move in and out like a camera lens. Trout and salmon appear to have the ability to see well into air and have good vision in semi-darkness. They respond strongly to sudden changes in light intensity (which would usually indicate danger), especially if they are within a closed environment from which they are unable to escape.

A woman wrote the very first published fishing manual nearly 500 years ago. Dame Juliana Berners, prioress of the Benedictine convent near St. Albans, England hand wrote the treatise f Fishing with an Angle in 1496. The boll included advice on how to construct a two-section rod and where the best places were to fish

Gills

Fish gills are composed of two basic parts: the gill covers and the gill filaments. The gill covers protect very delicate threads or **filaments** that are located in cavities on either side of the head. A special pump called the **brachial pump** maintains a flow of water over the gills.

When the mouth closes, water passes through the gills and out through the gill covers which open. The gill filaments are richly supplied with blood vessels that pick up oxygen out of the water. Carbon dioxide is released as a waste product. More activity increases the need for oxygen and this results in a corresponding increase in the opening and closing of the mouth and gills.

Nostrils and Smell

Trout and salmon have a well-developed sense of smell. It is believed that they use this ability to seek out and recognize the chemical characteristics of their home streams for spawning. This sense is sometimes helpful in avoiding predators. Fish breathe through their gills and mouth, not their nose.

Lateral Line (line along the side of the body)

There is a row of special scales with small holes along each side of the fish's body called the **lateral line**. The system is connected to a series of nerve endings can detect changes in pressure, sound, and movement. The lateral line helps to warn the fish of the approach of predators and search for prey.

Mouth

The mouth is used to catch and hold food of various types; but food is not chewed before being swallowed. The mouth is also important for breathing or respiration. Water is constantly taken in through the mouth and forced out over the gill filaments through the gills. This fish receives its oxygen by moving water over its gills.

Fins

Most fish have two sets of paired fins: the pelvic and pectoral fins, and four single fins: dorsal, caudal, anal and adipose. Some fins are spiny (although not on salmon or trout). Spines can be used for protection or for sexual display.

- The dorsal and anal fins are used for maintaining vertical balance and achieving quick changes in direction.
- The pelvic and pectoral fins are used for horizontal or lateral balance and resting.
- The adipose fin is small and fleshy on trout, salmon and whitefish and we don't know its purpose. Fishery managers, to identify certain stocks of fish or indicate that a fish is tagged, often clip it off.
- The caudal or tail fin is the most important fin as it is used to propel the fish through water by the flexing of strong muscles along the sides of the body. The caudal fin is also used by the female salmonids and male smallmouth bass to move gravel and scoop out the nests (redds) in which eggs are deposited.

Scales

The body surface skin of the fish, except for the head and fins, is protected by overlapping scales that grow in regular patterns and by an outer coating of mucus, which protects the fish from disease. Growth of the scales is continuous and takes place around the perimeter of each scale. Growth is more rapid in summer than in winter, thus, growth rings (looking somewhat similar to those of trees) of summer are farther apart than those of winter, and indicate the age and life history of the fish. When fish are sick or stressed, the rings are closer together. Rings spaced more apart indicate healthy growth and environmental conditions.

Ears

Fish do not have external ears but they can detect sound with an inner ear and labyrinth that function as organs of balance as well as hearing. Low frequency sounds can also be detected in the water by the lateral line system.

6.2. Habitat Requirements

If you know what a fish needs in a stream in order to survive, it is a natural progression to determine where and what is in need of protection or rehabilitation. This section will concentrate primarily on the needs of trout and salmon (referred to as **salmonids** by biologists). These fish can be found in many different habitats in our part of the world. Because they often have to cope with severe and varying conditions they can be remarkably resilient in habitat use, in feeding, growth and reproduction. Despite the fact that these fish adapt to change well they can be highly sensitive, environmentally "fussy" fishes; particularly in the "egg" and "young" stages.

The habitat requirements for fish are the things they need to live. As we learned in the first section, this is a combination of water, food, space, and cover. In this next section we'll look at the important habitat requirements of fish. Even within one species different habitat combinations are required for nursery areas, feeding and spawning. Understanding habitat will help you to better determine the health of the stream, its potential for trout and salmon and other fish, and the locations most likely to benefit from rehabilitation and enhancement.

Trout and salmon require very special conditions for:

- Successful **spawning** (the production of eggs)
- The development and hatching of eggs
- Growth and survival for their young
- Feeding

In general, salmonids require streams that have:

- **Temperatures** that are fairly cool
- **Shade**; there should be trees and shrubs along the bank of the stream
- Water with lots of **oxygen**
- Clean **gravel** of different sizes on the stream bottom
- Sufficient **flow of water**
- No major **physical obstructions** which will stop them from moving up or downstream
- **Cover** or places to hide when it gets too hot and to hide from predators
- **Clear water** so they can see insects to feed on
- **The right combination of habitats** for different parts of their life cycle
- Lots of small insects and animals for **food**

Let's look at each one of these in turn.

ADOPT-A- STREAM: WATERSHED, MARSH, LAKE, RIVER, ESTUARY

Temperature

Salmonids need much cooler water than other fish such as perch, bass, gaspereau or suckers. For example, if water temperature rises much above 20 - 25.C, for very long, most salmonids, especially in early stages, will become seriously stressed or will die. On the other hand, many species of bass, suckers and perch for example, thrive in much higher temperatures. Young trout and salmon prefer a water temperature between 15 and 18.C. Brook trout will die if the water temperature rises above 22 C. (72 degrees F.) for more than several consecutive days; rainbow and brown trout will die if it's hotter than 24.C. (75 degrees F.). Fish can adapt to a gradual change in temperature, but sudden drastic changes can shock and kill them.

Also, fish are cold blooded which means that their body temperature varies according to the temperature of the surrounding water. The warmer it gets, the faster their metabolism gets so they need more oxygen. The problem is that warmer water holds less oxygen.

Temperature also affects the growth and reproduction of fish. Fish lay eggs only at certain temperatures. Most salmonids prefer cooler temperatures: salmon, brown trout, brook trout and lake trout spawn during the late autumn and early winter; rainbow trout prefer the warmer temperatures from mid-April to late June. Temperature is also a major factor in the timing of fish migrations.

The temperature of a stream is regulated by springs, shade, and the stream width to depth ratio. Most streams begin as springs bubbling out of the ground. The spring water comes from snow melt and rain water that percolated into the soils of the surrounding hillsides the previous week, day, month, or year. Sometimes because of human activity the amount of rainwater that goes deep down into the soil is reduced, not allowing the water table to be replenished. This can cause springs to dry up, so that water levels in rivers decrease and water temperatures increase. Many streams come from lakes and their water is warmer when it enters the stream. In these streams even more care must be taken to make sure that the water doesn't get too hot.

Shade

The amount of shade along a stream is very important. Too much shading in a stream reduces the growth of instream plants (algae). This will mean less food for insects, and in turn less food for fish. In some places it can also make spring-fed streams too cool for salmonids, which prefer 16-17 C. temperatures for growth.

Too little shading encourages heating of the stream and raised temperatures. The percent of shading needed varies from stream to stream and depends upon the amount of spring water available to cool the stream, the stream's width and depth, and human land use activity in the area. There is a balance in all these and the optimum appears to be about 60% shade during

the peak of the day. In general, most streams don't have enough shade. A narrow, deep river channel also maintains cooler water temperatures by having less surface exposed to the air. Where width greatly increases, the shallow water is then highly susceptible to heating by direct contact with the air. Even in well-shaded streams, the water temperature follows the air temperature very closely if pools are poorly developed and the channel is wide and shallow. Direct sunlight warms things up even more, as everyone knows; it's cooler in the shade.

Oxygen

Trout and salmon that live in streams require high levels of **dissolved oxygen** (the amount of oxygen contained in the water). Fish are extremely sensitive to any decrease in the available supply of oxygen and can suffocate very quickly if they are forced to endure a low level for even a short period of time. Young fish or breeding fish have even greater oxygen requirements. Eggs lying in the gravel take in oxygen through their shell. A lowered level of oxygen may result in a delay in the development of the embryo and the hatching. These low levels can be caused by increases in temperature, excessive nutrients and silt which all can deplete oxygen. Moving water adds oxygen to the stream. The faster the water moves, the more oxygen goes in.

Gravel and Stream Bottom

For successful egg-laying, salmonids require clean, stable gravel of 1-10 cm in diameter, depending on size of the adult fish. The gravel must be clean and loose, so that water can flow through the gravel to provide each egg with enough oxygen, and so that waste products emitted by the eggs (such as carbon dioxide and ammonia) will flow away from the egg. The gravel must contain different sized stones. Smaller gravel is used for egg laying, larger stones are needed for many of the insects which live in the water, and boulder sizes are needed to ensure spaces for fish to hide and over-winter.

The best bottom for a trout and salmon stream is a mixture of gravel, rubble, rock, and boulder with a liberal sprinkling of sunken logs and stumps. The rock/gravel bottom, especially in riffles and runs, offers the best habitat for insects that the fish eat. This mixture should have very little sand and silt in it. You should be able to pick up the surface stones without exposing sand or silt and see insects on them.

Stream flow

Nova Scotia is known for extreme changes in the amount of water that flows in streams. In the spring the water often flows high because of winter snow melt and spring rains. This is called the **spring freshet** or flood. In the hot weather of summer many streams experience droughts and have very little water flowing through them. This is extremely hard on salmon and trout. The best streams have flows without these extremes. It is especially important to have enough water flowing in the normal low flow period of late August and September to provide adequate nursery areas for young fish. It is also important during the winter, so that

embryos and alvins do not freeze. Human activity in the watershed can result in higher freshets, lower summer and winter flows, and excessive ice formation.

Barriers to swimming up and downstream

During migrations between the ocean and the spawning and rearing sites in lakes and rivers, an unobstructed path is necessary for adults. Fry and juveniles also move to different habitats, as they grow older, so they require access up and down the stream and into side-channels and tributaries. Obstructions such as logjams, hydro power dams, and poorly installed culverts are especially damaging to the migrations of salmonids unless provisions for passage are made.

Clean Water

Clean, clear water is very important to trout and salmon. The water must be clear enough to permit the sunlight to reach the stream bottom where important plants and algae grow. These plants and algae are important food sources for many of the insects upon which trout and salmon feed. Also, high concentrations of solids such as silt in the water can damage the fragile breathing systems of insects and fish.

While some fish, such as suckers, locate food chiefly by smell or feel, trout and salmon need to see their food. Therefore, they feed and grow better in clear water. Water quality is critical during the spawning, incubation, and hatching periods. Heavy sedimentation can smother eggs in gravel and easily destroy them.

Cover/Shelter

Stream salmonids require cover such as undercut banks, logs, spaces under large rocks and boulders, overhanging trees and plants, and deep pools. This cover is used for feeding, hiding, resting, and over wintering. Additionally, overhanging plants shade the river to help control stream temperatures.

Fish spend a lot of time hiding from various predators, whether these predators be the web-footed, clawed, four-footed, or the two legged kind. Their hiding locations are commonly called areas of shelter. Shelter is critical to a fish's survival in a stream and various sizes of trout or salmon require different ranges of shelter. Ideally, most fish like to be protected or sheltered on three sides. This often means on the top, one side and bottom (e.g. an undercut bank). They also require a shelter that is a snug fit and not too roomy. Therefore, a fish will select a shelter that is close-fitting to its body size.

A shelter should break the water flow so that a "dead-space" or slow current area is created near it. A popular misconception is that salmonids like to swim against heavy currents. On the contrary, they prefer to rest where they don't have to exert themselves too much. As unlikely as it may seem, there are many "dead-spaces" among swift currents. Even the most torturous rapids will have holding areas as long as there is a structure that acts as a buffer to

the current.

Fry not only prefer the shallow, slow margins of a stream, but also seek shelter that conceals them. In the shallows, woody debris such as branches, twigs, and small fallen tree limbs can provide many nooks and crannies for small fish. Where this material is absent, jumbles of large sticks and small boulders can also provide good shelter areas. Larger, older trout look for more substantial cover in the deeper areas of the stream. Undercut banks, log-jams, stumps, and boulders all offer hiding spaces for the larger fish.

Relatively shallow water can also be a holding location as long as the surface is riffled, which masks the presence of the fish. Weed beds composed of healthy aquatic plants provide additional cover for young and adult alike.

To add variety to the shelter equation, shelter can be species-specific to a certain degree. Brown trout and brook trout prefer areas with overhead cover and therefore select the margins and edges of the stream. Rainbow trout, however, are not as selective and often position themselves in mid-river if a suitable shelter or current break is available. Salmon parr prefer the cover of broken water surface (e.g. on riffles) and spaces under rocks in riffle areas.

There is an approach to assessing salmonid habitats presented in section 9 which provides additional information on the specific needs and when you need to undertake restoration.

6.3. FACTS ON FISH

The next section contains fact sheets on the following fish species found in Nova Scotia:

Atlantic Salmon
Brook Trout
Brown Trout
Rainbow Trout
Smallmouth Bass
Striped Bass
Alewife
American Eel
American Shad
Brown Bullhead
Rainbow Smelt
White Perch
Yellow Perch
White Sucker

Atlantic Salmon (*Salmo salar*)



One of the best-known members of the salmonid family is the Atlantic salmon which is also known as: grilse, grilt, fiddler; landlocked salmon, ouananiche and grayling (all for landlocked fish); black salmon, slink, kelt (all for post-spawning fish); smolt, parr, Kennebec salmon, and Sebago salmon.

Physical Characteristics

Salmon can vary in colour depending on the water they're in, their age, and sexual activity. In fact there are so many different physical looks in the life of a salmon that it can be confusing. What follows are some of the common colour characteristics:

Salmon in saltwater: blue, green or brown on the back and silvery on the sides and belly. On the upper body you can find several x-shaped black spots.

Salmon in freshwater: bronze-purple in colour and sometimes with reddish spots on the head and body.

Spawning males: these fish develop a hooked lower jaw (kype)

Salmon finished spawning (kelts): very dark in colour

Facts on Salmon

The name salar comes from the Latin "salio" which means to leap. The Atlantic salmon can make leaps 3.7 m (12 ft) high and 5 m (16.3 ft) long!

Atlantic salmon are mentioned in the Magna Carta.

In the wild about 1 in 10 young salmon survive to become smolts and in many rivers fewer than 1 in 25 of those will return to spawn.

Most grilse are male.

Biologists can "read" the scales of salmon to determine how old they are, how many years they spent in fresh water, how many years they spent at sea and at what ages they spawned.

Young salmon (parr) in freshwater: 8 to 11 dark bars on the side with a red spot between each one.

Young salmon leaving fresh water for the sea (smolts): silvery in colour and usually about 12 to 20 cm (5-8 in) long.

Atlantic salmon can be easily confused with both brown trout and rainbow trout. However there are several characteristics that can help you distinguish the different species. Rainbow trout have a rows of spots on the tail (caudal) fin that is not found in salmon and brown trout have a reddish colouring on the adipose fin (the small fin in front of the tail on top of the body). Some of the different characteristics can be observed on the following pages in the line drawings.

Salmon Sizes

Sea-run salmon - can be as big as 1.5 m (59 in) and 36 kg (79 lb) but most are 9 kg (20 lb) or less.

Biggest known fish ever caught in Canada: a 25.1 kg (55 lb) fish caught in the Grand Cascapedia River, Quebec.

After two winters at sea: 2.7 to 6.8 kg (6-15 lb).

After one winter at sea (grilse): 1.4 to 2.7 kg (3-6 lb)

Landlocked Atlantic - 0.9 to 1.8 kg (2-4 lb). However a 16.1 kg (35.5 lb) specimen was taken in Sebago Lake, Maine over 50 years ago.

Distribution

Atlantic salmon are native to the North Atlantic Ocean and coastal rivers and can be found on both sides of the ocean including parts of Russia, Portugal, Iceland, and Greenland. In Canada and the U.S. they can be found from Northern Quebec and Labrador to the Connecticut River. Due to over fishing and the destruction of habitat, salmon no longer can be found in much of its original range and the numbers of fish have seriously declined. As an example, since the late 1800's, there has been no salmon in Lake Ontario. Landlocked populations of Atlantic salmon exist in some lakes of eastern North America, particularly in Newfoundland, Labrador and Quebec.

Natural History

Atlantic salmon spend part of their life feeding and growing during long migrations in the sea, and then return to reproduce in the fresh water stream where they hatched. This type of pattern, moving from the sea to freshwater, is described as being **anadromous**.

Atlantic salmon that are ready to spawn begin moving up rivers from spring through fall. These spawning runs are surprisingly consistent and occur at the same time each year for each river. Salmon populations are often spoken of as "early run" or "late run". Salmon travel long distances, as much as 500 km (312 mi) upstream and are known for their ability to leap small waterfalls and other obstacles. During this journey, the salmon does not eat, though it rises readily to an artificial fly. Landlocked salmon living in lakes move up into tributary streams to spawn.

Spawning occurs during October and November usually in gravel-bottom riffles at the head or tail of a pool. The female looks for places where the water is seeping down into clean gravel. Spawning occurs in the evening and at night. The female digs a nest (**redd**) 15-35 cm (6-14 in) deep in the gravel by turning on her side, flipping her tail upward and pulling the gravel up until a hole is excavated. She then usually moves upstream and repeats the whole process. After the female and male spawn in the redd the 5-7 mm eggs are buried with gravel by the female and the whole process is repeated several times until the female has shed all of her eggs. Females produce an average of 1500 eggs per kilogram of body weight (700 eggs/lb). After spawning the adults (now called kelts) usually drop downstream to rest in a pool. Contrary to some stories, adults do not die after spawning. Exhausted and thin, they often return to sea immediately before winter or remain in the stream until spring. Some will survive to spawn a second time but few survive to spawn 3 or more times.

Salmon eggs develop slowly (about 110 days) over the winter while water flowing through the nest keeps the eggs clean and oxygenated. In most of our rivers the eggs survive quite well and are protected from freezing or silt. The eggs hatch in the spring, usually April, and the young salmon (alvins) remain buried in the gravel for up to 5 weeks while they absorb the large yolk sac. It's at this stage that many young fish are lost. Over the winter silt and sand often move

Fishing Facts

The Atlantic salmon has been prized for centuries, both commercially and for sport. However, dam construction in rivers has blocked access to many spawning streams and siltation has destroyed many others.

In addition pollution, acid rain, over fishing and poaching have all contributed to a drastic decline in Canada's Atlantic salmon stocks.

Today, except for small fisheries in Quebec and Labrador, Canada's commercial fishery is closed. Recreational fisheries are very closely regulated, and "hook and release" angling is increasingly promoted.

Through salmon enhancement programs biologists and local community groups are working to restore the production potential of many salmon rivers.

into the nest and can trap the young fish. If they make it through this stage, the young salmon that emerge are about 2.5 cm (1 in) long in May or June.

During this freshwater stage before they migrate to sea they are known as parr. Salmon parr are territorial and feed during the day. They eat mainly water insects but will also eat other invertebrates when available. Young salmon usually live in shallow riffle areas 25 to 65 cm (10-26 in) deep that have gravel, rubble, rock, or boulder bottoms. Salmon parr may be eaten by many kinds of predators including trout, eels, other salmon, mergansers, kingfishers, mink and otter. During their first winter the parr stay under rocks on the bottom of the stream.

After two or three (but anywhere from 2 to 8) years in fresh water salmon parr turn into smolts and prepare for life in salt water. In the spring, these parr become slimmer and turn silvery. During the spring run-off, as water temperatures rise, smolts form schools and migrate downstream at night. It is during this downstream migration that smolts "learn" or become imprinted with the smell or other features of their particular river.

At sea salmon are known to travel long distances. Many salmon from Maritime rivers travel as far as the western coast of Greenland where the waters are rich in food. Here, salmon grow rapidly, feeding on crustaceans and other fishes such as smelt, alewives, herring, capelin, mackerel, and cod. Salmon will stay at sea for one or more years. The salmon will spend only one year at sea are smaller and called grilse when they return to freshwater to spawn. At sea, salmon are eaten by cod, pollack, swordfish, tunas and sharks but have been known to live to 11 years.

More Facts on Salmon

Salmon have been reared in hatcheries for decades to provide smolts for river stocking programs.

Today they are commercially farmed in large ocean pens, a rapidly growing industry in Atlantic Canada.

Brook trout (*Salvelinus fontinalis*)

This salmonid is also called speckled trout, brook charr, brookie, lake trout, square tail, sea-trout, Eastern brook trout, native trout, coaster, and breac.

Physical Characteristics

The brook trout is a handsome fish. Like salmon, their colour varies depending on the water they are in and their sexual activity. Here are some of the common characteristics:

Adult in freshwater: green to dark brown and black on the back and sides. Light-coloured wavy lines on upper back, dorsal fin and upper part of the caudal (tail) fin. Red spots surrounded by blue halos and many light spots are usually present on the sides. The belly is lighter, white to yellow in females, or reddish in males. The leading edges of the lower fins have a bright white border followed by a black border and reddish coloration.

During spawning: colours intensify and males can become a deep orange-red on the belly.

Adult in saltwater: silvery on the sides and dark blue or green on the back. Pale red spots may be visible on the sides as well as the white leading edge on the fins. When returning from the sea these trout regain their freshwater colours.

Young brook trout or parr: 8 to 10 dark vertical bars (called parr marks) on the sides.

Facts on Brook Trout

Larger brook trout that live in northern waters sometimes eat small mammals such as mice, shrews and voles.

A 61 cm (24 in.) sea-run trout that weighed 3.4 kg (7.5 lb) was caught in Halifax County Nova Scotia in 1871.

It can be seen today in the Nova Scotia Museum.

ADOPT-A- STREAM: WATERSHED, MARSH, LAKE, RIVER, ESTUARY

The largest "brookie" on record was taken in Ontario in 1915 weighing 14.5 lb (6.6 kg) and 34 in (86 cm) long. Brookies in Nova Scotia typically range from 15-35 cm (6-14 in) long.

Distribution

The brook trout is native to eastern North America from the Atlantic seaboard to Massachusetts, south along the Appalachian Mountains, west to Minnesota and north to Hudson Bay. It is found in a range of waters from tiny ponds to large rivers, lakes, and salt-water estuaries. Its popularity as a sport fish has resulted in brook trout introductions throughout the world. Widely distributed throughout the Maritimes, brook trout are our most sought-after freshwater fish.

Natural History

Brook trout prefer cool clear waters of 10 to 18°C with a lot of cover. Usually they live in spring-fed streams with many pools and riffles where they can use undercut banks, submerged objects such as large rocks and stumps, deep pools, and shelter from overhanging vegetation as hiding places. Brook trout are meat-eaters (carnivorous). They eat mostly water and land insects but will take anything they can swallow. Larger trout will eat leeches, small fish, mollusks, frogs, and salamanders.

Brook trout in Nova Scotia spawn in October and November in shallow, gravelly areas of streams where there is a clean bottom and good water flows. Spring-fed headwaters are ideal but they'll also spawn in the gravel-bottomed areas of lakes where spring waters occur. The female digs a nest (redd) 10-15 cm (4-6 in) deep in the gravel with her body. After the eggs have been laid and fertilized, they are covered and left to develop slowly over the winter. A 25 cm (10 in) female trout can produce about 500 three to five mm eggs. Water flowing through the redds keeps the eggs clean and oxygenated. Hatching occurs in the spring and the larvae (alvins) remain still and undisturbed in the gravel while they absorb the large yolk-sac.

Young trout (fry) emerge from the gravel at a length of 2.5-3.5 cm and begin feeding on aquatic

Fishing facts

The brook trout is the most popular sport fish in the Atlantic Provinces. It is taken with spinning tackle, live bait or flies.

Unfortunately many natural populations of brook trout in Nova Scotia have declined. They are vulnerable to over fishing and human practices that affect their habitat. For example, siltation can smother developing eggs, dams can block access to spawning areas, or the loss of trees along a stream bank can reduce shade and cause summer water temperatures to get too high.

Brook trout have been reared in hatcheries for over a hundred years. Hatchery trout are widely stocked in natural waters to supplement "wild" populations or to introduce the brook trout to new areas. Sometimes trout are stocked in small ponds or lakes near urban areas to provide "put and take" sport fisheries.

insects. They prefer shallow areas where the temperatures are 11-15°C and where rubble (rocks of 10-40 cm (4-16 in)) on the stream bottom provides cover. At the end of their first year, brook trout in Nova Scotia are 5-10 cm (2-4 in) long. Their growth depends very much on local conditions. Brook trout living in larger rivers and lakes would probably be 25 or 30 cm (10-12 in) at age 3, but those in small streams might only reach a length of 15 cm (6 in). Trout usually mature at three years old and rarely live past age 5.

Some populations of brook trout migrate to sea for short periods. They move downstream in the spring or early summer and remain in estuarine areas where there's lots of food. After about 2 months they return to freshwater. Brook trout probably migrate to sea in response to crowded conditions, low food supplies, or unfavourable temperatures in their home waters. Some overwinter in estuaries, and there are shore movements along our coast. Not all fish in a population migrate nor do they necessarily go every year. Sea-run brook trout live longer and grow larger than strictly freshwater trout. Brook trout predators include mergansers, herons, kingfishers, mink, owls, osprey, otter, perch, eels, and other trout.

Brown Trout (*Salmo trutta*)



The brown trout is also a salmonid and is known as German brown trout, German trout, Lochleven trout, European brown trout, or brownie.

Physical Characteristics

"Brownies" get their name from the brown or golden brown on their backs. Here are some of their other characteristics:

- their sides are silvery and bellies are white or yellowish • dark spots, sometimes encircled by a pale halo, are plentiful on the back and sides
- spotting also can be found on the head and the fins along the back
- rusty-red spots also occur on the sides
- the small top fin in front of the tail has a reddish hue
- sea-run brown trout have a more silvery coloration and the spotting is less visible.

Facts on Brown Trout

Apart from moving upstream to spawn, adults tend to stay at the same station in a river with very little movement to other areas of the stream areas. They can be found at these stations day after day, even year after year!

The closest relative of the brown trout is the Atlantic Salmon (*Salmo salar*). The brown trout's name (*Salmo trutta*) means salmon trout.

The largest brown trout ever taken was hooked recently in Arkansas, U.S weighing just over 40 pounds.

They closely resemble Atlantic salmon and rainbow trout but the salmon has no red coloration on the adipose fin and the rainbow trout has distinct lines of black spots on the tail. Young brown trout (parr) have 9-14 dark narrow parr marks along the sides and some red spotting along the lateral line.

Brown trout can grow to be quite large, especially sea-run fish. Brown trout weighing up to 31 kg (68 lb) have been recorded in Europe and a specimen weighing 13 kg (28.5 lb) was caught in Newfoundland. Typically they range from 2.3 to 3.2 kg (5-7 lb) but reach 5.9 kg (13 lb) in Guysborough Harbour.

Distribution

Brown trout naturally occur throughout Europe and western Asia. They range from Finland south to North Africa, west to Iceland and as far east as Afghanistan. Introduced throughout the world, they were first placed in Canadian waters in 1890. Today they are well established in rivers, lakes and coastal areas in much of North America and are found in all Canadian provinces except Manitoba, Prince Edward Island, and the Northwest Territories. Sea-run populations occur in Atlantic Canada and Quebec.

Brown trout are well established in several Nova Scotia watersheds. They are no longer being stocked in areas that they inhabit. Nova Scotia brown trout come from German and Lochleven (Scotland) ancestral stocks.

Natural History

Brown trout prefer cool clear rivers and lakes with temperatures of 12-19°C. They are wary and elusive fish that look for cover more than any other salmonid. In running waters they hide in undercut banks, instream debris, surface turbulence, rocks, deep pools and shelter from overhanging vegetation. Brown trout are meat-eaters (carnivorous). They eat insects from water and land, and take larger prey such as worms, crustaceans, mollusks, fish, salamanders, and frogs as their size increases.

Brown trout spawn in the fall and early winter (October to February) at the same time or later than brook trout. They return to the stream where they were born, choosing spawning sites that are spring-fed headwaters, the head of a riffle or the tail of a pool. Selected sites have good water flows through the gravel bottom. The female uses her body to excavate a nest (redd) in the gravel. She and the male may spawn there several times. A 2.3 kg (5 lb) female produces about 3400 golden coloured eggs that are 4-5 mm in diameter. Females cover their eggs with

Fishing Facts

Brown trout prefer very similar habitats to our native brook trout except that they can tolerate slightly higher temperatures. They often use the lower reaches of rivers and streams where it is unsuitable for brook trout.

Biologists thought the brown trout out-competed and displaced the native brook trout and stocking programs were discontinued.

Brown trout do live longer and grow larger than brook trout. They have become quite popular with anglers and are caught in estuaries with lures and streamer-type flies. There is no commercial fishery.

gravel after spawning and the adults return downstream. The eggs develop slowly over the winter, hatching in the spring. A good flow of clean well-oxygenated water is necessary for successful egg development.

After hatching the young fish (alvins) remain buried in the gravel and take nourishment from their large yolk-sacs. By the time the yolk-sac is absorbed, water temperatures have warmed to 7-12.C. The fish (now known as fry) emerge from the gravel and begin taking natural food.

Brown trout fry are aggressive and establish territories soon after they emerge. They are found in quiet pools or shallow, slow flowing waters where older trout are absent. They grow rapidly and can reach a size of 165 mm (6.5 in) in their first year.

Yearling brown trout move into cobble and riffle areas. Adults are found in still deeper waters and are most active at night. They are difficult to catch and are best fished at dusk. Brown trout living in streams grow to about 1.8 kg (4 lb) but lake residents and sea-run fish grow larger. Most mature in their third to fifth year and many are repeat spawners.

In sea-run populations, brown trout spend 2-3 years in freshwater then migrate downstream to spend 1 or 2 growing seasons in coastal waters near the river mouth. There they feed on small fishes and crustaceans. Most return to their home streams to spawn but some straying occurs. Brown trout live up to 14 years and can spend as long as 9 years in the sea.

Rainbow Trout (*Oncorhynchus mykiss*)



This member of the salmonid family is also called Steelhead, Kamloops trout, steelhead trout, silver trout, or coast rainbow trout.

Physical Characteristics

Like most other members of the salmonid family, the appearance of rainbow trout varies.

Adults in freshwater: colour varies from metallic blue to green or yellow-green to brown on the back becoming silvery on the sides and light on the belly. Many small black spots cover the head, back, sides and fins, and spots on the tail are in obvious rows. The adipose fin (small fin in front of the tail on the back) has a black border. Mature fish have a distinctive rosy stripe along the side that extends from the gill cover to the caudal fin.

Adults in saltwater: sea-run rainbow trout (steelheads) are more silvery in colour, may lack the rosy stripe, and show less spotting on the sides.

Young rainbow trout (parr): have 5-13 well-spaced dark parr marks on the sides and show less spotting on the body than adults.

Rainbow trout may look very similar to Atlantic salmon and brown trout, but can be distinguished by the regular rows of spots on the tail, the lack of any coloured spots and the absence of red in the adipose fin.

Rainbow trout can grow as big as 25.8 kg (57 lb) but in Nova Scotia usually grow up to 2.7 kg

Facts on Rainbow Trout

The largest rainbow trout was caught in Alaska in 1970 and weighed 19.10 kg (42 lb).

The rainbow trout is commonly used as a laboratory animal for water quality testing.

ADOPT-A- STREAM: WATERSHED, MARSH, LAKE, RIVER, ESTUARY

(6 lb).

Distribution

Rainbow trout are actually native to the eastern Pacific Ocean and fresh waters of western North America. They naturally ranged from Mexico to Alaska and inland to the Rockies. However, they have been widely introduced throughout the world, and now occur across central North America to the eastern coast. Rainbow trout were first introduced to Atlantic Canada in the late 1800's. Today they are stocked in rivers and lakes throughout Nova Scotia and are known to reproduce in the Bras d'Or Lake watershed.

Natural History

Different populations of rainbow trout may have very different life history patterns. Rainbow trout may live in lakes or ponds, they may be stream dwellers or they may spend part of their lives at sea before returning to freshwater (anadromous) to reproduce.

They prefer water temperatures of 12-18.C and do well in clear, cool, deep lakes or cool, clear, moderately-flowing streams with abundant cover and deep pools. They spawn in the spring (usually from March to May in Atlantic Canada) in small tributaries of rivers, or in inlets or outlets of lakes. Rainbow trout usually home to the streams where they hatched.

Spawning occurs in shallow riffles with gravel bottoms. The female uses her body to dig a nest (redd) in the gravel. One or two males will spawn with her in the nest, after which she buries the fertilized eggs. She repeats this process until all her eggs are used. Most female rainbow trout produce about 1,000-4,000 eggs. The eggs are 3-5 mm in diameter and hatch in 4-7 weeks depending on the temperature. In another 3-7 days the young absorb the yolk sac and emerge from the gravel.

The young of lake-dwelling fish may move into the lake by the end of their first summer. Some stay in a tributary up to 3 years before entering the lake. Young rainbow trout seek cover and prefer slow-moving shallow stream areas where rubble, rocks, instream debris and undercut banks provide shelter. Older trout move into faster and deeper stream waters. Rainbow trout that migrate to sea (steelheads) spend from 1-4 years in freshwater before they transform into smolts to prepare for life in salt water. Rainbow trout smolts lose their parr markings and become silvery. They migrate to sea in spring and remain there for a few months to several years before they return to fresh water.

Fishing Facts

A popular sport fish, rainbow trout are fished with wet and dry flies, lures or natural bait.

The flesh is tasty and may be prepared many ways.

Rainbow trout have been reared in hatcheries for decades to support stocking programs. They are also reared commercially in ponds for food and for sport, and more recently in salt water pens.

Rainbow trout take a wide variety of foods, but in freshwater they eat mainly insects, crustaceans, snails, leeches, and other fish if available. At sea they eat mainly fish, crustaceans, and squid. Rainbow trout growth varies widely depending on their habitat, diet and life history pattern. Generally fish that go to sea or live in large productive lakes, grow largest and live longer. Rainbow trout usually mature at ages 3 to 5 at sizes that range from 15-40 cm (6-16 in) long. Many will spawn repeatedly. Rainbow trout can live to 11 years.

Smallmouth bass (*Micropterus dolomieu*)



This fish, a member of the sunfish family is also called northern smallmouth bass, smallmouth black bass, black bass, and brown bass.

Physical Characteristics

The smallmouth bass has the following characteristics:

- A robust, slightly laterally compressed fish
- Its colour varies from brown, golden brown, olive to green on the back becoming lighter to golden on the sides and white on the belly
- It has 8-15 narrow, vertical bars on the sides and dark bars on the head that radiate backwards from the eyes
- Its head is relatively large, with a large red, orange, or brown eye
- Its lower jaw protrudes
- Its two dorsal fins are joined; the front one is spiny and the second one has 1 spine followed by soft rays
- Its pelvic fins sit forward on the body below the pectoral fins
- Three spines border the front of the anal fin and a single spine is found on each pelvic fin
- Young fish have more distinct vertical bars or rows of spots on their sides and the caudal or tail fin is orange at the base followed by black and then white

Facts about Smallmouth Bass

Some male smallmouth bass return to the same nest year after year; over 85% of them build their nest within 138 m (150 yd) of where they nested in earlier years.

The world record smallmouth bass was caught in Kentucky, U.S.A. in 1955 and weighed 5.4 kg (11.9 lb). It measured 68.6 cm (27 in) long and 54.9 cm (21.7 in) in girth.

They have been seen "sunning" in pools with water temperatures of 26.7° C.

Smallmouth bass can reach over 4 kg (9 lb) in parts of central Canada but usually don't exceed 1.1 kg (2.5 lb) in Nova Scotia.

Distribution

The smallmouth bass is a freshwater fish originally found in lakes and rivers of eastern and central North America. As a result of widespread introductions, it now ranges from southern Nova Scotia and New Brunswick, south to Georgia, west to Oklahoma, north to Minnesota, west to North Dakota and east from southern Manitoba to Quebec. It also occurs in a few areas of western North America and has been introduced in Europe, Asia, and Africa.

Natural History

Smallmouth bass prefer clear, quiet waters with gravel, rubble, or rocky bottoms. They live in mid-sized, gentle streams that have deep pools and abundant shade, or in fairly deep, clear lakes and reservoirs with rocky shoals. Smallmouth bass tend to seek cover and avoid the light. They hide in deep water, behind rocks and boulders, and around underwater debris and crevices. Smallmouth bass prefer temperatures of 21-27° C. As temperatures fall, they become less active and seek cover in dark, rocky areas. In the winter they cease feeding, remain inactive on the bottom, staying near warm springs when possible.

Spawning takes place from late May to July in shallow (usually 0.3-0.9 m (1-3 ft) deep) protected areas of lakes and rivers, when the water temperature is 16 to 18° C. The male prepares a nest on a sandy, gravel or rocky bottom by cleaning an area 0.3 to 1.8 m (1-6 ft) in diameter. He defends the nest from other males and attracts a series of females into the nest to spawn. After spawning the female leaves and the male remains to guard the nest and fan the eggs. Females usually produce from 5,000 to 14,000 eggs, depending on their size. The eggs are from 1.2-2.5 mm in diameter and stick to stones in the bottom of the nest.

The young are about 5.8 mm long when they hatch in 4-10 days depending on the temperature. Hatching success can vary a lot. Sudden changes in temperature or water level can cause the eggs to die from shock or cause the male to abandon the nest, leaving it open for predators. After hatching, the male remains with the young for another 3-4 weeks while they absorb the yolk sac and begin to leave the nest.

Young fish tend to stay in quiet, shallow areas with rocks and vegetation. They begin feeding on plankton (tiny organisms suspended in the water), and switch to larger prey like water insects, amphibians, crayfish, and other fish as they grow. (Crayfish are native to New Brunswick but are not found in Nova Scotia). Two-year old bass are about 12.7 cm (5 in) long.

Older bass prefer rocky, shallow areas of lakes and rivers and retreat to deeper water at high water temperatures. Most bass do not travel great distances and those in streams spend all season in the same pool. Smallmouth bass mature at ages 3-6 when they are about 17 to 28 cm (6.7-11 in) long. Males usually mature a year earlier than females. They are known to live 15 years.

Some smallmouth bass predators are yellow perch, sunfishes, catfishes, white suckers and turtles.

Fishing Facts

Smallmouth bass are a fish of great sporting quality that have been popular with anglers since the early 1800's.

This popularity led to widespread introductions and the culture of smallmouth bass. It was harvested commercially until the 1930's but over-fishing led to its restriction as a sport fish.

Smallmouth bass can be taken with wet or dry flies, by trolling or casting with live bait or lures, or still fishing with crayfish, minnows or frogs.

Striped Bass (*Morone saxatilis*)



Other common names for this fish include: striper bass, striped sea bass, and striper.

Physical Characteristics

Striped bass have the following characteristics:

- A long, laterally compressed fish
- Its colour is olive green to blue or black on the back; the sides are pale to silvery (sometimes with brassy reflections); its belly is white
- It has 7-8 dark horizontal stripes on the sides
- Both eyes and mouth are relatively large and the lower jaw protrudes
- The pelvic fins sit forward on the body below the pectoral fins
- The first dorsal fin (on the back) is spiny and the second has one spine followed by several soft rays
- A single spine lies at the front of each pelvic fin and three short spines precede the anal fin
- Young often lack stripes and have 6-10 dusky bars on the sides

Striped bass have been recorded as large as

Facts about Striped Bass

A striped bass weighing 28.6 kg (62.9 lb) was caught near Reversing Falls in the Saint John River, New Brunswick in 1979.

The world record (angling) striped bass weighed 35.6 kg (78 lb) was caught at Atlantic City, New Jersey in 1982.

A striped bass tagged and released in the Saint John River, New Brunswick was recaptured 36 days later in Rhode Island, U.S.A. 805 km (503 mi) away! (22.4km/day 14 mi/day)

After fertilization striped bass eggs swell to about three times their original diameter to a size of 3.6 mm.

Surveys show the average striped bass angler on the Annapolis River, Nova Scotia spends about 50 hours on each fish caught.

56.7 kg (124.7 lb) North Carolina, 1891). However most striped bass caught are 13.6 kg (30 lb) or less.

The short (less than half the fin length) anal fin spines and body stripes distinguish striped bass from white perch, the other member of the temperate bass family found in Maritime waters. The white perch lacks stripes and 2 of its anal spines are longer than half the fin length.

Distribution

The striped bass is a coastal species found in rivers, estuaries, and inshore waters of eastern North America from the St. Lawrence River and southern Gulf of St. Lawrence to northern Florida, as well as the northern coast of the Gulf of Mexico. It was introduced on the Pacific coast of North America over 100 years ago, where it now ranges from California to southern British Columbia. Striped bass have been introduced and become established in some landlocked lakes in the southern and central U.S.

Striped bass have been introduced to parts of Europe and Asia.

Natural History

Striped bass is a schooling fish, living in the sea and returning to fresh water to spawn (anadromous). It is most common in steady-flowing, turbid rivers that have low slopes and large estuaries. During their saltwater life many striped bass make long sea migrations. However not all fish migrate and some populations do not migrate at all. Some fish remain in the estuary of their home rivers.

Striped bass spawn in May and June after moving upriver the previous fall, usually at water temperatures of 14 to 22. C. The length of this journey can vary from a long journey inland to just above the head of tide. Striped bass sometimes spawn in brackish water.

Striped bass produce many eggs. In fact, more than three million have been recorded for a 22.7 kg (50 lb) female! About 100,000 eggs is more typical of bass in our rivers. Striped bass spawn near the water surface in water 0.3-6.1 m (1-20 ft) deep. The eggs have a large oil globule and

Fishing Facts

Historically valued both for food and for sport, stocks of striped bass have been declining since the 1970's. This is probably due to a combination of over fishing, habitat destruction, pollution and natural population cycles.

The striped bass is becoming a popular sport fish in Canadian waters and can be caught by casting, trolling, jigging, and fly fishing. They are fished in the surf or along shorelines and estuaries wherever schools of small food fishes are found and best fishing is often in the evening at high tide. Striped bass can be fished with live bait, lures (bucktails, Rapalas), plugs and poppers (skipping bugs). Bait success depends on the location and feeding habits of bass at the time but gaspereau, eels and worms are popular.

It is not fished commercially in Nova Scotia.

are semi-buoyant. Ideally the current that prevents them from getting silted over and smothered on the bottom carries them along. The eggs hatch in 2-3 days depending on the temperature (15-18.6.C).

Newly hatched fish are about 5 mm long. After absorbing yolk-sac, they feed on zooplankton (tiny invertebrates suspended in the water).

Striped bass are carnivores and take progressively larger prey as they grow. They eat a variety of invertebrates such as insect larvae, marine worms, and crustaceans as well as many kinds of schooling fishes, especially herring and gaspereau.

Adults feed most actively just after sunset and just before dawn and can be seen moving in with the tide, rolling and flashing as they feed on smaller fish. Canadian striped bass grow fairly rapidly and can be 14.5 cm (5.7 in) at age 1. They usually mature at age 3-6 years when they are about 34-53 cm (13.4-21.7 in) long. Males usually mature a year earlier than females, but do not live as long. Striped bass can live to 31 years.

Other fish such as Atlantic tomcod, Atlantic cod, silver hake and larger striped bass eat small striped bass. Adult striped bass have few predators except humans.

Young striped bass form schools and spend their first two or three years in the lower reaches of rivers and in estuaries, preferably where there is a sand and gravel bottom and some current. After this period, many leave their home waters and make long sea migrations along the Atlantic coast. Striped bass populations from North Carolina to the Bay of Fundy are typically migratory and travel in large schools moving north in the summer and south in the winter. They probably return to their home rivers when they reach sexual maturity and are ready to spawn, however mature fish do not necessarily return every year to spawn. In general, most migrating striped bass are female. Some of the large striped bass caught along the Maritime coasts probably originate from U.S. rivers.

Striped bass populations go through cycles. Every so many years the young-of-the-year offspring survive in particularly high numbers and become what is called a dominant year class in the population. Year class success is probably determined in the first two months of life and may be related to environmental conditions during this period.

Alewife (*Alosa pseudoharengus*)

Common names for the alewife are gaspereau, river herring, sawbelly, or kiack.

Physical Characteristics

The alewife is a member of the herring family. Here are some things to look for:

- A slender, laterally compressed fish coloured greyish-green on the back, and silvery on the sides and belly
- Gasperaux entering freshwater are often copper-tinged
- A single black spot is present on each side, just behind the head
- The eye is relatively large and has an obvious eyelid
- A row of scales, known as scutes, form a sharp edge along the mid-line of the belly which is how the alewife came to be called "sawbelly".

The alewife in Nova Scotia is usually 25-30 cm (10-12 in) long and weighs up to 340 gr (12 oz). There is no lateral line.

Another species known as the blueback herring is very difficult to distinguish from the alewife. They inhabit the same watersheds and have similar natural histories. Many reports of alewife

Facts on Alewife

Alewife eggs, or roe, are canned and sold as a delicacy.

Despite the many thousands of eggs laid by spawning alewife very few offspring actually survive. In some populations as few as three young-of-the-year fish migrate downstream for each female that spawned.

probably include the blueback herring as well.

Distribution

The alewife is found in rivers and lakes along the eastern coast of North America from Newfoundland to North Carolina and the adults live in coastal marine waters 56-110 m (180-350 ft) deep. Landlocked populations exist in several Ontario and New York lakes. Since the Welland Canal was built in 1824, the alewife has spread throughout the Great Lakes.

Natural History

In the Maritimes the alewife spends most of its life growing in salt water feeding mainly on zooplankton, tiny invertebrates, that live in the water column. Each spring from April to July large runs of adult alewives migrate up coastal rivers to spawn in freshwater lakes, ponds and streams (this movement from sea to freshwater makes the alewife an anadromous fish).

Alewives also spawn in brackish water. Like trout and salmon, alewives use their sense of smell to return to the streams and lakes where they hatched or near by watersheds. Female alewives usually begin spawning at age 4, repeat spawn each following year and may live to be 10. Male alewives often mature a year earlier than females. About 75% of alewives entering Nova Scotia rivers are repeat spawners. Alewives can move into coastal areas in late winter but will not migrate into fresh water until river temperatures begin to warm. Males enter the river first. Alewives only migrate into freshwater during daylight hours. However spawning occurs at night and can occur in standing, slow moving or fast mid-river water. A single female can lay as many as 200,000 eggs.

After spawning the adults begin the downstream migration to the sea within a few days.

Alewife eggs are about 1mm in diameter and are left to lie on the bottom or float with the current. Depending on the water temperature, the eggs hatch in about a week. After the yolk-sac is absorbed the tiny, larval fish stay near the spawning grounds preferring shallow, warm and sandy areas. They feed on tiny species of zooplankton. From August to October young-of-the-year, (sizes from 32-152 mm (1.25-6 in) migrate downstream in large groups or schools to live in estuaries and coastal areas. Adults over winter at sea in the George's Bank, Gulf of Maine or Nantucket Shoals and as far south a Florida. Alewives can live at least 10 years.

Fishing Facts

During the spawning runs commercial fishermen set large trap nets or enclosures called weirs in coastal rivers and estuaries to catch migrating alewives. Major Canadian fisheries are on the Shubenacadie, Miramichi, and Saint John Rivers.

The catch is used for fishmeal, lobster bait, pet food or it is smoked, canned, salted or pickled. Although tasty, alewives are not favoured locally for human consumption due to their large number of bones.

Alewives are eaten by many species of fish and birds including striped bass, salmonids, smallmouth bass, eels, perch, bluefish, weakfish, terns and gulls.

American Eel (*Anguilla rostrata*)



Physical Characteristics

The American eel has a long snake-shaped body. It has no pelvic fins and the fins along the top of the body are continuous. The body is covered with mucus, which is where the expression "slippery as an eel" comes from. Their colour changes as they grow up and there are different names for eels at these different stages.

"Glass eels" are young eels approaching the shore at sea. Their bodies are transparent with a distinct black eye.

"Elvers" are eels that are just adapting to fresh water and are greyish-green in colour.

"Yellow eels" are adults in freshwater. Their colour varies from yellowish to greenish to olive-brown, being darker on the back and lighter on the belly.

"Silver, bronze, or black eels" are sexually mature eels which darken to a bronze-black hue on the back with silver underneath.

American eels can grow to a size of 1270 mm (50 in) and weigh up to 4.5 kg (10 lb).

Fishing Facts

Commercial fishermen harvest silver and yellow eels with many kinds of gear including weirs, traps, otter trawls, nets, handlines, eel pots and spears.

Eels are sold for human consumption and as bait for other fisheries. Many are shipped fresh or frozen to Europe where they are considered a delicacy and served smoked or jellied.

Elvers have been harvested for use in pond culture and grow-out operations. The American eel is caught by recreational fishermen.

Distribution

American eels are found in freshwater streams and rivers, brackish coastal waters and the Atlantic Ocean of eastern North America from southern Greenland and Labrador to the Gulf of Mexico and northern South America. It is the only member of the freshwater eel family found in North America and is wide spread in the Maritime Provinces.

Natural History

The American eel goes on long oceanic migrations to reproduce. Unlike fish such as Atlantic salmon and alewife that return to freshwater to spawn, eels are catadromous, which means they spend most of their lives in freshwater lakes and streams, returning to sea to spawn. No one has ever seen American eels spawn but it is believed to occur in the Sargasso Sea, east of the Bahamas.

Spawning occurs from February through April and hatching probably occurs within a few days. The tiny transparent eel larvae (known as leptocephali), only a few millimetres long, drift with ocean currents to the coastal areas of North America. They grow rapidly until the fall.

Once they are between 8-12 months old and about 55-65 mm (2.1- 2.6 in) long they transform into glass eels. At this stage, eels actively migrate toward freshwater. As they enter brackish and freshwater they begin to develop colour and are known as elvers. Elvers and glass eels reach the Maritime coasts in April and May. At first the elvers are active at night and rest near the bottom during the day. They may stay in estuaries for some time moving up and downstream with the tide as they physiologically prepare to live in fresh water. When elvers begin to migrate upstream they become active during the day and are thought to use the current and the odour of brook water to find their way. This upstream migration can take several years with distances as far as 1000 km (600 mi) involved.

Elvers eat aquatic insects, small crustaceans and fish parts. After a year in freshwater elvers are about 127 mm long (5 in). Following this stage, eels enter a growth phase lasting many years in which they are known as yellow eels. Some eels do not migrate upstream as elvers but

Facts about Eels

Eels do not become definitely male or female until they are 20-25 cm (8-10 in) long!

What sex an eel becomes is thought to be partly determined by environmental conditions such as crowding and food abundance.

In areas (southern U.S.) where food abundance and water temperatures favour rapid growth rates, a higher percentage of male eels are found. In cooler areas, such as Nova Scotia, where eels grow more slowly but reach an overall larger size, there tends to be more females. This is an advantage since larger females produce more eggs and can contribute more offspring.

Eels can absorb oxygen through their skin and can travel overland particularly in damp, rainy weather.

remain instead to live in estuaries. Yellow eels are most active at night and spend the day concealed in vegetation or burrowed in the bottom. Their diet includes insect larvae, fish, crabs, worms, clams, and frogs. They also feed on carrion and are able to tear pieces off food items too large to be swallowed whole.

In late summer and fall some adult American eels in eastern Canada begin their spawning migration to the Sargasso Sea. During this time they change to the "silver eel" stage and become sexually mature. Males can mature at age 3 but females mature later usually at ages 4-7. However eels can spend up to 40 years in fresh water. Female eels produce from 0.5 to 4.0 million eggs. It appears that all eels die after spawning. Adult eels are eaten by larger fish such as sharks, haddock, and swordfish and also by gulls and bald eagles.

American Shad (*Alosa sapidissima*)

Physical Characteristics

The American shad, like the alewife (gasperau), is a member of the herring family and has the following characteristics:

- Slender and silvery-coloured with a blue-green metallic hue on the back
- Has a black spot, similar to the alewife, located on the side, just behind the head - on the shad, this spot is followed by several smaller dark spots
- The eye has an obvious eyelid
- A row of scales known as scutes form a sharp "sawbelly" edge along the midline of the belly
- There is no lateral line

American shad can grow to 76 cm (30 in) and weigh 6.8 kg (15 lb). However, adults found in Canadian rivers are usually 45 to 50 cm (18-20 in) long and weigh from 1.4 to 2.7 kg (3-6 lb).

Distribution

Facts on Fishing

American shad were much more abundant in the past. During the 1800's a thriving fishery for shad existed along the Atlantic coast supporting an annual catch as high as 23,000 tons (50 million pounds). Today small commercial fisheries exist but numbers have greatly declined due to over-fishing and changes in our rivers. Dams often block access to vast areas of spawning habitat. Even where fishways provide access, many young shad may not survive the downstream migration.

Shad are fished commercially in rivers during the spawning runs. The eggs (roe) are most desirable so large numbers of mature females are taken. The flesh is sold fresh and salted. Shad are angled and considered a fine game fish.

American shad are anadromous (moving from the sea to freshwater) fish found along the Atlantic coast of North America from Newfoundland to Florida. Large spawning runs used to occur in the Shubenacadie and Annapolis rivers (also Saint John, Petitcodiac and Miramichi) but they are found in many Maritime coastal rivers. They have been introduced along the Pacific coast and now range from Alaska to California.

Natural History

The American shad lives for several years at sea before returning to spawn in the stream where it hatched. Shad avoid cold temperatures and prefer to stay in water 8°C or warmer. Water temperature and currents determine much of their migration and behaviour.

Each spring, schools of shad, using their sense of smell, begin to migrate up coastal rivers and tributaries when water temperatures reach 12°C.

Spawning in the Maritimes occurs during June and July in water temperatures of 13-20°C.

Migration stops in temperatures over

20°C. American shad do not usually travel as far upstream as the alewife. They spawn in rivers at night in mid-water in streams with a wide range of bottom types. The eggs are about 3 mm across and drift along with the current to hatch in 8-12 days depending on the temperature.

A female can produce anywhere from 60,000-600,000 eggs but shad in Canadian rivers usually produce about 130,000 eggs. Many shad in the Maritimes are repeat spawners, however shad in southern populations die after spawning.

Young shad spend their first summer in the river feeding on insects and crustaceans. They swim near the bottom in water as deep as 3.7 to 4.9 m (12-16 ft) but at night they are found near the surface. When they migrate to sea in the fall, they have grown to a size of 7.5 to 12.5 cm (3-5 in). They migrate to the sea as temperatures in the river drop.

At sea, shad live in schools and move according to the bottom temperatures, seeking areas that are 7-13°C. They stay near the bottom during the day, dispersing at night to all depths.

Immature and spawned-out adults remain offshore in areas like the Bay of Fundy until winter, when they move farther out to sea in order to stay in preferred water temperatures. At sea they eat zooplankton (tiny invertebrates that live in the water), small bottom crustaceans, and occasionally small fish. Most shad mature at age 4 or 5 when they are about 48-53 cm (19-21 in) long. Shad can live up to 13 years.

Although not a major food source for other animals, shad are eaten at sea by seals, sharks, blue-fin tuna, kingfish, and porpoises. Young shad in freshwater are eaten by bass, American eels, and birds.

Brown bullhead (*Ictalurus nebulosus*)**Physical Characteristics**

Nova Scotia's only member of the freshwater catfish family is easy to identify with its distinctive sets of whisker-like formations around the mouth. These are called barbels and the bullhead has four pairs.

The following can also identify the bullhead:

- A thick rounded body, heaviest toward the front
- A broad, large, somewhat flattened head
- Sharp, saw-toothed, spines at the base of the dorsal and pectoral fins. These spines can be "locked" in an erect position.
- The tail or caudal fin is square and there is an adipose fin (small fin on the back in front of the tail)
- Its colour is dark brown to olive green on the back ; its sides are sometimes mottled with dark

Facts about Bullheads

The spines at the base of the dorsal and pectoral fins can be "locked" into an erect position. This is thought to help protect the bullhead against predators, making it much harder to swallow.

Brown bullheads take many kinds of bait and can be easily caught by anglers. They are best fished with worms at dusk.

The flesh of the brown bullhead is very tasty. They are reared commercially in the southern U.S.

Brown bullheads are extremely resistant to pollution. In areas of heavy pollution they can be the only fish species present.

blotches and the belly is cream coloured

- There are no scales but the skin has many taste glands

In Nova Scotia it seldom grows more than 30 cm (1 ft) long and 0.5 kg (1 lb) in weight. Bullheads weighing as much as 2.7-3.6 kg (6-8 lb) have been caught in Ontario.

Distribution

The brown bullhead is found in the fresh waters of eastern and central North America, from the Maritime Provinces to Florida, and westward to southern Saskatchewan, Missouri, and Texas. It occurs across southern Canada from Saskatchewan to the Maritimes. The brown bullhead has been introduced to western North America and Europe.

In Atlantic Canada the brown bullhead exists only in New Brunswick and mainland Nova Scotia.

Natural History

Brown bullheads usually live on the bottom in the shallow, weedy, mud-bottomed areas of lakes or large slow-moving streams. They tolerate higher water temperatures and lower oxygen levels than many other fish species.

They feed on the bottom at night, using their barbels to search for food. They eat a variety of foods including insects, fish eggs, leeches, mollusks, crayfish, worms, algae, plants, and small fishes. Young bullheads feed mainly on insects and plankton (tiny organisms suspended in the water).

Bullheads spawn in the late spring when water temperatures approach 21°C. One or both parents excavate a shallow nest in a protected area of mud or sandy bottom. Spawning occurs in the daytime and several thousand cream coloured eggs are deposited in the nest. The parents care for the eggs by fanning them with their fins and physically stirring them up. After hatching, the young catfish are jet black and resemble tadpoles. They swim in a "school" and are protected by their parents for several weeks until they are about two inches long.

The brown bullhead usually matures at age 3 and lives for 6-8 years. The chain pickerel and other members of the pike and perch families eat them.

Rainbow smelt (*Osmerus mordax*)

Other common names are Atlantic rainbow smelt, smelt, American smelt, freshwater smelt, Atlantic smelt, leafish, and frost fish.

This fish is one of two members of the smelt family found in Atlantic Canada. The other member found here is capelin.

Physical Characteristics

The rainbow smelt is a small slender fish that grows to about 25 cm (10 in). It has the following characteristics:

- Olive-green on the back, becoming lighter on the sides
- Sides have a purple, pink and blue iridescence especially when freshly caught
- The belly is silvery
- Relatively large mouth with fang-like teeth and a protruding lower jaw
- The caudal (or tail) fin is deeply forked
- An adipose fin (small fin in front of the caudal fin on the top) is present
- The lateral line is incomplete
- Spawning males are covered on the head, body and fins with tiny bumps (nuptial tubercles)
- Smelt in freshwater are darker becoming almost black on the back

Facts about Smelt Freshly caught smelt smell very much like cucumber! No doubt this feature is responsible for the common name "smelt". This odour disappears after preservation or freezing.

Males smelt are more abundant on the spawning grounds than females. This is probably because they can spawn up to 8 consecutive nights but females may spawn only 3 or 4 nights.

Distribution

The rainbow smelt is found in rivers and coastal areas of eastern North America from Labrador to New Jersey and on the west coast from Vancouver Island around Alaska to the Arctic Ocean. Landlocked populations also occur in lakes and ponds throughout the Atlantic region. They have been introduced in the Great Lakes and have increased their range to other Ontario drainages through unauthorized introductions.

Natural History

The rainbow smelt is a schooling fish, which grows and matures in shallow coastal waters and migrates up freshwater streams to spawn (anadromous). Smelt move into estuaries in the fall and begin to move up the streams after the spring thaw.

Spawning occurs from February-June usually at water temperatures from 4-10°C. Smelt do not necessarily return to the stream of their birth to spawn, especially if there are other nearby streams. Smelt in landlocked lakes swim up tributary streams or in some cases spawn along the shoreline. Spawning occurs at night in fast moving water. Several males spawn with one female. The fertilized eggs become sticky and attach to the bottom, sometimes forming a thick layer. One female can produce as many as 93,000 eggs. After spawning the adults return to the estuary during the day but may return upstream to spawn again on subsequent nights. Some fish die after spawning. The rest leave freshwater after spawning to spend the summer in coastal waters.

Smelt eggs are about 1mm in diameter and take anywhere from 11-29 days to hatch, depending on the temperature. Smelt fry are 5 to 6 mm long when they hatch and drift downstream to brackish water. They use water depth for cover and feed near the surface at night. Young smelt feed on plankton (tiny organisms suspended in the water), and may grow to 5 cm (2in) by August.

Older fish eat larger invertebrates and other fish. Smelt grow most rapidly in their first year and can tolerate increasing amounts of saltwater, as they get older. They prefer temperatures of 6-14°C and stay close to shore, seeking cover in eelgrass beds or below the water.

Fishing Facts

Smelt are fished commercially and for sport. Winter fishing for smelt is a popular sport. Anglers take them on lines through the ice, using worms as bait. In spring, anglers dipnet or seine them in the spawning tributaries.

Commercial fisherman catch them in box nets, bag nets, gillnets or by trawling.

The largest Maritime fishery occurs in the Miramichi estuary. Smelt are sold fresh or frozen and are very tasty.

Smelts in the Miramichi average 13.9 cm (5.3 in) at age 2, and 20.6 cm (8.1 in) by age 5, southern populations grow faster. Smelt in small landlocked lakes may only reach a length of 10.2 cm (4 in). Smelt usually mature at age 2 in the Maritimes and can live to age 17. Females live longer and grow larger than males.

Smelt are eaten by bluefish, striped bass, salmonids as well as birds, and harbour seals.

White Perch (*Morone americana*)

Oddly enough, the white perch is actually a member of the bass family and is not a true perch. Other common names for the white perch are silver perch, sea perch, silver bass, narrow-mouthed bass, and bass perch.

Physical Characteristics

The white perch has the following characteristics:

- A deep, thin body that slopes up steeply from the eye to the beginning of the dorsal fin
- Colours which can be olive, grey-green, silvery-grey, dark brown or black on the back becoming a lighter green on the sides and silvery-white on the belly
- The pelvic and anal fins (both on the belly) are sometimes rosy coloured
- Like all members of the bass family it has two dorsal fins on the back and the pelvic fins sit forward on the body below the pectoral fins
- The first dorsal fin has nine spines but the second one is soft rayed • there are three spines at the front of the anal fin, and a single spine precedes the second dorsal fin and each pelvic fin
- It has many small sharp teeth
- Its scales are relatively large and the lateral line is complete

Facts about White Perch

The oldest known white perch lived 17 years.

The world angling record for white perch is a 2.15 kg (4.7 lb) fish taken in Messalonskee Lake, Maine in 1949.

It can grow to 48.3cm (19 in) and 2.72 kg (6 lb).

It is very similar in shape to the striped bass, also found in our waters. The white perch has a deeper, less rounded body than the striped bass. The anal fin spines of the striped bass are less than one-half the fin length, but the second and third anal spines in the white perch are greater than this.

Distribution

White perch are found in fresh and brackish waters along the Atlantic coast from the southern Gulf of St. Lawrence to North Carolina and inland along the upper St. Lawrence River to the lower Great Lakes. It is present in all three Maritime Provinces.

Natural History

White perch is a fish that can live in fresh or salt water and does best when summer water temperatures reach 24.C. In the Maritimes, it occurs mostly in freshwater lakes and ponds. Sea-run populations are found in some coastal rivers and estuaries.

Spring spawning takes place when water temperatures are 11-16.C, late May-late July in shallow water over many kinds of bottom. Males and females each spawn several times and the tiny 0.9 mm eggs become sticky after fertilization and attach to vegetation and bottom materials. White perch are quite prolific; a 25 cm (10 in) female can produce 247,700 eggs.

The length of time for hatching depends on the water temperature. When the water is cooler, hatching takes longer (4-4.5 days at 15.C versus about 30 hours at 20.C). Newly hatched white perch are 2.3 mm long and feed on plankton (tiny organisms in the water). They grow rapidly and can reach 65 mm (2.5 in) by late summer.

Growth rates of white perch vary among regions and populations. Few studies have been done on Maritime populations. Most perch in our waters are less than 15 cm (6 in). Larger pan-sized white perch that weigh 225 to 450 g (0.5-1 lb) are taken in some Nova Scotia lakes. Lake Ontario fish can reach 33.5 cm (13.2 in) and 780 g (1.72 lb). Even larger sizes have been reported in some U.S. waters.

White perch in lakes are known to feed both during the day and at night. Fresh and saltwater populations move to surface (or inshore) waters at night, retreating to deeper water during the

Fishing Facts

The white perch has very tasty flesh and where it grows large enough can be a popular sport fish. They are caught on bait (worms, small minnows) lures, or streamer-type flies.

White perch are fished commercially in Chesapeake Bay, U.S. and the lower Great Lakes.

day. They perch eat mostly aquatic insect larvae when they are small. As they grow, many kinds of fish such as smelt, yellow perch, killifish, and other white perch are eaten. They usually mature at 3 years and live 5-7 years.

White perch are thought to compete with some game fishes for food. In some places a lack of harvesting, either by anglers or other species of fish, can lead to large populations of stunted, small white perch. Smallmouth bass, chain pickerel, and large trout will eat white perch.

Yellow perch (*Perca flavescens*)



This, the only true member of the perch family in Nova Scotia, is also called perch, lake perch, and American perch.

Physical Characteristics

The yellow perch has the following characteristics:

- Its colour is black-green, to olive, to golden brown on the back and extending down the sides in tapered bars
- The rest of the sides are yellowish becoming grey to white on the belly
- It has two dorsal fins (on the back), the first one has 13-15 sharp spines, the second has only one spine followed by soft rays
- The pelvic fins with one spine sit forward on the belly almost directly below the pectoral fins
- The pectoral fins are amber-coloured and transparent whereas the pelvics are yellow to white and opaque
- Eyes are yellow to green
- The scales feel rough to the touch
- The colour of a spawning male fish intensifies; its lower fins can become orange to bright red.
- Young yellow perch are first transparent, then silvery or pale green

Facts about Yellow Perch

Occasionally yellow perch are found with the unusual colouring of grey-blue or red and the absence of dark bars on the side.

The yellow perch has been called "a good bold-biting fish" "the most extravagantly handsome of fishes" "a ravager of all smaller fish" and "bait-stealing little devils".

Students studying the anatomy of bony fishes most often use the yellow perch.

ADOPT-A- STREAM: WATERSHED, MARSH, LAKE, RIVER, ESTUARY

The yellow perch can grow to 1.9 kg (4.2 lb) but in Nova Scotia it does not exceed 30 cm (12 in) and 450 g (1 lb).

Distribution

Yellow perch can be found in freshwater of North America from Nova Scotia south along the Atlantic coast to Florida, west from Pennsylvania to Missouri, northwest to Montana, north to Great Slave Lake, southwest to James Bay and east to New Brunswick and Nova Scotia. It has been introduced widely in the south and western U.S. and has spread to southern British Columbia. Yellow perch cannot be found in Prince Edward Island, Cape Breton Island or Newfoundland. It is occasionally found in brackish water along the Atlantic coast.

Facts about Yellow Perch

The yellow perch is fished both for sport and for food. Anglers can catch them in summer and winter with fish or worms as bait. Yellow perch have been fished commercially in Canada for over a hundred years and are sold both fresh and frozen. The flesh is white and tasty.

Yellow perch are sometimes infected with the broad tapeworm (*Diphyllobothrium latum*) that can be transmitted to humans if the flesh is improperly cooked.

Natural History

The yellow perch is a schooling, shallow water fish that can adapt to a wide variety of warm or cool habitats. They are found in large lakes, small ponds, or gentle rivers but is most abundant in clear, weedy lakes that have muck, sand, or gravel bottoms. They prefer summer temperatures of 21-24. C. Yellow perch feed on aquatic insects, crustaceans, and a variety of fishes and their eggs.

Spawning occurs from April through July, but usually during May in Nova Scotia, at water temperatures of 9-12.C. The adults move into shallow areas of lakes or up into tributary streams. Males are first to arrive and the last to leave. Yellow perch spawn at night or in early morning, most often in areas where there is debris or vegetation on the bottom.

The female perch sheds her eggs in a long jelly-like spiral or accordion-folded strand. Several males fertilize the eggs during spawning. The egg mass can be as much as 2.1 m (7 ft) long, 51-102 mm (2-4 in) wide and weigh 0.9 kg (2 lb)!

Females produce an average of 23,000 eggs but have been known to shed up to 109,000 eggs. The egg masses are semi-buoyant and attach to the vegetation or bottom material. They receive no parental care and can be cast ashore during storms or eaten by predators. Yellow perch eggs are 3.5 mm in diameter and hatch in 8-21 days, depending on the temperature. Newly hatched perch are about 5 mm long.

Young perch grow quickly and remain near the shore during their first summer, swimming in large schools that often include other species. Perch in Nova Scotia waters do not grow as large as those living in the warmer, larger, or more productive habitats of central Canada. In general northern populations grow more slowly but live longer, and females grow faster than males.

Adults move in schools farther offshore than the young. They move between deeper and shallow water in response to changing food supplies, seasons, and temperatures. Perch feed in the morning and evening, taking food in open water or off the bottom. At night they rest on the bottom. Yellow perch remain active and feed during the winter.

Yellow perch can outbreed and out-feed speckled trout or other fish in a lake. This can sometimes lead to an overpopulation of small, stunted fish (less than 15 cm (6 in)).

Other fish such as smallmouth bass, chain pickerel, and lake trout eats yellow perch. Birds like mergansers, loons, kingfishers and gulls also take them.

White Sucker (*Catostomus commersoni*)



This fish, the only member of the sucker family found in Nova Scotia, is also called the common sucker, common white sucker, eastern sucker, sucker, black sucker, mud sucker, mookie and muckie.

Physical Characteristics

The white sucker has the following characteristics:

- A torpedo-shaped fish distinguished by its sucker-like mouth located on the underside of its blunt, rounded snout
- Its mouth has thick lips covered with little fleshy bumps (papillae)
- Its colour varies from grey to coppery brown to almost black on the back and upper sides, becoming lighter on the lower sides to white on the belly
- During spawning, the darkness on the back intensifies and the body becomes more golden in colour
- Spawning males develop coarse bumps (nuptial tubercles) on the anal fin and lower tail (caudal) fin
- It has relatively large scales, one dorsal fin, no adipose fin and the lateral line is complete
- Young white suckers from 5 to 15 cm (2-6 in) in length usually have three large dark

Fishing Facts

The flesh of the white sucker is bony but can be very tasty, particularly when hot-smoked.

Young suckers are sold as bait but there is little other commercial interest in the species. Suckers should not be used as bait in lakes that do not already contain suckers.

White suckers are not a popular sport fish but they can be caught on wet flies, small spinners and small hooks baited with dough balls or worms.

ADOPT-A- STREAM: WATERSHED, MARSH, LAKE, RIVER, ESTUARY

spots on the sides

They can grow to 63 cm (25 in) and more than 3.2 kg (7 lb) but reach about 46 cm (18 in) in Nova Scotia.

Distribution

The white sucker is a North American species found in freshwater lakes and streams from Labrador south to Georgia, west to Colorado and north through Alberta and British Columbia to the Mackenzie River delta. In Canada, it is absent from Newfoundland, eastern Labrador, Prince Edward Island, south-western British Columbia and much of the far north.

Natural History

The white sucker can adapt to a wide range of environmental conditions but generally lives in the warm, shallow waters of lakes and quiet rivers. They prefer summer temperatures of 24°C. In streams they are most abundant in pool areas with ample underwater debris, streamside vegetation, and water depth to provide cover.

In lakes they are usually found in the upper 6.2-9.2 m (20-30 ft) of water, moving to shallows to feed. They are bottom feeders that browse the bottom, sucking in aquatic insects, small clams, and snails, and then spitting out the inedible sand and gravel. They feed mostly at dawn and dusk, and are active year round.

White suckers spawn in the spring (May and June), migrating upstream to spawning areas (small streams and tributaries) when water temperatures are 10-18°C. Suckers typically spawn in shallow gravel riffles where the water is up to 30 cm (1 ft) deep and where the speed is moderate. Lake populations of white suckers with limited access to streams will occasionally spawn on gravel shoals where there are waves. Although some spawning occurs in daytime, most takes place at sunrise and sunset. One female spawns with several males. Females usually produce 20,000-50,000 eggs, but can produce up to 139,000 eggs. Suckers do not build a nest, but scatter their eggs, which stick to the bottom, or drift downstream and attach elsewhere.

The eggs hatch in 8 to 11 days, depending on the temperature (10-15°C). The young remain in the gravel for 1 or 2 weeks and then migrate downstream at a size of 12 to 17 mm. Sometimes only 3% of white sucker eggs survive to this stage. Young suckers in lakes are found along shorelines with sand or gravel bottoms. In streams they prefer

Facts about Suckers

Spawning migrations of white suckers can be numerous and very dense - 500 have been known to swim upstream past a single point in 5 minutes.

Although examining the growth rings on their scales ages most fish, this method is not always reliable for suckers older than 5 years. They are best aged using sections of their pectoral fin rays.

sand and gravel shallow areas with moderate currents.

At first white suckers do not feed on the bottom. Their mouth is at the end of their snout, and they feed near the surface of the water on plankton (tiny organisms suspended in the water). When they grow to about 16-18 mm (0.6-0.7 in), their mouths shift to the underside of the head and they begin taking food from the bottom. White suckers grow most rapidly during their first year and can reach a length of 17.9 cm (7 in) by age 1. Growth rates vary considerably in different areas, but in all populations females grow more rapidly than males, reach larger sizes, and live longer. They usually mature at ages 5 to 8, and males mature a year earlier than females. Suckers can live up to 17 years.

Although there is evidence that suggests that the white sucker can compete for food with other sport fish, they can be a major food item in the diet of other fish such as Atlantic salmon, brook trout, pike and bass. Birds and mammals also eat them.

Appendix D: Fish Collection Tracking Sheet

Fish Collection Tracking Sheet

Pre-Job General Information		
Project:	Project Number:	Task:
Date:	Personnel:	WC/WB ID:
Weather:	Precipitation (past 24 hours):	Reach ID:

Site Characteristics **Photos taken of the site?** **Yes (US, DS, LB, RB, Substrate)**

Stream Type (% Surface Area)		Water Quality Measurements	
Riffle		pH	
Run		SAL (ppt)	
Pool		CON (µS/cm)	
Other (specify)		SPC (µS/cm)	
Substrate (% Surface Area)		TDS (mg/L)	
Bedrock		DO (% , mg/L)	
Boulder (>25 cm)		* Temp measurements are recorded below	
Rubble (14-25 cm)			
Cobble (3-13 cm)		Physical Measurements (average over reach)	
Gravel (0.2-3 cm)		Bankfull width (cm)	
Sand (0.06-2 mm)		Wetted Width (cm)	
Silt (<0.006 mm)		Depth (cm)	
Muck/Detritus		Length of Reach (m)	
Clay/Mud		Velocity (estimate)	

Fish Caught? (if so, list species)
 Add any commentary or observations from survey effort.

Revisions to Electrofisher settings required?

Sketch of Site: Include flow direction, locations of habitat features/cover ex. Large boulders, large woody debris, overhanging vegetation, and undercut banks

ELECTROFISHING (Electrofishing must proceed in an upstream direction)

Method Used: <input type="checkbox"/> Depletion <input type="checkbox"/> CPUE		Pass 1	Pass 2	Pass 3
Site Set-up: <input type="checkbox"/> Open <input type="checkbox"/> Closed	Effort (seconds)			
Upstream Waypoint:	Voltage			
Downstream Waypoint:	Frequency			
Water visibility: <input type="checkbox"/> Good <input type="checkbox"/> Fair <input type="checkbox"/> Poor	Water temp (°C)			
*Measure Temperature at Beginning of each pass	Air Temp (°C)			
***DO NOT Electrofish if water temp is greater than 22°C ***	# of Fish Caught			
* Do NOT Electrofish if temperature is greater than 22°C				

TRAPPING & NETTING

Gear Used: <input type="checkbox"/> Fyke Nets (#_) <input type="checkbox"/> Minnow Traps (#_) <input type="checkbox"/> Eel Pots (#_) <input type="checkbox"/> Seine	Bait:
Locations and Depths (UTM, cm):	Time In (hr):
	Time Out (hr):

Appendix E

SOP for Fish Habitat Assessments

STANDARD OPERATING PROCEDURE: DETAILED FISH HABITAT ASSESSMENT – STREAMS

1 PURPOSE

The purpose of this document is to provide standard methods for detailed fish habitat assessments performed by McCallum Environmental Ltd. (MEL) employees and subconsultants in lotic, freshwater habitats.

2 SCOPE

This document provides standards for data collection for detailed fish habitat assessments and describes a limited range of field-based measures for linear watercourses (i.e. lotic systems).

Fish habitat is inherently difficult to measure and quantify directly. Therefore, this SOP incorporates measures that evaluate specific features that are characteristics of, or inherent to a function of fish habitat and can indicate the extent to which a particular fish habitat characteristic or function is provided within a stream. This SOP aims to provide procedures for detailed fish habitat assessments which may be modified depending on the requirements and scope of a particular project.

Measures are habitat variables that can be quantified directly, or if not, visually estimated in the field. This SOP aims to incorporate measures of fish habitat with the following criteria, whenever possible:

- Quantifiable – habitat variables can be measured numerically, or when not possible, visual-based methods are standardized to the maximum practical extent.
- Rapid – habitat variables can be measured within the expected time frame of assessment (1/2 – 1 day per watercourse depending on watercourse size).
- Repeatable – a clear protocol for taking measurements can be described such that different users taking the measurement on the site would arrive at similar conclusions.
- Sensitive – changes or impacts to the stream would result in changes/impacts in the habitat variable. Variables are responsive to changes in the stream system.

It is important to note that the methods outlined in the SOP are best suited for previously mapped watercourses as they employ the use of transects. MEL defines watercourses based on guidance from Nova Scotia Environment (NSE, 2015). The following parameters were used to define watercourses:

- Presence of a mineral soil channel;
- Presence of sand, gravel and/or cobbles evident in a continuous pattern over a continuous length with little to no vegetation;
- Indication that water has flowed in a path or channel for a length of time and rate sufficient to erode a channel or pathway;
- Presence of pools, riffles or rapids;
- Presence of aquatic animals, insects or fish; and,
- Presence of aquatic plants.

According to the guidance provided by NSE, any surface feature which meets two of the criteria above meets the definition of a regulated watercourse. In MEL's experience, many first-order, headwater streams which meet the criteria of a regulated watercourse in Nova Scotia are not represented on topographic mapping or through provincial GIS layers. As such, it is critical that a general reconnaissance

of watercourses within a study area is completed prior to undertaking detailed fish habitat assessments as outlined in this SOP.

It is also important to note that many rivers and stream comprise areas of “open water” – areas where the watercourse takes on more pond-like conditions, often times caused by beaver dams or other natural or anthropogenic obstructions. “Open water” areas are defined in this SOP as areas of stillwater, or a flat, wide portion of a watercourse with no visible current. The scope of this SOP for fish habitat assessment in streams includes open water habitat up to a maximum depth of 2 m. For open water areas with depths greater than 2 m, fish habitat assessments procedures for lentic areas (ponds and lakes) should be followed. However, the decision of whether to apply lotic or lentic fish habitat assessments to open water areas depend on a number of other factors, including overall goals of the survey, and will ultimately be at the discretion of the Project Coordinator. Procedures for fish habitat assessments in lentic systems are outlined in a separate SOP.

Prior to conducting fish habitat assessments, all field staff should acquire knowledge on the habitat preferences of fish expected to be encountered within a particular freshwater system. All field staff should possess a general understanding of the biology and habitat preferences of anticipated local fish species and age classes. This knowledge will provide important context to empirical habitat assessments and will help field crews identify unique habitat features in the field. Detailed information on the biology of fishes in Nova Scotia can be found in Scott and Crossman (1973), McPhail and Lindsey (1970), and the Nova Scotia Adopt A Stream Manual (2005).

3 SAFETY

The following documents provide important safety considerations and Personal Protective Equipment (PPE) for this type of work, and should be consulted before proceeding with any fish collection survey:

- MEL HSE Policy;
- MEL Remote Work Policy; and,
- MEL Working Near Shallow Water Policy.

A Field Work Tracking Sheet must be completed and signed by all field crew members prior to departing for any field work. Refer to Section 6.1 for details on field planning.

Water levels can change dramatically and can be hazardous to those working in large river flows. Field crews should not enter watercourses with swift water or dangerous currents. Discuss any potential safety concerns when completing the Field Work Tracking Sheet with the entire field crew, and before entering any streams.

4 FISH HABITAT ASSESSMENT - THEORY

Field approaches to fish habitat assessments and evaluations are incredibly varied. The selection of appropriate habitat assessment tools or evaluation methods is determined by the questions you wish to answer about a particular system. Depending on survey objectives, a variety of methods may be employed. Overall, fish habitat assessments are site-specific and methods must be tailored to the freshwater habitats being investigated.

As described by DFO (2012), methods for fish habitat assessments fall into three stages based on the potential impacts of a project – Primary, Secondary, and Tertiary. A Primary assessment is generally desktop based and may incorporate a rapid field reconnaissance to qualitatively assess fish habitat. This stage of assessment is usually sufficient when the magnitude of effect from a project is considered relatively low. A Secondary assessment is heavily field-based and involves validating habitat types within a Project Area by quantitatively measuring stream features. This stage of assessment is required when predicted fish habitat impacts from a project cannot be fully mitigated. Tertiary assessments are typically reserved for anticipated impacts on large river systems and changes in natural flow patterns, which fall outside the scope of this SOP. The methods outlined in this SOP fall under the Secondary stage of assessment methods. This SOP has been designed specifically to collect data to define existing fish habitat attributes in targeted mapped or field-delineated streams. Streams may be targeted for detailed fish habitat assessments for a number of project-related reasons, including project design, assessment of anticipated project-related effects, and restoration or engineering work. However, the scope of this SOP does not include fine-scale delineation of fish habitat (i.e. habitat mapping).

The measurable features outlined in this SOP are based on the following general attributes that are important in influencing fish habitat within a given stream. These include:

- channel dimensions, gradient, and velocities
- channel substrate size and type
- habitat complexity and cover
- riparian vegetation cover and structure
- anthropogenic alterations or disturbance

The methods outlined in this SOP and the field sheet (Detailed Fish Habitat Assessment – Streams”, Appendix A, herein referred to as “field sheet”) were derived from the following sources:

- The Nova Scotia Fish Habitat Assessment Protocol: A Field Methods Manual for the Assessment of Freshwater Fish Habitat (2018);
- DNR / DFO – New Brunswick Stream Habitat Inventory Datasheets;
- Standard Methods Guide for the Classification and Quantification of Fish Habitat in Rivers of Newfoundland and Labrador for the Determination of Harmful Alteration, Disruption and Destruction of Fish Habitat (2012);
- Reconnaissance (1:20,000) Fish and Fish Habitat Inventory (2001);
- The US EPA Rapid Bioassessment Protocols For Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish (1999); and,
- The Canadian Aquatic Biomonitoring Network Field Manual, Wadeable Streams (2012).

Specific stream terminology is used and referred to throughout the procedures outlined in Section 6. Definitions of specific terms and associated acronyms, as well as diagrams and calculations are provided in a Glossary at the end of the document (Section 8).

For larger river systems (typically 3rd order streams and over), detailed, low-elevation aerial imagery can be interpreted to support habitat descriptions. This technique is particularly useful when habitat complexity increases or water depths/flows reduce wadeability. In addition, aerial imagery interpretation is helpful when assessing areas that have been historically altered through anthropogenic activities, such as freshwater systems that have been ditched or diverted, which are difficult to delineate in the field.

Low-elevation aerial imagery is especially effective in determining channel dimensions (bankfull and wetted widths) and instream habitat features (e.g. islands, gravel bars, etc.) for larger rivers that are not obscured by crown closure. However, for smaller, headwater streams, channel size and crown closure eliminate the effectiveness of aerial interpretation. Drones can be used to collect fine-scale aerial imagery if not already publicly available. Whenever possible, aerial imagery should be followed with field verification using the procedures outlined in this SOP.

5 MATERIALS

- standard MEL PPE
- chest waders with wading belt
- polarized sunglasses (useful for reducing glare)
- field sheets on write-in-the-rain paper
- pencils
- multi-parameter water quality instrument (YSI or equivalent)
- GPS
- velocity meter
- measuring tape
- meter stick (2 m length)
- clinometer
- phone or digital camera
- a copy of the Stream Habitat Mapping Legend (Appendix B)

6 FISH HABITAT ASSESSMENT METHODS – PROCEDURES

A **watercourse**, as defined in Section 2, is bound by distinct downstream and upstream endpoints when delineated in the field. MEL biologists typically identify unnamed, linear watercourses with numbers starting with first-order, headwater streams. When first order streams combine, the second order stream will be designated with a new number, unless flow is significantly disproportionate across headwater streams (i.e. one first-order stream contributes the vast majority of flow to the second order stream).

A **reach** is length of stream comprising one homogenous habitat type (i.e. a run). Reaches are numbered from an upstream – downstream orientation. Larger streams comprising variable habitat types are therefore divided into multiple reaches. In smaller, first-order streams, major habitat types may be so short as to not warrant the continuous establishment of very small reaches. For efficiency in the field, when individual habitat types are small in overall length (<5 m), they may be lumped together into one reach.

A **transect** is a particular location within a reach where a cross-sectional survey is performed. A transect is line across a stream perpendicular to the flow and along which measurements are taken (e.g. velocities, depths, etc.), so that morphological and flow characteristics along the line are described from bank to bank. Transects are numbered from an upstream-downstream orientation. For the purposes of this SOP, one transect is to be completed for every 50 m length of reach (e.g. if a run is 150 m in length, 3 transects would be established along the run). If multiple habitat types have been lumped together (< 5 m in length) to form a reach, a transect must be established within each habitat type represented within the reach. However, the amount of transects and transect locations may be shifted slightly or altered during the field assessment based on specific habitat features observed, or access, wadeability, and safety concerns.

The watercourses to be surveyed will be defined by the Project Coordinator – these may comprise an entire watercourse, or a section of a watercourse.

The procedures outlined in Section 6 include both reach-scale and transect-scale data collection – that is to say that some measurements are taken repeatedly at cross-sections (predominantly quantitative measurements), whereas other measurements are based on reach averages (predominantly qualitative, visual-based assessments). Generally speaking, a detailed habitat assessment for streams involves walking the length of the watercourse chosen for assessment, establishing reaches for each change in habitat type, and stopping to take specific cross-sectional measurements along the length of each reach.

6.1 Planning: Before You Leave

1. Review detailed written scope provided to you by the Project Coordinator. This will identify priority deliverables, timelines, and budget allowed for each task. Detailed methods should be provided in this scope (i.e. watercourses to be surveyed).
2. Determine your field crew – fish habitat assessments should be completed with a minimum crew size of 2 people.
3. Determine the location(s) of the survey, size of area to be surveyed and easiest access to the site based on the work scope provided by the Project Coordinator. Sample design should be verified by the Project Coordinator.
4. Complete a review of available data from watercourse delineation surveys. If fish collection surveys have been completed, review the results of those surveys prior to commencing field work. A desktop review of fish species distribution records should be conducted if no fish collection surveys have been completed.
5. Print field sheets and prepare site maps and GPS units as required.
6. Fill out a field tracking sheet. Have all crew members review and sign off on the field tracking sheet.

6.2 Field Procedure

6.2.1 Site Setup

1. It is preferable to begin surveys at the top (upstream end) of the watercourse to be surveyed as reaches and transects are to be numbered in an upstream-downstream orientation.
2. Record general survey data including Project name, date, crew member names, weather, and watercourse identification information. If stream order is known, record on the field sheet. Stream order can be identified through desktop mapping prior to or after field data collection.
3. Begin to establish a reach. Identify the habitat type present. If smaller (<5 m in length) habitat types are to be lumped together, identify all present. Record the upstream boundary coordinate (for smaller reaches the upstream and downstream coordinates can likely be established at the same time). For longer reaches, when the downstream end can't be seen from the upstream end, the downstream boundary coordinate can be recorded once the entire reach has been surveyed.
4. Describe and record general reach characteristics including flow type and entrenchment.
5. Measure the gradient of the stream:

- If conditions allow (clear visibility of the meter stick is obtainable along the entire reach), measure the gradient of the reach in the field using a clinometer. To use the clinometer, first determine the height from the ground to the eyes of the person holding the clinometer. This height can be flagged on the meter stick, which will be held vertical from the base of the survey point by a second team member at the downstream end of the reach. Starting at horizontal from the upstream end of the reach, the observer will tilt or lower the clinometer until it is aligned with the flagged point on the meter stick, and then will read the degrees changed off the clinometer.
 - If the clinometer cannot be used to measure gradient in-field, estimate the gradient based on the following morphological thresholds:
 - i. <1% (flat)
 - ii. 1-4% (riffle/run)
 - iii. 4-7% (rapids)
 - iv. >7% (step-pool, cascade, falls)
 - Estimated gradients should be verified by desktop mapping using elevation data such as Digital Elevation Models (DEM) or Google Earth.
6. Measure and record water quality parameters, including temperature, conductivity (SpC), total dissolved solids (TDS), pH, dissolved oxygen (DO). Record turbidity based on a visual assessment of the watercourse if not included as a parameter on the water quality meter (refer to Section 8 – Glossary).
 7. Begin a field sketch (aerial view) which will be completed for each reach. The Stream Habitat Mapping Legend (Appendix B) can be used as a drawing and labelling guide. Note the locations of the transects and width measurements used in the assessment. Indicate left and right banks, flow direction, orientation, significant landmarks and landscape, barriers, channel shape and habitat types.

Note: the legend presented in Appendix B is extensive and incorporates a number of habitats/features that MEL biologists do not frequently encounter within Nova Scotia's headwater inland systems. New symbols/labels can be created so long as they are described in a legend superimposed on the field sketch.

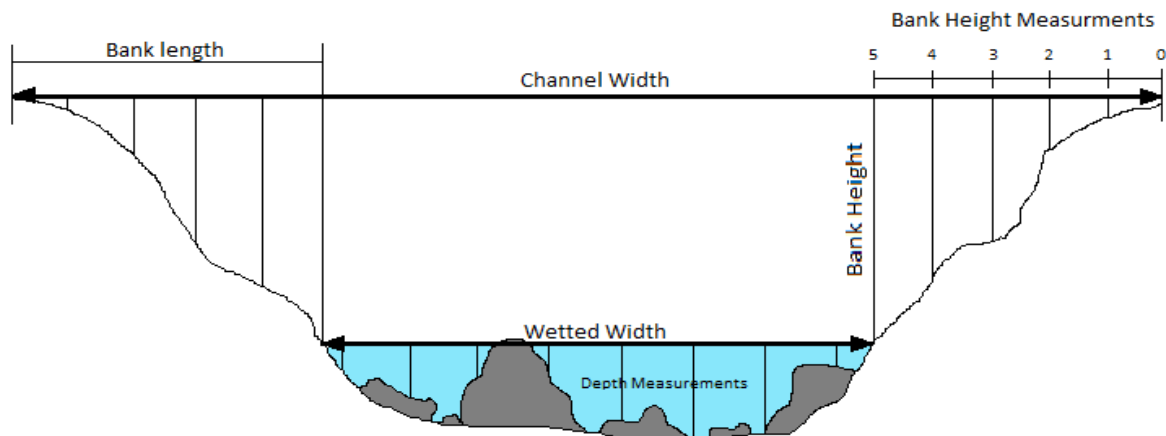
6.2.2 Transects

Record the GPS location (waypoint) of each transect surveyed. Identify each transect with a sequential number from upstream to downstream. A transect must be established for every 50 m of a particular habitat type (reach). If smaller habitat types (< 5 m in length) have been lumped together into a single reach, a transect must be established within each habitat type represented.

1. Record the habitat type being surveyed.
2. Begin measuring the channel cross-section from the left bank looking downstream. Pin the measuring tape into the banks or have a crew member hold the tape at the bankfull level and record the bankfull width on the field sheet. Keep the measuring tape in this position for the duration of cross-section measurements.
3. Measure and record wetted width.
4. Record bank height measurements from the both the left and right banks out to the wetted width of the stream (see diagram below – this is also provided on the field sheet). To do this, divide each bank into equidistant intervals (5 is typical for larger streams but this may be reduced for smaller streams, particularly when bankfull width and wetted width are similar). The distance to

be recorded refers to the distance from each bank as noted on the measuring tape (left bank would be '0', right bank would be the full bankfull width). Using a meter stick, measure the height of the bank (as inferred from the measuring tape across the stream) from the substrate. Note that if wetted width is equal to bankfull width, only one bank height measurement would be recorded for both the left and right bank (at '0' and at full bankfull width). Also note that left and right bank may vary in terms of distance to the wetted stream.

5. When wetted widths are > 1 m, perform a minimum of 10 depth and velocity measurements at equidistant intervals along the transect (see diagram below). If wetted width is < 1 m, record 3 depth and velocity measurements. Starting at the left bank, use the meter stick and a velocity meter to determine the depth of the water and water velocity at equal distances across the wetted portion of the cross-section. Velocity measurements should be taken at 0.6 water depth. The distance to be recorded refers to the distance from the left bankfull width as recorded from the measuring tape (left bank would be '0'). Use the water level on the downstream side of the meter stick to determine depth as the level on the upstream side may be affected by stream velocity. An estimated negative depth, or height above the water level, should be taken if a measurement is located with no water depth in the adjacent area (an island or section of riffle with no significant depth or flow). A measurement of zero can also be taken if the river bottom is approximately the same height as the water level.



6. If substrate varies significantly at the transect location from that estimated for the entire reach (which may occur if smaller habitat types are lumped together), note it on the field sheet and record percent composition by substrate type.
7. Take representative photos at each transect of the following:
 - a. Looking upstream
 - b. Looking downstream
 - c. Right bank (downstream orientation)
 - d. Left bank (downstream orientation)
 - e. Substrate

6.2.3 Between Transects

1. Once transect measurements are complete begin walking to the next transect location.
2. Note, waypoint, and photograph any unique habitat features or observations, including any information that will aid in producing a field sketch for the site:
 - Areas of upwelling or groundwater seeps
 - Gravel or point bars

- Ice scarring
 - Beaver dams
 - Back channels or off-channel habitats
 - Islands
 - Potential spawning areas (e.g. redds)
 - Culverts
3. Note any potential barriers to fish passage/migration observed and mark and record their waypoints. Describe the permanency of the barrier – for example, barriers like waterfalls are permanent whereas a channel may be seasonally dry. Record any applicable measurements or observations of the barrier on the field sheet. Take photos and/or videos of each potential barrier. Refer to the Glossary (Section 8) for details on barriers to fish passage.
 4. Once the next transect is reached, repeat procedures outlined in Section 6.2.2.

6.2.4 Reach Assessment

1. Once all transect cross-section measurements are taken within a reach, estimate the percent composition of streambed substrates according to the categories identified on the field sheet. Substrates categories are defined by the length of the intermediate axis (see Glossary for details).
2. Record the average degree of embeddedness of the substrate (see Glossary for details).
3. Conduct a pebble count whenever conditions are suitable. To conduct a pebble count, streams must be wadeable across the entire transect and the majority of the substrate must be of mineral origin. Pebble count tables are provided at the end of the field sheet:
 - Measure the intermediate axis of 100 randomly chosen rocks. One crew member will conduct the pebble count while the other crew member records the count measurement on the field sheet.
 - Beginning at one bank of the channel cross section, begin walking to the opposite bank, putting one foot directly in front of the other. Lean down and touch the substrate material that is nearest to the toes on your front foot without looking.
 - Pull out the material (if possible) that the tip of your finger is touching. Be careful not to bias the substrate to the largest pebble nearest to your finger rather than the one touching your finger. Do not bias the selection by avoiding larger boulder on the stream bed when walking across the stream.
 - Measure its intermediate axis in centimeters (cm). This is the diameter perpendicular to the longest axis (see Glossary for diagram). If the rock cannot be pulled out then measure it in the water. Relay the diameter (to the nearest 10th of a cm) to the other crew member. The recording crew member will record the measurement in the pebble count table on the field sheet.
 - Continue walking and measuring until 100 measurements are recorded. If the measuring crew member reaches the opposite bank before 100 measurements are taken, begin a zig-zag pattern through the stream, walking one foot in front of the other from bank to bank.
4. Estimate the amount of in-stream cover available within the entire reach. Record the percent area of the stream within the reach that each cover-type provides as potential refuge for fish. Note that overhanging vegetation must be within 1 m of the water's surface to count as cover. To assess whether pool depth provides cover, hold your boot above the bottom of the pool to what would be equivalent to residual depth of the pool. If you cannot see your boot, you can consider that area as instream cover. Add cover percentages of all cover types within the reach to obtain total instream cover.

5. For riparian areas, estimate the percentage of ground covered by trees, shrubs, grasses (includes sedges and ferns, and bare ground within 10 m from the bank's edge within the reach and record them on the field sheet. These values may add to more than 100%, as there can be different levels of vegetation covering the same area of ground.
6. Estimate the percentage of both left and right riverbanks within the reach with active erosion.
7. For the entire reach, estimate the percent stream shade and record it on the field sheet.
8. For the entire reach, identify the dominant riparian vegetation category on the field sheet (Grass, Shrub, Coniferous Forest, Deciduous Forest, Mixed Forest, Wetland, or None).
9. Finish the field sketch (aerial view) for the entire reach, using the Stream Habitat Mapping Legend as a guide. Note the locations of the transects used in the assessment. Indicate left and right banks, flow direction, orientation, significant landmarks and landscape features, barriers, channel shape and habitat types.

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8 GLOSSARY

Bankfull Level – the level of water flow in a river just before it spills over the banks into the floodplain. The bankfull level can be identified by changes in bank angle, vegetation, and soils.

Bankfull Width (i.e. channel width) - the width of the river channel at the bankfull level.

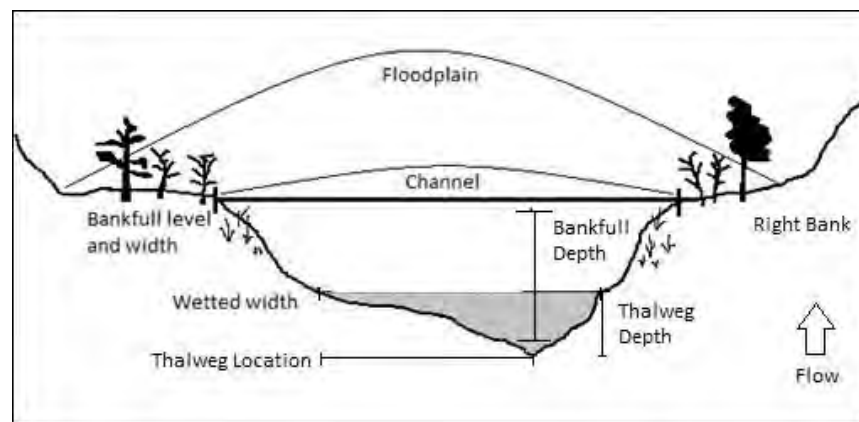


Image 1: Components of a channel cross-section

Barrier - areas or objects that may potentially be barriers to the movement of fish. Barriers can be natural (e.g. waterfalls), or man-made (e.g. culverts). Water velocity can also act as a barrier when the velocity (due to constriction or some other variable) is too great for fish to swim against. It is important to document all barriers or obstructions for each section of stream that is assessed. Record the following information for all barriers observed, when applicable:

- type of barrier
- location of barrier (waypoint)
- barrier permanency
- vertical height of the barrier (measured or estimated)
- length and width of the barrier
- slope of the barrier
- additional observations that help to describe the obstruction

Embeddedness - refers to the degree larger substrate is surrounded by finer sand and silt material that fills in spaces between the individual rocks. Highly embedded substrate limits spawning and rearing success of fish, reduces habitat for benthic macroinvertebrates, and impairs a river's ability to form a thalweg and transport material. A stain line on the rock may indicate the level of burial and aid

in the estimation. Note: Bedrock would be recorded as unembedded. Sandy or organic substrate is recorded as completely embedded because it is embedded within itself.

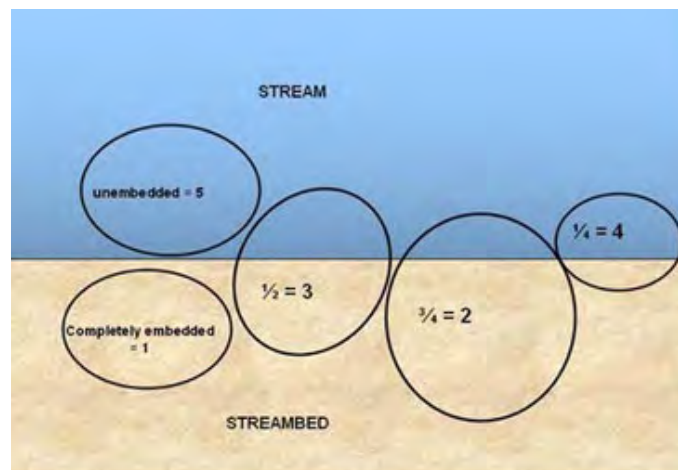


Image 2: Varying substrate embeddedness (Source: EC, 2012)

Entrenchment - the vertical containment of a stream, or the disconnection of the channel from a floodplain. A stream may also be entrenched by the use man-made berms. In streams that are highly entrenched, overbank flooding occurs less frequently than less entrenched streams. For the purposes of this SOP, entrenchment is qualitatively described in the field through a visual assessment, and is categorized as one of the following: Highly Entrenched (HE), Moderately Entrenched (ME), Slightly Entrenched (SE), or Not Entrenched (NE). “Not Entrenched” streams are typically associated with streams areas that have no defined channel (see “Habitat Types” for description).

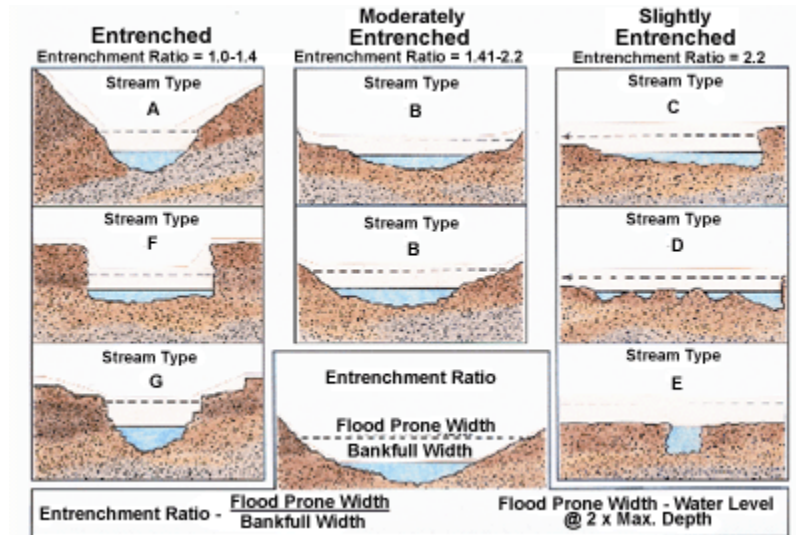


Image 3: Degrees of entrenchment (the term “entrenched” equates to “highly entrenched” for the purposes of this SOP. Source: https://cfpub.epa.gov/watertrain/moduleFrame.cfm?parent_object_id=1259)

Erosion - an area of slumping displaying a loss of bank material. Do not confuse an eroded bank with undercut bank. While eroding forces create undercut banks these banks tend to remain stable due to an established root system.

Flow Type – refers to the presence of flowing water within a stream on a temporal scale. For the purposes of this SOP, streams are categorized into the following flow types (source: AT, 2009):

- **Perennial (P)** - A stream that flows continuously throughout the year.
- **Intermittent (I)** - Streams that go dry during protracted rainless periods when percolation depletes all flow.
- **Ephemeral (E)** - A watercourse that flows during snowmelt and rainfall runoff periods only.

Any watercourse or watercourse reach may have components of each flow type. For instance, perennial, with intermittent sections.

Gradient - The slope of the stream, or rate of vertical drop per unit of length of the channel bed (presented as a percentage). The following is a simple desktop method using Google Earth to determine stream gradient. This method will not be as precise as a direct field survey but should provide a good estimate of stream gradient:

Using Google Earth, determine the elevation at the upstream extent of the stream (the beginning) and the downstream extent (the end). If you are looking for the slope of a particular section (i.e. reach) instead of the entire stream, use the boundaries of the survey section for your endpoints.

Calculate **Rise** by subtracting the elevation at the downstream extent from the elevation at the upstream extent. Determine **Run** by measuring the length of the stream using the Google Earth ruler tool.

Use the following basic formula to calculate the stream’s slope/gradient:

$$\text{SLOPE} = \frac{\text{RISE}}{\text{RUN}}$$

Habitat type - a categorical description of the types of aquatic environments within a stream. Habitat types that are commonly encountered include:

- **Riffle** - a shallow and fast section of stream with, often within a series of pools and runs. Water flow is agitated and surface is broken by rocky substrate, which appears turbulent. Substrate is coarse (gravel – cobble dominated).



Image 4: A riffle (Source:

<http://smallstreamreflections.blogspot.com/2017/05/in-riffles.html>)

- **Pool** – a deep and slow section of river, generally occurring near the corners of meanders, or created by the vertical force of water falling down over logs or boulders. Pools have a rounded bottom and may comprise the full or partial width of the stream. For the purposes of this SOP, a pool is defined as having a minimum residual depth of 20 cm.
- **Run** - an area of stream characterized by moderate current, continuous, smooth surface and depths greater than riffles. Runs are stretches of the stream, typically downstream of pools and riffles, where stream flow and current are moderate.

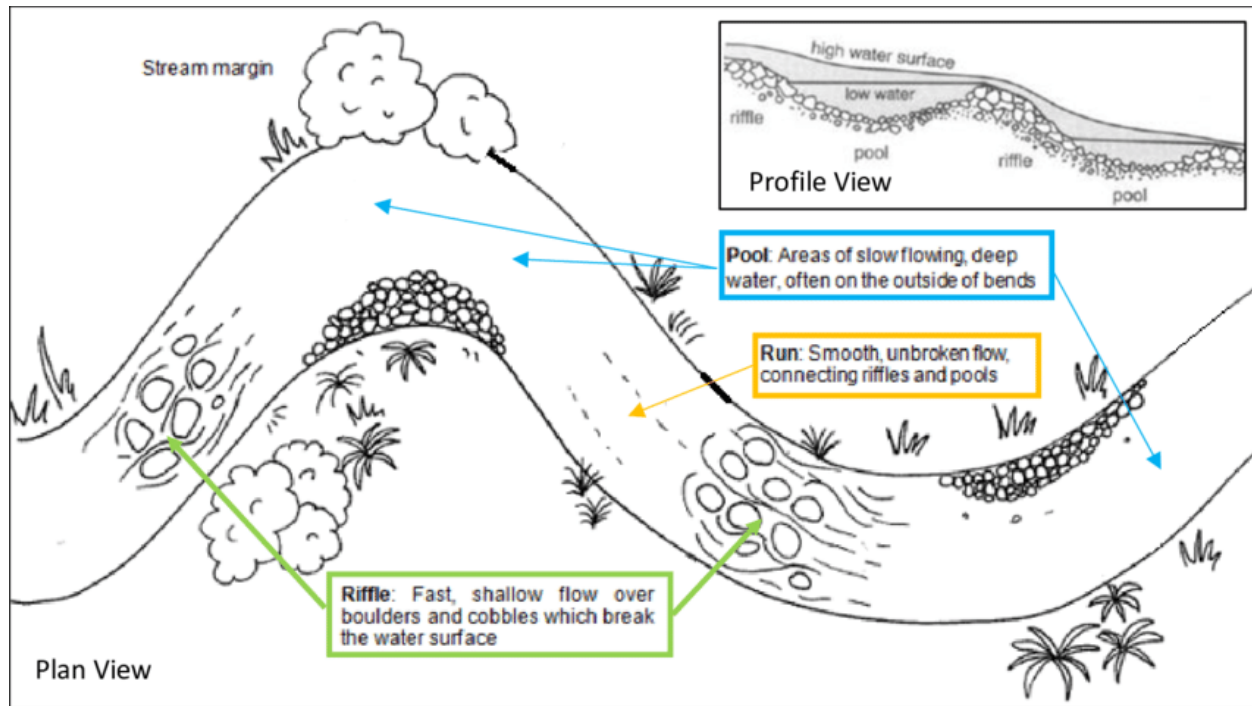


Image 5: A typically riffle-run-pool sequence within a stream (Source: https://www.researchgate.net/figure/Elements-of-a-river-reach-pool-riffle-and-run_fig13_322765638)

- **Rapids** – area of steeper gradient with irregular and rapid flows, often with turbulent white waters. Deeper than riffles, with substrate being extremely coarse (large cobble – boulder).

- **Chute/Falls/Cascade** – Significant white water present. Can be an area of channel constriction, usually due to bedrock instructions. Associated with a rapid change in stream gradient with most water free-falling over a vertical drop or series of drops.



Image 6: A cascade

- **Step-pool** – a series of staircase like pools which occur in steeper channel sections. Each pool has a defined step made of larger substrate, followed by a drop into a pool.



Image 7: Step-pool habitat (Source:

https://www.researchgate.net/figure/Artificial-step-pool-sequence-in-the-Mala-Raztoka-Brook_fig6_277075982)

- **Flat** – associated with low gradient streams, water is very smooth (flow is not obvious), and substrate often comprises organic matter, mud, and sand. Area characterized by low velocity and near-uniform flow; differentiated from pool habitat by high channel uniformity.



Image 8: A flat

- **Boulder-bed** – area characterized by a significant occurrence of large boulders as a result of glacial till deposits. Water may be visible between boulders or heard flowing subsurface



Image 9: A boulder-bed

depending on the time of year of the survey. Channel dimensions may be obscured. Boulders may be bare or have vegetation cover (typically mosses or alders).

- **No defined channel (NDC)**– typically occurring in small headwater streams, these areas are more accurately characterized as general drainage, with poorly or no defined channel banks and substrates largely comprised of organic forest soils. Water flow is diffusely spread out (i.e. sheet flow). Often associated with wetland habitat. NDCs may have diffused standing water during higher seasonal flow periods, or may be completely dry and lacking surface water of any kind, but may act as a connection between defined channels upstream and downstream.



Image 12: An area of a stream with NDC during high flow



Image 11: An area of a stream with NDC during low flow

The following table provides additional detail to aid in identification of habitat types (McCarthy, Grant, and Scruton, 2006).

Habitat Type	Habitat Parameter	Description
Fast Water	Mean Water Velocity Stream Gradient	> 0.5m/s Generally > 4%.
Rapid	General Description Mean Water Velocity Mean Water Depth Substrate Stream Gradient	Considerable white water ¹ present. > 0.5 m/s < 0.6 m Usually dominated by boulder (Coarse ²) and rubble (Medium ²) with finer substrates (Medium and Fine ²) possibly present in smaller amounts. Larger boulders typically break the surface. Generally 4-7%
Falls/ Chute/ Cascade	General Description Mean Water Velocity Mean Water Depth Substrate Stream Gradient	Mainly white water present. The dominating feature is a rapid change in stream gradient with most water free-falling over a vertical drop or series of drops. > 0.5 m/s Variable and will depend on degree of constriction of stream banks. Dominated by bedrock and/or large boulders (Coarse). > 7% and can be as high as 100%.
Run	General Description Mean Water Velocity Mean Water Depth Substrate Stream Gradient	Relatively swift flowing, laminar ³ and non-turbulent. > 0.5 m/s > 0.3 m Predominantly gravel, cobble and rubble (Medium) with some boulder (Coarse) and sand (Fine) in smaller amounts. Typically < 4% (exception to gradient rule of thumb)
Moderate Water	Mean Water Velocity Stream Gradient	0.2-0.5m/s >1 and < 4%
Riffle	General Description Mean Water Velocity Mean Water Depth Substrate Stream Gradient	Relatively shallow and characterized by a turbulent surface ⁴ with little or no white water. 0.2 – 0.5 m/s < 0.3 m Typically dominated by gravel and cobble (Medium) with some finer substrates present, such as sand (Fine). A small amount of larger substrates (Coarse) may be present, which may break the surface. ⁵ Generally >1 and < 4%
Steady/ Flat	General Description Mean Water Velocity Mean Water Depth Substrate Stream Gradient	Relatively slow-flowing, width is usually wider than stream average and generally has a flat bottom. 0.2 - 0.5 m/s >0.2 m Predominantly sand and finer substrates (Fine) with some gravel and cobble (Medium). > 1 and < 4%
Slow Water	Mean Water Velocity Stream Gradient	Generally < 0.2m/s (some eddies can be up to 0.4m/s). < 1%.
Plunge / Trench / Debris Pools	General Description Mean Water Velocity Mean Water Depth Substrate Stream Gradient	Generally caused by increased erosion near or around a larger, embedded object in the stream such as a rock or log or created by upstream water impoundment resulting from a complete, or near complete, channel blockage. These pool types may be classified as an entire reach (e.g., pools greater than 60% of the stream width) or as sub-divisions of a fast water habitat. < 0.2 m/s > 0.5 m depending on stream size (e.g., may be shallower in smaller systems). Highly variable (i.e., coarse, medium or fine substrates) Generally < 1%
Eddy	General Description Mean Water Velocity Mean Water Depth Substrate Stream Gradient	Relatively small pools caused by a combination of damming and scour; however scour is the dominant forming action. Formation is due to a partial obstruction to stream flow from boulders, roots and/or logs. Partial blockage of flow creates erosion near obstruction. It is typically < 60% of the stream width and hence will be a sub-division of a faster-water habitat type (e.g., Run with 20% eddies). Typically < 0.4 m/s, but can be variable. > 0.3 m. May vary depending on obstruction type, orientation, streambed and bank material and flows experienced. Predominantly sand, silt and organics (Fine) with some gravels (Medium) in smaller amounts. Variable

¹ White water is present when hydraulic jumps are sufficient to entrain air bubbles which disturb the water surface and reduces visibility of objects in the water.

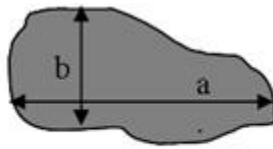
² Coarse, Medium and Fine substrate types are classified according to the Standard Methods Guide for the Classification/Quantification of Lacustrine Habitat in Newfoundland and Labrador (Bradbury *et al.* 2001).

³ Laminar describes the surface of the water as smooth and glass-like with no reduced visibility of objects in the water.

⁴ Turbulence is present if there are local patches of white water or if water movement disturbs a portion of the surface.

⁵ Pocket water often constitutes an important component of riffles in Newfoundland and Labrador and is characterized by a predominance of larger substrates (e.g., boulders) breaking the surface. The result is a riffle with many eddies around the boulders.

Intermediate Axis - the axis on which the pebble will roll down the stream.



The intermediate axis of a substrate (b).

Image 13: (Source: EC, 2012)

Instream Cover - includes large woody debris, undercut banks, unembedded large substrate, aquatic vegetation, deep pools, and overhanging vegetation within 1 m of the water's surface. These features provide valuable refuge and resting areas for fish. As the instream features become embedded by fine silt and sand, cover for fish is reduced. To be considered viable instream cover for this assessment, areas must be obscured from the surface by the cover element itself (boulder, LWD, vegetation, bank).

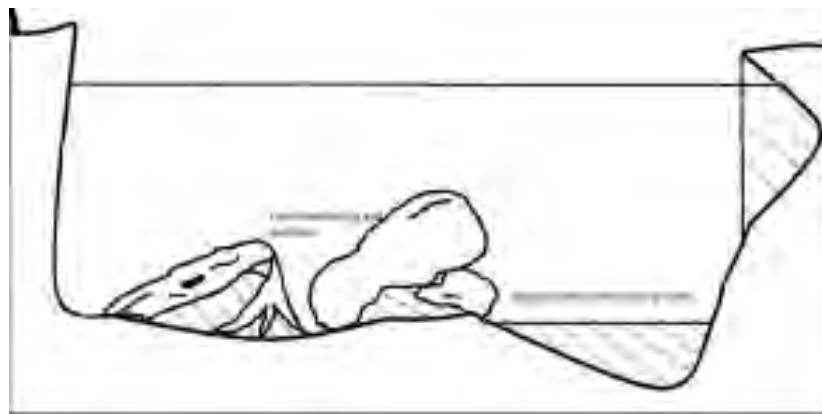


Image 14: Example of cover types within a transect (Source: NSHSI, 2018)

The following terms may be used to guide the description and identification of cover. Bolded cells indicate categories of in-stream cover, specifically.

Large Woody Debris	Fallen trees, logs and stumps, root wads, and piles of branches within or along the edges of streams.
Boulders	Large substrate under which fish can hide. Refuge for fish must be provided between the boulder and the channel bottom (i.e. a boulder that is complete embedded does not provide in-stream cover).
Undercut Banks	An undercut bank occurs when the river cuts into the bank, removing rocks and soil while leaving some portion of the bank overhanging the river. Undercut banks generally are stabilized by the presence of vegetation and roots that hold the topsoil intact.
Deep Pools	To assess whether pool depth provides cover, hold your boot above the bottom of the pool to what would be equivalent to residual depth of the pool. If you cannot see your boot, you can consider that area as instream cover.

Overhanging vegetation	Riparian cover overhanging the stream. Note: overhanging over must be within 1 m of the water's surface to count towards in-stream cover.
Emergent vegetation	Aquatic plants growing above or extending above the water surface (e.g. cattails, sedges, grasses, rushes)
Submergent vegetation	Aquatic plants that grow entirely below the water surface (e.g., elodea, bladderwort, pipewort, potamogeton), and includes numerous mosses and macroalgae)

Riparian Area – strip of land adjacent to watercourses which plays an important role in stream productivity and overall function. For the purposes of this SOP, the riparian area is considered all ground within 10 m from the bank's edge.

Redd – salmonid spawning nests. Characterized as circular to oblong patches of recently cleaned, gravel-cobble-sized substrate that contrasts the surrounding substrate. Redds typically have a depression from the surrounding substrate and may have a 'mound' on the downstream end of the disturbance. If identified, redds would be measured, photographed and their location recorded on GPS.

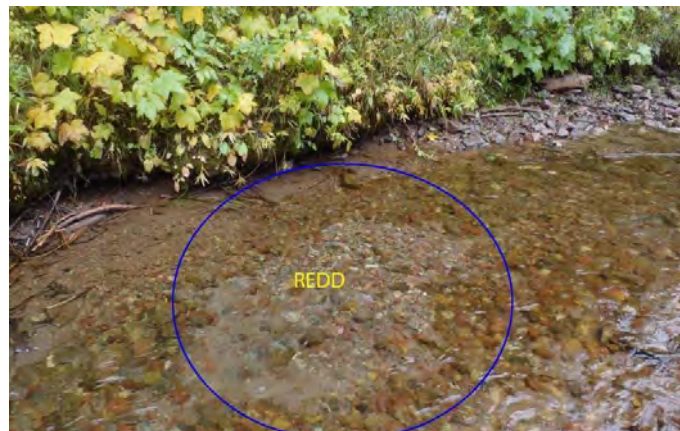


Image 15: A salmonid redd (Source: <https://www.tu.org/blog/redd-surveys-shaping-priorities-in-michigans-pere-marquette/>)

Stream Order - the hierarchical ordering of streams based on the degree of branching. It is a simple quantitative method to categorize stream segments based on their relative position within the drainage basin. Stream order provides a general indication of stream size, stream function and energy sources. Determine the stream order by labeling the first stream at the head of the watershed as 1 and increasing the order by 1 each time two streams of the same order join until you reach the watercourse/watercourse reach being assessed.

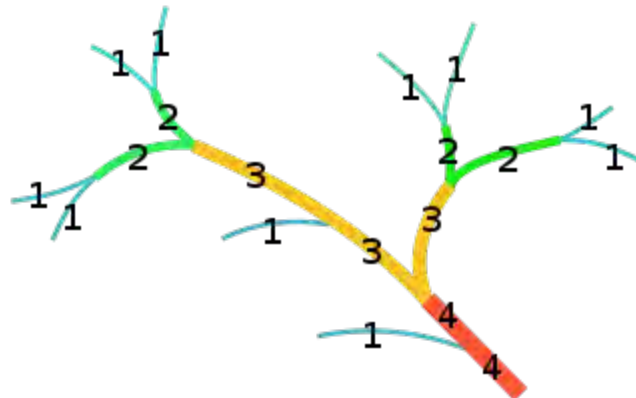


Image 16: Example of stream order classifications (based on Strahler, 1957).

Stream Shade – this is the canopy cover created by riparian vegetation above the stream. Midday sun is the most direct and influential on stream temperatures, so shade estimates should be made between 10:00 am and 2:00 pm, when possible.

Substrate Types – The following table may be used to aid in identification of substrate types (from DFO 2012).

Bedrock	Continuous solid rock exposed by the scouring forces of the river/stream
Boulder	Rocks ranging from 25cm to >1 m in diameter
Rubble	Rocks ranging from 14-25 cm in diameter
Cobble	Rocks ranging from 3-13 cm in diameter
Gravel	Small stones ranging from 2mm to 3 cm in diameter
Sand	Grains ranging from 0.06 to 2 mm in diameter, frequently found along stream margins or between rocks and stones.
Silt	Very fine sediment particles, usually <0.06 mm in diameter
Muck/detritus	Organic material from dead organisms (plant and/or animal)
Clay/mud	Find deposits between rocks and covering other substrates

Transect - A line across a stream perpendicular to the flow and along which measurements are taken, so that morphological and flow characteristics along the line are described from bank to bank. For the purposes of this SOP, “transect” and “cross section” are used interchangeably.

Watercourse - Any provincially regulated watercourse as defined by NSE guidance (2015).

Watercourse Name - The official name of the stream being surveyed as referenced on provincial topographic maps. If no official name exists, enter “unnamed”.

Watercourse Reach - A length of stream characterized by a single habitat type (e.g. a run). Complex streams will comprise many reaches. In smaller, first-order streams, major habitat types may be so short as to not warrant the continuous establishment of very small reaches. When individual habitat types are small in overall length (<5 m), they may be lumped together into one reach.

Wetted Width – the width of the stream that contains water at the time of the assessment.

Turbidity - The concentration of suspended sediments and particulate matter in the water. Measure of the relative clarity of a liquid. If not measured, turbidity is to be visually assessed and recorded based on the following codes:

- T (Turbid) - very turbid or muddy appearance, objects visible to 15 cm depth
- M (Moderately Turbid) - cloudy, objects visible to 45 cm depth
- L (Lightly Turbid) - occasionally cloudy, objects visible to 1 m
- C (Clear)

APPENDIX A
Detailed Fish Habitat Assessment – Streams

Detailed Fish Habitat Assessment - Streams

General Survey Data			
Project:	Project #:	Date:	Surveyors:
Watercourse Name:	Watercourse #:	Reach #:	Stream Order:
Weather (°C, cloud %, precipitation):			
Reach Boundary Coordinates: U/S _____ D/S _____			
Photos: Transects <input type="checkbox"/> Barriers <input type="checkbox"/> Other Features (_____)			
Reach Characteristics			
Reach Length (m):	Gradient* (%):	Entrenchment: HE <input type="checkbox"/> ME <input type="checkbox"/> SE <input type="checkbox"/> NE <input type="checkbox"/>	
Flow Type*: P <input type="checkbox"/> I <input type="checkbox"/> E <input type="checkbox"/>	Does reach include other habitat types (< 5 m in length)? <input type="checkbox"/>		
Habitat Type:	If applicable, check all habitat types included in reach: Riffle <input type="checkbox"/> Run <input type="checkbox"/> Flat <input type="checkbox"/> Pool <input type="checkbox"/> Cascade <input type="checkbox"/> Step <input type="checkbox"/> Other <input type="checkbox"/> (_____)		
Water Quality			
Temperature (°C):	pH:	Dissolved Oxygen (mg/L):	
Conductivity:	TDS:	Turbidity (T, M, L, C, or NTU):	

Substrate	
% Bedrock	
% Boulder (>25 cm)	
% Rubble (14-25 cm)	
% Cobble (3-13 cm)	
% Gravel (0.2-3 cm)	
% Sand (0.06-2 mm)	
% Silt (<0.006 mm)	
% Muck/Detritus	
% Clay/Mud	
Embeddedness (%)	
Pebble Count?	<input type="checkbox"/>

Cover	
% Large Woody Debris	
% Boulders	
% Undercut Banks	
% Deep Pools	
% Overhanging Veg	
% Emergent Veg	
% Submergent Veg	
Total Cover (%)	

*P: perennial, I: Intermittent, E: Ephemeral

*Note methodology (clinometer, estimate, desktop).

Categories for estimates: <1% (flat), 1-4% (riffle/run), 4-7% (rapids), >7% (step-pool, cascade, falls)

Banks and Riparian Area (Right and Left Banks are looking downstream)							
Bank	% Trees	% Shrubs	% Grass	% Bare	% Eroding	% Shade	Dominant Riparian Veg.
Left Bank							Grass <input type="checkbox"/> Shrub <input type="checkbox"/> Coniferous Forest <input type="checkbox"/> Deciduous Forest <input type="checkbox"/> Mixed-wood Forest <input type="checkbox"/> Wetland <input type="checkbox"/> None <input type="checkbox"/>
Right Bank							

Barriers		
Types (circle all present): No visible channel Underground flow Velocity Beaver Dam Dry Falls Culvert Other (_____)	Locations and Comments (waypoint, height, width, slope of barrier and depth of plunge pool. Note any hydrological indicators if no visible channel or underground flow are circled):	Permanency: Permanent <input type="checkbox"/> Temporary/Seasonal <input type="checkbox"/> Undetermined <input type="checkbox"/> Manmade <input type="checkbox"/> Date Observed:

Date:

Location:

Assessor:

Detailed Fish Habitat Assessment - Streams

Note: Transect measurements are to be taken every **50 m** of a single habitat type (i.e. reach). If minor habitat types (<5 m) have been lumped into the overall reach, take representative transect measurements at each habitat type present. See diagram under "field sketch" for reference.

Transect Information									
Transect #:			Easting:				Northing:		
Habitat Type:			Wetted Width (m):				Bankfull Width (m):		
Cross-Section Measurements (all measurements in m, taken in increments from max bank out to wetted edge)									
Left Bank	Distance:								
	Height:								
Right Bank	Distance:								
	Height:								
Velocities (taken from left bank to right bank – left and right banks are looking downstream)									
Distance (m):									
Depth (m):									
Velocity (m/s):									
Substrate Obs:									
Photos: Downstream <input type="checkbox"/> Upstream <input type="checkbox"/> Left Bank <input type="checkbox"/> Right Bank <input type="checkbox"/> Substrate									

Transect Information									
Transect #:			Easting:				Northing:		
Habitat Type:			Wetted Width (m):				Bankfull Width (m):		
Cross-Section Measurements (all measurements in m, taken in increments from max bank out to wetted edge)									
Left Bank	Distance:								
	Height:								
Right Bank	Distance:								
	Height:								
Velocities (taken from left bank to right bank – left and right banks are looking downstream)									
Distance (m):									
Depth (m):									
Velocity (m/s):									
Substrate Obs:									
Photos: Downstream <input type="checkbox"/> Upstream <input type="checkbox"/> Left Bank <input type="checkbox"/> Right Bank <input type="checkbox"/> Substrate									

Transect Information									
Transect #:			Easting:				Northing:		
Habitat Type:			Wetted Width (m):				Bankfull Width (m):		
Cross-Section Measurements (all measurements in m, taken in increments from max bank out to wetted edge)									
Left Bank	Distance:								
	Height:								
Right Bank	Distance:								
	Height:								
Velocities (taken from left bank to right bank – left and right banks are looking downstream)									
Distance (m):									
Depth (m):									
Velocity (m/s):									
Substrate Obs:									
Photos: Downstream <input type="checkbox"/> Upstream <input type="checkbox"/> Left Bank <input type="checkbox"/> Right Bank <input type="checkbox"/> Substrate									

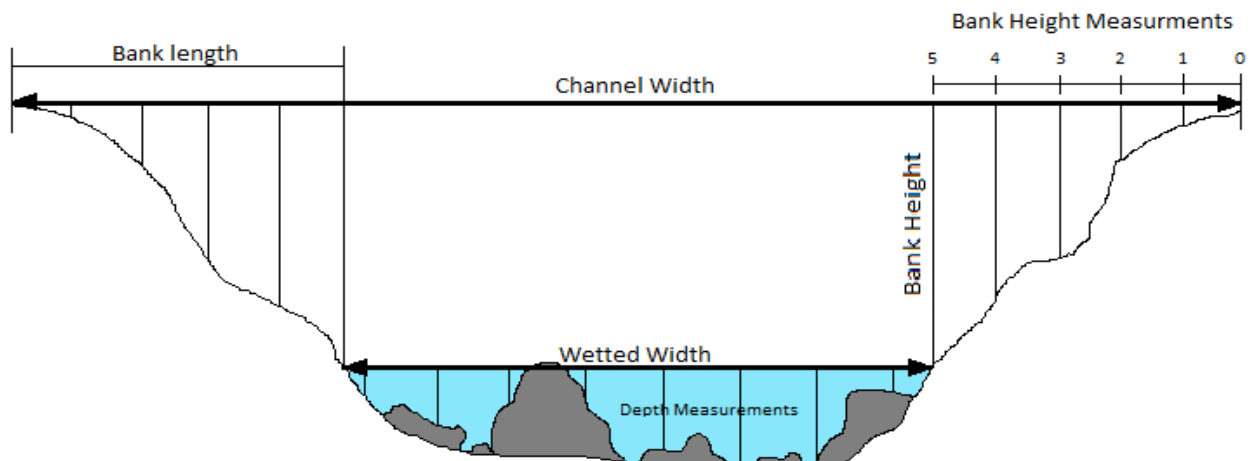
Date:

Location:

Assessor:

Detailed Fish Habitat Assessment - Streams

Field Sketch



Date:

Location:

Assessor:

Detailed Fish Habitat Assessment - Streams

Pebble Count: Transect # ____ . Record intermediate axis in cm.

Pebble Count: Transect # ____ . Record intermediate axis in cm.

Pebble Count: Transect # ____ . Record intermediate axis in cm.

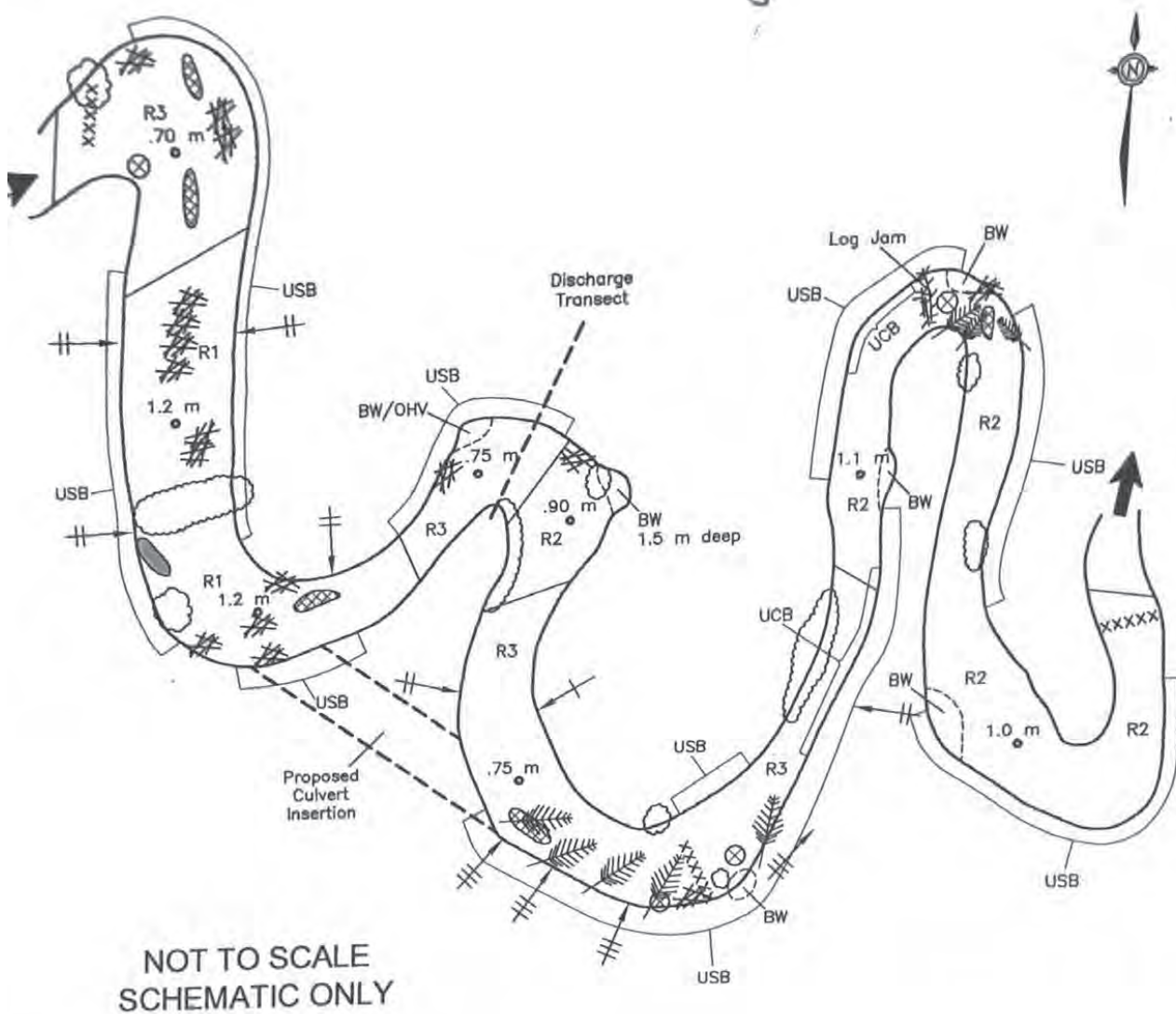
Pebble Count: Transect # ____ . Record intermediate axis in cm.

Date:

Location:

Assessor:

APPENDIX B
Example Stream Habitat Mapping Legend



LEGEND - STREAM HABITAT MAPPING SYSTEM

Channel Unit/Habitat Type:

- FA Falls; Very Swift, Vertical Drop; Impossible to Fish
- CA Cascade; Very Swift, Turbulent; Passable to Fish
- CH Chute; Channel Restricted, Swift, Moderate Depth
- RA Rapids; Very Swift, Deep, With Cover
- RF Riffle; Swift, Shallow, Turbulent
- R1 Class 1 Run; Moderately Swift, Deep With Cover
- R2 Class 2 Run; Moderately Swift, Moderate Depth and Cover
- R3 Class 3 Run; Moderately Swift, Shallow, Limited Cover
- FL Flat, Slow, Laminar Flow, Depositional

- P1 Class 1 Pool; Slow, Deep
- P2 Class 2 Pool; Slow, Moderate Depth
- P3 Class 3 Pool; Slow, Shallow
- IP Impoundment Pool; Pool Formed by Dam

- BW Backwater; Slow, Reverse Flow
- BG Boulder Garden
- SN Snye; Isolated Area of Zero Velocity
- 1.5 m Indicates Channel Unit Depth
- | Channel Unit Divider

Substrate Particle Size:

- Si Silt (<0.06mm)
- Sa Sand (0.06 - 2mm)
- Gr Gravel (2-64mm)
- Co Cobble (64-256mm)
- Bo Boulder (>256mm)
- Bd Bedrock

Shore and Bottom Slope:

- Flat (Shallow slope)
- ↔ Repose (moderate, stable slope)
- ↗ Steep Slope
- ↖ Vertical

Habitat Feature:

- Sand/Mud Bar
- ⊗ Gravel Bar
- ⊗ Island
- ⊗ Woody Debris Pile
- ⊗ Root Wad
- UCB Undercut Bank (fish cover)
- USB Unstable Bank (slumping or eroding)
- OHC High Quality Overhead Cover
- ISC High Quality Instream Cover
- LE Ledge; Bedrock Intrusion, Vertical Drop
- ⊗ Overhanging Vegetation (Tree)
- Overhanging Vegetation (Shrub)
- ⊗ Overhanging Vegetation (Grass)
- ⊗ Inundated Vegetation
- SV Submergent Vegetation
- EV Emergent Vegetation
- TV Terrestrial Vegetation
- BA Bare-no vegetation
- SH Shrubs
- GF Grass/Forbs
- DF Deciduous Forest
- CF Coniferous Forest
- MW Mixed Wood Forest
- MT Minnow Trap
- BL Beaver Lodge
- XX Beaver Dam
- ➔ Direction of Flow
- ⊙⁺ Benchmark

Appendix F

Fish Capture Data

Sporting Mountain: Fish and Fish Habitat Data

Watercourse 1

Table 1: Electrofishing data concerning the recorded operational and environmental standards throughout WC1

Reach #*	Method Used (CPUE or Depletion)	Effort (seconds)	Voltage	Frequency	Water Temperature	Air Temperature	Water Visibility	Waypoint Coordinates	
								Upstream	Downstream
Reach 1	CPUE	642.1	350	80	13.9	20	Poor	657726/ 5062753	657654/ 5062604
Reach 2	CPUE	721.2	350	80	14.7	25	Fair	657654/ 5062604	657662/ 5062501
Reach 3	CPUE	663.7	350	80	15.3	25	Poor	657662/ 5062443	657583/ 5062501

*Electrofishing reach areas do not correspond with detailed habitat assessment reaches. Refer to Figure 2 (Appendix A) for locations of detailed habitat assessment reaches.

Table 2. Biological data regarding fish sampled within WC1

Reach #	Capture Method	Species Code	Fork Length (mm)	Total Length (mm)	Weight (g)	Age/Age Class
Reach 1	EF1	BKT	125	135	17.59	Adult
	EF1	BKT	115	120	15.95	Parr
	EF1	BKT	93	100	10.75	Parr
	EF1	BKT	105	110	12.91	Parr
	EF1	EEL	-	120	3.17	Juvenile
Reach 2	EF2	BKT	103	108	12.36	Parr
Reach 3	EF3	BKT	158	165	39.31	Adult
	EF3	BKT	108	112	17.92	Parr
	EF3	BKT	79	83	5.97	Parr

Sporting Mountain: Fish and Fish Habitat Data

Watercourse 2

Table 3. Electrofishing data concerning the recorded operational and environmental standards throughout WC2

Reach #	Method Used (CPUE or Depletion)	Effort (seconds)	Voltage	Frequency	Water Temperature	Air Temperature	Water Visibility	Waypoint Coordinates	
								Upstream	Downstream
Reach 1	CPUE	642.1	350	80	13.9	20	Poor	657969/ 5062931	658001/ 5062829

Table 4. Biological data regarding fish sampled within WC2 (no fish captured)

Reach #	Capture Method	Species Code	Fork Length (mm)	Total Length (mm)	Weight (g)	Age/Age Class
Reach 1	EF1	-	-	-	-	-

Appendix G

Photo Log

Sporting Mountain: Fish and Fish Habitat Photograph Log



Photo 1: WC 1 Reach 1 Transect 1



Photo 2: WC 1 Reach 1 Transect 1



Photo 3: WC 1 Reach 1 Transect 2



Photo 4: WC 1 Reach 1 Transect 2

Sporting Mountain: Fish and Fish Habitat Photograph Log



Photo 5: WC 1 Reach 1 Transect 3



Photo 6: WC 1 Reach 1 electrofishing location.



Photo 7: WC 1 Reach 1 Upstream



Photo 8: WC 1 Reach 1 Upstream

Sporting Mountain: Fish and Fish Habitat Photograph Log



Photo 9: WC 1 Reach 2 Transect 1



Photo 10: WC 1 Reach 2 Transect 1

Sporting Mountain: Fish and Fish Habitat Photograph Log



Photo 11: WC 1 Reach 2 Transect 2



Photo 12: WC 1 Reach 2 Transect 2



Photo 13: WC 1 Reach 2 Transect 3



Photo 14: WC 1 Reach 2 Transect 3

Sporting Mountain: Fish and Fish Habitat Photograph Log



Photo 15: WC 1 Reach 2 Transect 4



Photo 16: WC 1 Reach 2 Transect 4



Photo 17: WC 1 Reach 2 Transect 5



Photo 18: WC 1 Reach 2 Transect 5

Sporting Mountain: Fish and Fish Habitat Photograph Log



Photo 19: WC 1 Reach 2 Upstream



Photo 20: WC 1 Reach 2 Upstream



Photo 21: WC 1 Reach 3 Transect 1. End of WC 1



Photo 22: WC 1 Reach 3 Transect 1. End of WC 1

Sporting Mountain: Fish and Fish Habitat Photograph Log



Photo 23: WC 1 Inaccessible area



Photo 24: WC 1 Inaccessible area



Photo 25: WC 2 Start



Photo 26: WC 2 Start

Sporting Mountain: Fish and Fish Habitat Photograph Log



Photo 27: WC 2 Reach 1 Transect 1



Photo 28: WC 2 Reach 1 Transect 1



Photo 29: WC 2 Reach 1 Transect 2



Photo 30: WC 2 Reach 1 Transect 2

Sporting Mountain: Fish and Fish Habitat Photograph Log



Photo 31: WC 2 Reach 1 Transect 3



Photo 32: WC 2 Reach 1 Transect 3



Photo 33: End of study area



Photo 34: End of study area

Sporting Mountain: Fish and Fish Habitat Photograph Log

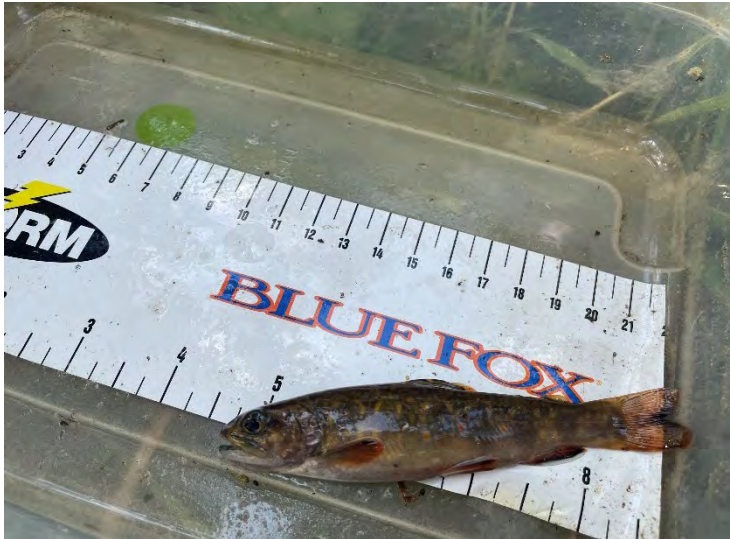


Photo 35: WC1 Brook Trout



Photo 36: WC1 American Eel

Appendix H

Canada Lynx Management Plan

CANADA LYNX MONITORING PLAN

Sporting Mountain Quarry Expansion Project Version 2.0

PREPARED FOR

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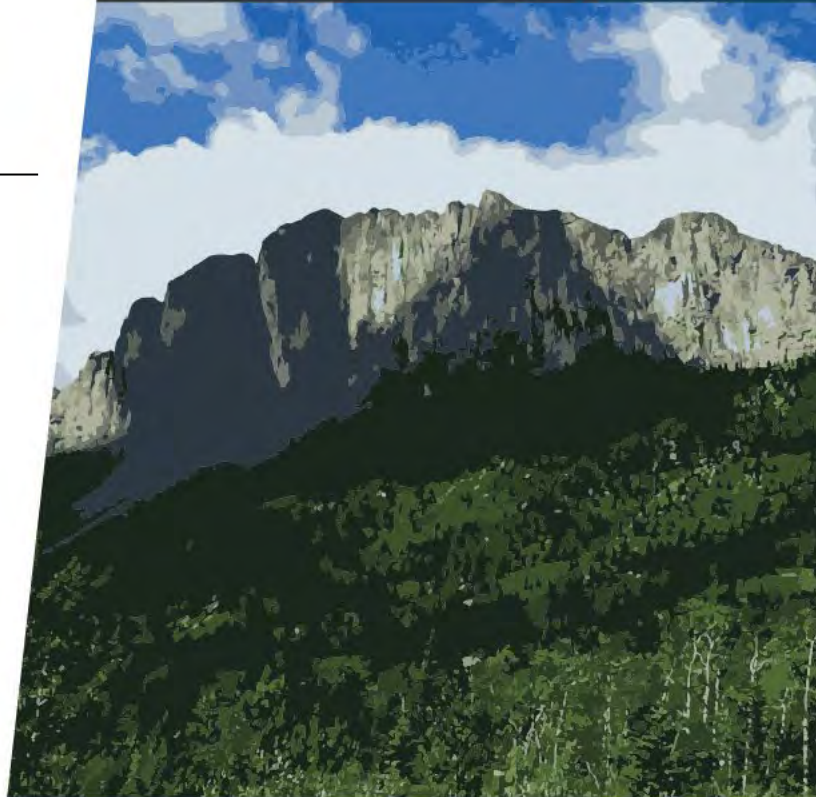
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August 22, 2022



McCallum Environmental Ltd.





SPORTING MOUNTAIN QUARRY

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1 INTRODUCTION

Nova Construction Co. Ltd. (Nova) is proposing to expand the existing Sporting Mountain Quarry, located in Seaview, Nova Scotia (Figure 1; Appendix A). The Project was registered for an Environmental Assessment (EA) as a Class I undertaking under Section 9(1) of the Regulations. On August 25, 2020, the Minister determined that the Environmental Assessment Registration Document (EARD) was insufficient and additional information was required.

McCallum Environmental Ltd. (MEL) has been retained by Nova to develop a Canada Lynx Monitoring Plan (CLMP) to monitor the site for Canada lynx use per additional information request 2.f:

Project specific avoidance and mitigation measures for blue-felt lichen, frosted glasswhiskers, and other species at risk and their critical habitat including follow-up monitoring programs.

The intent of this CLMP is to provide a general overview of proposed Canada lynx monitoring methods as well as proposed mitigation and adaptive management strategies. This CLMP is a living document and Nova Scotia Department of Natural Resources and Renewables (NSDNRR) will be consulted for feedback and recommendations on the proposed methods. NSDNRR provided comments on the CLMP on August 22, 2022. These comments are integrated into this plan (Version 2.0).

1.1 Objectives and Scope

The objectives of the CLMP is to assess potential Canada lynx activity within the revised expansion area and land adjacent the Project.

The CLMP provides:

1. Provide an overview of the monitoring program, including data collection, proposed methodologies, timelines, and reporting.
2. Present mitigations and adaptive management strategies should Project-related impacts be observed during the monitoring program.

2 CANADA LYNX

Canada lynx (*Lynx canadensis*) are listed as endangered under the Nova Scotia Endangered Species Act (NSESA) and as S2S3 by the Atlantic Canada Conservation Data Center (ACDC). Small populations of Canada lynx are present in localized occurrences within the highlands of Cape Breton Island (NSDNR, 2012). The primary prey species and alternate prey species of Canada lynx are snowshoe hare (*Lepus americanus*) and American red squirrel (*Tamiasciurus hudsonicus*).

A Canada lynx buffer Special Management Practice (SMP) zone are present within the EA Study Area surrounding wetland 2 (WL2; Figure 2, Appendix A). Canada lynx buffer SMP zones are part of a provincial recovery effort where 100 m is applied to all undisturbed, forested bogs (NSDNR, 2012). Open



bogs are reliable producers of cones, the significant food source for American red squirrels, as such, protecting the habitat of red squirrels protects this Canada lynx food source (NSDNR, 2012).

3 PROJECT BACKGROUND

MEL completed the biophysical surveys to prepare an EARD for the proposed Project. During the assessments, completed in 2019, MEL observed confirmed and potential evidence (both scat and tracks) of Canada lynx within and beyond the Study Area.

The original expansion area (EARD) was proposed to encroach on the Canada lynx buffer SMP. Comments made by NSDNR staff as part of the 2019 EA review indicated that “the Department recommends that the quarry expansion boundaries not extend past the previous clear-cut boundaries in order to maintain the integrity, hydrology, and function of the delineated Wetland 2 for species at-risk, such as the Canada Lynx, Canada Warbler, and Blue Felt Lichen; and to maintain the integrity of the unimpacted portion of the Department’s identified Lynx buffer”. Nova developed a revised expansion area (area reduced by 12.7%) to avoid the intact habitat within the lynx buffer and restrict quarry expansion to the clear-cut habitat within the buffer (Figure 2; Appendix A). Mark McGarrigle (NSDNR SAR Biologist) and Elizabeth Walsh (NSDNR Regional Biologist) indicated during a meeting on May 21, 2021, that they are comfortable with layout of the revised expansion area.

4 CANADA LYNX MONITORING

The following subsections outline the proposed Canada lynx monitoring methods. Snow tracking surveys are proposed along six transects.

4.1 Transect Details

MEL generated a habitat model to determine areas with greater habitat potential for Canada lynx prey (i.e., snowshoe hare and American red squirrel), which is preferably dense immature forests comprising of spruce and balsam fir (Orr and Dodds, 1982). Immature coniferous stands between 10-35 years and above winter snow levels are identified by NSDNR (2012) as being important for supporting Canada lynx prey species (Table 1).

Table 1. Canada Lynx Prey Habitat Requirements (NSDNR, 2012)

Prey Species	Habitat Requirements
Snowshoe hare	Patches of mid-regeneration (15-35 years old) conifer dominated habitat
	Tree height above winter snow levels
Red squirrel	Bogs
	Adjacent mature/overmature softwood and mixedwood stands
	100 m buffer strip of unharvested forest

Based on the desktop review of forest cover type, six 1-km transects were placed within and surrounding the revised expansion area (Figure 2, Appendix A). Transects that are situated beyond the EA Study Area



are located on crown land. No transects are proposed immediately south or east of the Study Area because all of this land is privately owned.

Table 2. Canada Lynx Transect Details

Transect ID	Transect Length (m)	Within Revised Expansion Area (Y/N) ¹	Within Canada Lynx Range (Y/N)	Within Canada Lynx SMP Buffer Zone (Y/N)	Within MEL Generated Lynx Prey Habitat Model (Y/N)	Transect Description
T1	984	Y	Y	Y	N	Portions of T1 exist within the revised expansion area and WL2.
T2	1,006	N	Y	Partial	Y	Extends north of the EA Study Area in crown land.
T3	1,000	N	Y	Y	Y	Existing trail where potential Canada lynx sign was identified in 2019.
T4	929	N	Y	Partial	Y	Crown land northwest of the EA Study Area
T5	982	N	Y	Y	Y	Crown land west of the EA Study Area
T6	1,018	N	Y	Partial	Y	Portion of T6 exists within WL2, the majority of transect is on crown land, west of the EA Study Area
T7	720	Y	Y	N	Y	Access road to quarry, existing quarry and expansion area.

¹ Transect will be relocated when quarry expands into route of current transect

All transects exist within Canada lynx range, all exist within Canada lynx SMP buffer zones (except T7), and all transects except T1 intersect polygons associated with the MEL generated Canada lynx prey habitat model.

4.2 Survey Methods

Snow tracking surveys will be completed on foot by an observer experienced in the recognition of wildlife tracks and scat. Transect selection will be adjusted in the field, based on safety, accessibility, habitat, and conditions. Once the first survey is complete, the same set of transects will be used for any future rounds, unless safety and access dictate a change in transects.

Snow tracking surveys will occur in snow conditions suitable for tracking; within 48 hours + following a >10 cm snowfall, as long as there are no additional precipitation events or high winds in the intervening days. Surveys should not be conducted during periods of rain, snowfall, or blowing snow. MEL will use local weather forecasts, highway cameras, and direct observations of tracking conditions from on-site



personnel (if available) prior to mobilizing, to ensure appropriate tracking conditions are present. MEL will clearly document weather conditions prior to, and during each survey; and surveys will be cancelled if tracking conditions degrade partway through a survey.

During all targeted Canada lynx surveys, all wildlife sightings, tracks, and scat will be recorded. If Canada lynx observations or potential lynx evidence is identified, the scat or tracks will be georeferenced, photographed (with a scale) and the surrounding habitat will be described. The following literature will be referenced to confirm Canada lynx sign:

- Mammal Tracks & Sign – A Guide to North American Species (Elbroch M. , 2003); and,
- Tracking & the Art of Seeing: How to Read Animal Tracks and Sign. 2nd ed (Rezendes, 1999).

No Species at Risk permit is necessary, as survey methods do not require MEL to harm, harass or approach Canada lynx.

4.3 Survey Frequency and Timing

One baseline Canada lynx survey will be completed in the winter of 2022/2023, prior to quarry expansion. Future monitoring includes **one survey every two years during active quarry development.** If no active quarrying occurs in a year scheduled for monitoring, monitoring will be delayed until the next year where quarry expansion is active.

Monitoring will be completed for the entire life of the quarry expansion.

4.4 Reporting

An annual report will be submitted to NSDNRR, in years that monitoring is completed, which summarizes the methods and results of the monitoring. Depending on the findings, adaptive management or additional mitigation measures may be implemented.

5 MITIGATION AND ADAPTIVE MANAGEMENT

Efforts have been made to avoid intact portions of the Canada lynx SMP buffer via revising the expansion area. Mark McGarrigle (NSDNRR SAR Biologist) and Elizabeth Walsh (NSDNRR Regional Biologist) indicated during a meeting on May 21, 2021, that they are comfortable with layout of the revised expansion area.

The results of the monitoring plan will aid in supplementing, where necessary, the mitigation commitments outlined in the EARD. Findings from the monitoring will be evaluated to support adaptive management approaches, if required. Adaptive management strategies may include additional monitoring. Findings will also inform potential quarry development activities and mitigations.



6 LIMITATIONS

All efforts will be taken to survey during the aforementioned conditions, however, alternative survey methods may be required if winter conditions do not allow for the desired snowfalls. Priorities will always be to survey where and when it is deemed safe with the best possible opportunities to observe Canada lynx and winter wildlife tracks. This may mean that surveys may take place after a snowfall <10 cm.

This plan is proposed to monitor and mitigate Project related effects to Canada lynx. However, it is important to acknowledge other non-Project related activities may also impact Canada lynx (e.g., forestry activity). Nova cannot control impacts from activities unrelated to the Project.

7 CLOSURE

This plan has been prepared with the intent to share with NSDNRR for input and feedback on proposed objectives and methodologies.

Please do not hesitate to contact the undersigned with any questions you may have.

Jeff Bonazza, M.Env.Sci.
Project Manager
McCallum Environmental Ltd.



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APPENDIX A. FIGURES

Prepared For:

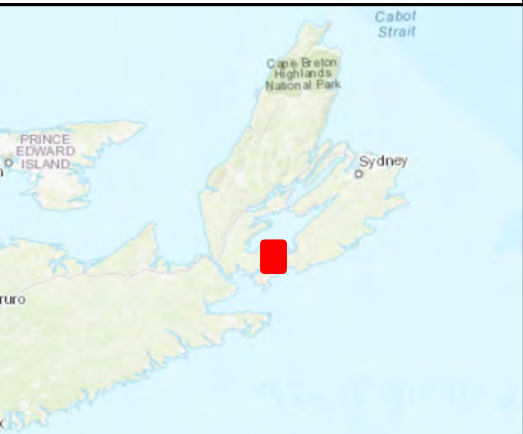


FIGURE 2

Canada Lynx Monitoring Plan
Transect Locations

Sporting Mountain
Quarry Expansion Project

- Study Area
- Revised Expansion Area
- Canada Lynx Monitoring Transect
- Canada Lynx Prey Predicted Habitat (MEL)
- Canada Lynx Buffer
- Crown Land
- Field Delineated Wetland
- Field Delineated Watercourse



Coordinate System: NAD 1983 CSRS UTM Zone 20N
Projection: Transverse Mercator
Datum: North American 1983 CSRS
Units: Meter



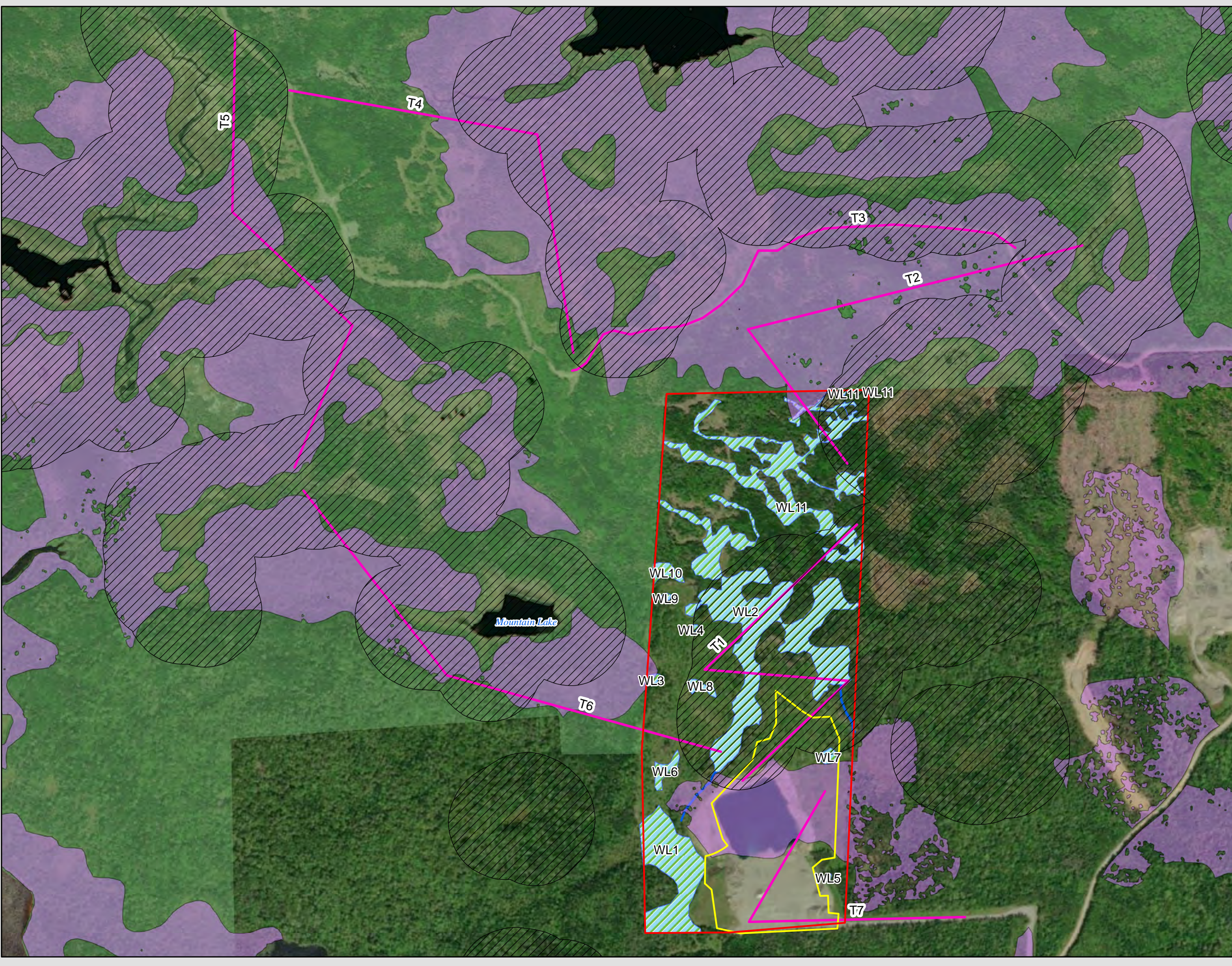
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Drawn By: MD
Reviewed By: JB
Date: 2022-08-22



McCallum Environmental Ltd.



Appendix I

Lichen Management Plan

LICHEN MANAGEMENT PLAN
Version 2.0

Sporting Mountain Quarry
Expansion Project

PREPARED FOR

Nova Construction Co. Ltd.
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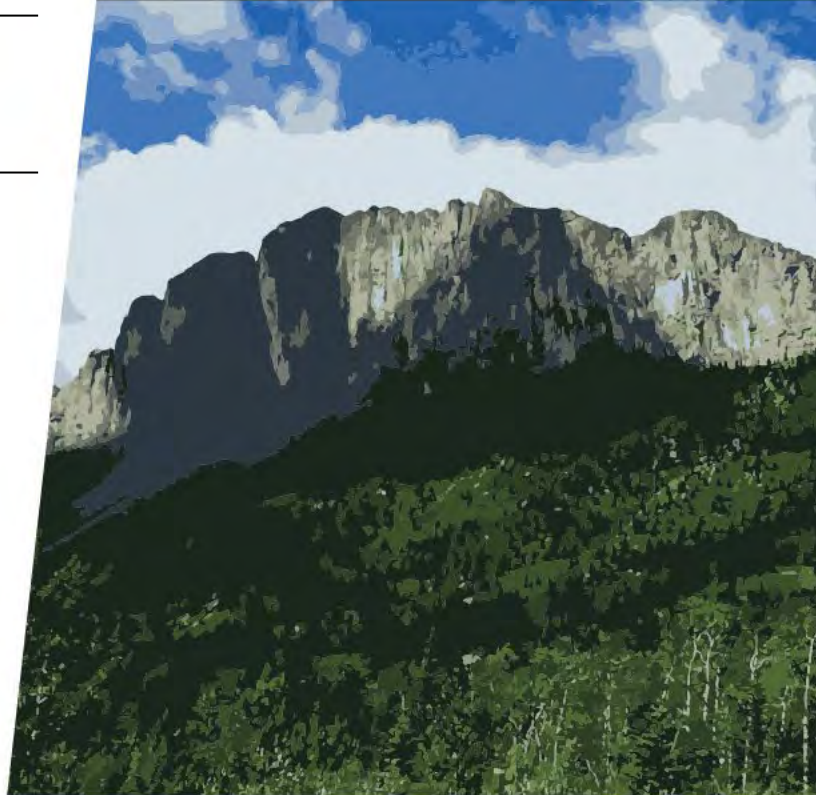
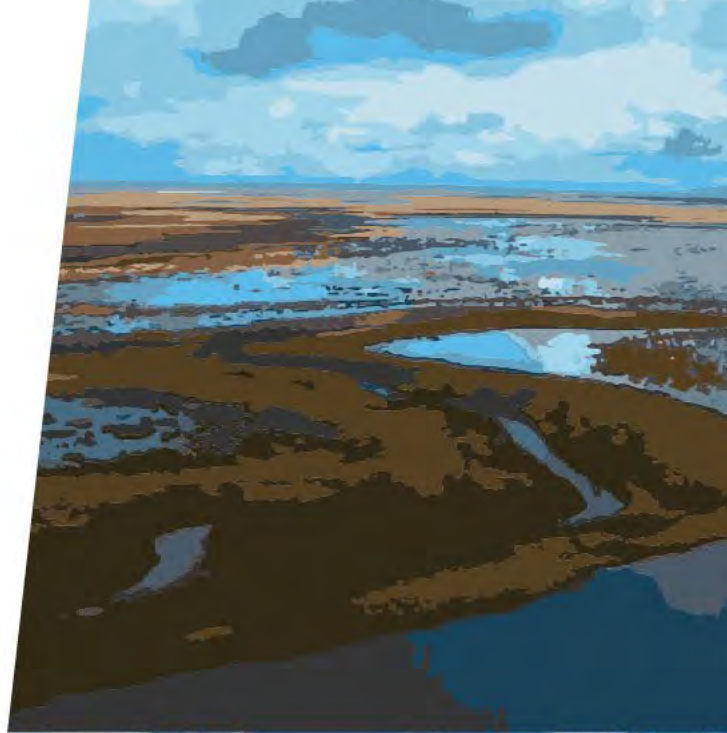
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August 11, 2022



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SPORTING MOUNTAIN QUARRY

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1 INTRODUCTION

Nova Construction Co. Ltd. (Nova) is proposing to expand the existing Sporting Mountain Quarry, located in Seaview, Nova Scotia (Figure 1; Appendix A). The Project was registered for an Environmental Assessment (EA) as a Class I undertaking under Section 9(1) of the Regulations. On August 25, 2020, the Minister determined that the Environmental Assessment Registration Document (EARD) was insufficient and additional information was required.

McCallum Environmental Ltd. (MEL) has been retained by Nova to develop a Lichen Management Plan (LMP) to mitigate effects to Species at Risk (SAR) lichens and to monitor the health of potentially indirectly impacted SAR lichen observations, per additional information request 2.f:

Project specific avoidance and mitigation measures for blue-felt lichen, frosted glasswhiskers, and other species at risk and their critical habitat including follow-up monitoring programs.

The intent of this LMP is to provide a general overview of proposed lichen monitoring methods as well as proposed mitigation and adaptive management strategies. This LMP is a living document and it was shared with the Nova Scotia Department of Natural Resources, and Renewables (NSDNRR) on July 13, 2022. On July 27, 2022, Mark McGarrigle (NSDNRR SAR Biologist) and Elizabeth Walsh (NSDNRR Regional Biologist) provided feedback and recommendations on the proposed methods. NSDNRR comments are reflected in this revised LMP (Version 2.0). Refer to Table 1 for the LMP revision log.

Table 1. LMP Revision Log

Version #	Version Date
1.0	July 11, 2022
2.0	August 11, 2022

1.1 Objectives and Scope

The objectives of the LMP are to monitor for potential Project-related indirect effects to observed SAR lichen, and to describe propose mitigations, adaptive management, to reduce harm to SAR lichen species.

The general objectives of the LMP are to:

1. Outline potential pathways for Project-related direct and indirect effects to observed SAR lichen occurrences.
2. Provide an overview of the lichen monitoring program, including data collection, proposed methodologies, timelines, and reporting for all monitored SAR lichens.
3. Present mitigations and adaptive management strategies should Project-related impacts be observed during the monitoring program.



2 PROJECT BACKGROUND

MEL completed the biophysical surveys to prepare an EARD for the proposed Project. During the assessments, completed in 2019, two SAR lichens: blue felt lichen (*Pectenium plumbeum*; SARA and COSEWIC Special Concern, NSESA Vulnerable, and ACCDC S3) and frosted glass whiskers (*Sclerophora peronella*; SARA and COSEWIC Special Concern and ACCDC S3S4) were identified.

Nova developed a revised expansion area (area reduced by 12.7%) that maintains a setback of 100 m, as recommended within the *At-Risk Lichens – Special Management Practices* (NSL&F, 2018), from the single frosted glass whiskers observation and all but one observation of blue felt lichen, BlueFelt1 (Table 2, Figure 2; Appendix A).

Table 2. SAR Lichen Observations

Common Name	Scientific Name	Observation ID	Number of Thalli ¹ or Stalks ²	Distance from Revised Expansion Area (m)	Direction from Revised Expansion Area	Location Description
Blue felt lichen	<i>Pectenium plumbeum</i>	BlueFelt1	3	31.8	W	Upland habitat adjacent WC1 and between WL1 and WL2
		BlueFelt2	1	352.4	N	Upland habitat, 3 m south of WL2
		BlueFelt3	1	352.5	N	WL11
		BlueFelt4	1	400.3	N	WL11
		BlueFelt5	1	527.4	N	Upland habitat, 25 m north of WL11
Frosted glass-whiskers	<i>Sclerophora peronella</i>	Frosted1	~100	283.5	NW	Upland habitat on crown land, 14 m west of Study Area

¹Number of thalli is specific to blue felt lichen

²Stalk number is specific to frosted glass whiskers

3 POTENTIAL PROJECT RELATED EFFECTS

No direct impacts are proposed to SAR lichen from Project development, however, the Project has potential to indirectly impact SAR lichen via edge effects and air quality (i.e. dust). Poikilohydric organisms, such as lichens, have the inability to regulate and maintain their water content (Boudreault et al. 2008; COSEWIC 2002; Nash III, 2008), which makes them susceptible to edge effects and could result in desiccation, decreased health, or death. The extent in which lichens are impacted by edge effects (referred as depth of influence) depends on many variables and is context dependent. The size of the



clearing, substrate, species, and climate are some of the variables that may contribute to the depth of influence.

Decreased air quality is another potential driver that could negatively impact lichens. The Project is predicted to result in localized particulate mobilization through dust generation during quarry expansion. Dust deposition may result in increased alkalinity in substrate pH composition (e.g., bark of host tree) and bioaccumulation in lichen tissue which can impact lichen health and species richness (Degtjarenko, 2016; Naeth and Wilkinson 2008; Farmer, 1993).

NSDNRR requires a 100 m buffer for both blue felt lichen and frosted glass-whiskers (NSL&F 2018). As per Table 2, with the revised expansion area, a 100 m setback is maintained for all identified SAR lichen except for BlueFelt1. BlueFelt1 is approximately 31.8 m west of the revised quarry expansion area. The area between BlueFelt1 and the current quarry operations has been cleared and planned operations are proposed to move northeast, and away from BlueFelt1. No quarry activities will occur closer than they currently are to BlueFelt1. This revised expansion area and the proposed encroachment within the 100 m buffer at BlueFelt1 was presented to Mark McGarrigle (NSDNRR SAR Biologist) and Elizabeth Walsh (NSDNRR Regional Biologist) on May 21, 2021. NSDNRR indicated that they are comfortable with the proposed approach related to encroachment within the 100 m buffer to BlueFelt1 if quarry expansion moves away from the observation and ensuring WC1 is protected.

4 LICHEN MONITORING

The following lichen monitoring plan has been developed to track changes to lichen status and health, with respect to Project development. Specifically, this plan aims to achieve the following:

1. Monitor lichen health to detect change to the observed lichen due to edge effects and changes in air quality (i.e., dust from quarry activities);
2. Monitor the effectiveness of the *At-Risk Lichens – Special Management Practices* (NSL&F 2018) 100 m setback; and,
3. Provide data to inform provincial and federal SAR recovery strategies and action plans for these species and direct future mitigation and adaptive management approaches.

4.1 Monitoring Methodology

Monitoring will occur for all identified SAR lichen within 100 m of the revised expansion area (Figure 2; Appendix A). This includes one of the five observations of blue felt lichen (BlueFelt1). Additionally, a second observation of blue felt lichen (BlueFelt2), which is beyond the 100 m setback (352 m north of the revised expansion area), will also be monitored. Baseline monitoring will be completed prior to quarry expansion and construction monitoring will occur once per year for a five-year period. A general overview of the monitoring stations and data collected are described in the following sections.



4.1.1 Monitoring Stations

A monitoring station will be established at BlueFelt1 and BlueFelt2 (Figure 2; Appendix A). Monitoring stations will be clearly flagged on neighboring trees or the host tree branch and labelled with a metal forestry tag using a unique monitoring ID. If multiple thalli exist on a host tree, each thalli will be assigned a unique ID.

4.1.2 Monitoring Data Collected

The monitoring program would involve collecting data at the vegetation community, and the phorophyte details on thallus health.

Chlorosis and necrosis ranks for each thallus will be determined in the field but also Image J software may be used to determine a more accurate approximation of % chlorosis and necrosis.

An attempt will be made to use imaging software to monitor frosted glass whiskers, however, due to the small size and the nearly invisible thallus, this technique may not be applicable. Determining % necrosis/chlorosis in the field may not be possible either for this species. See below for the data collected at the vegetation community, host tree, and thallus level.

4.1.2.1.1 Vegetation Community Level

- Vegetation Type as per the Forest Ecosystem Classification (FEC) for Nova Scotia - NSDNR, 2010;
- Wetland Classification and type (softwood swamp, hardwood swamp, mixedwood swamp), if applicable;
- Stand age (regenerative, immature, mature, over mature);
- Tree species present;
- Distance from edge of wetland from proposed/existing Project related infrastructure and non-Project related clearings;
- Canopy cover rank (1: <25%; 2: 25-50%; 3: 50-75%; 4:>75%);
- Invasive species present (yes or no, and list species);
- Photograph of habitat; and
- Any additional notes on the site relevant to the monitoring (e.g., threats such as forest harvesting).



4.1.2.1.2 Phorophyte Descriptions and Data Collection

- Coordinates of the host tree in NAD83 UTM 20;
- Tree species;
- Age class (mature, over-mature, dead and note if tree is standing or leaning);
- Canopy cover relative to host tree (use ranks 1 to 4);
- Lichen species present;
- Bryophytes present (Yes or No? Identify species if possible);
- Photograph of host tree;
- Distance from proposed/existing Project related infrastructure and non-Project related clearings; and,
- Comments.

4.1.2.1.3 Thallus Descriptions

- Unique thallus ID;
- Life stage (Juvenile [lacking apothecia], Adult, Necrotic, Dead);
- Necrosis rank (1: 0%; 2: 1-25% ;3: 26-50%; 4: 51% - 75%; 5: >76%);
- Chlorosis rank (1: 0%; 2: 1-25% ;3: 26-50%; 4: 51% - 75%; 5: >76%);
- Area of the lichen will be determined by analysis of photographic images using imaging processing data such as Image J. Additionally, measurements of horizontal and vertical axis of thallus will be taken in the field;
- Rank of apothecia¹ (1: 0%; 2: 1-25%; 3: 26-50%; 4: 51% - 75%; 5: >76%);
- Rank of herbivory (1: 0%; 2: 1-25%; 3: 26-50%; 4: 51% - 75%; 5: >76%), and identification of grazing species (e.g., slugs), if observed.
- Cardinal direction the thallus is facing.
- Height up the tree thallus is positioned (cm);

¹ Apothecia rank is based on the absolute cover of the total thallus size



- Photograph of thallus with scale (ruler or quadrat will be used as a scale); and
- Additional comments.

4.2 Reporting

An annual report will be submitted to NSDNRR which summarizes the methods and results of the monitoring. The report will include a summary on lichen health, and verification of Project effects predictions. At the end of Year 5 monitoring, Nova will consult with NSDNRR regarding additional mitigations and/or monitoring.

The findings of this plan aim to further the current state of knowledge of the effects to lichens from industrial activities, specifically quarrying.

5 MITIGATION AND ADAPTIVE MANAGEMENT

Efforts have been made to avoid SAR lichen occurrences, and maintain a 100 m setback where practicable, through detailed Project design.

The results of the monitoring plan will aid in supplementing, where necessary, the mitigation commitments outlined in the EARD. Findings from the lichen monitoring program, peer-reviewed studies and species-specific SARA Recovery Strategies, Action Plans, and Management Plans will be evaluated to support adaptive management approaches, if required. Adaptive management strategies may include additional monitoring, increased dust suppression and consideration of alternative dust suppression methods. Adaptive management and review of mitigation measures may occur each year following review of monitoring results.

6 LIMITATIONS

This plan is proposed to monitor and mitigate Project related effects to SAR lichen. However, it is important to acknowledge other non-Project related activities may impact lichen health (e.g., forestry activity). Nova cannot control impacts from activities unrelated to the Project. Forestry activity or other non-Project related industrial activities may be unavoidably captured in the monitoring plan and influence the overall health and microclimate of the monitored lichens and habitat. As a result, if effects are observed in the monitored lichen (e.g., evidence of necrosis), this will not necessarily be attributed to the Project and may be a result of exterior factors. Efforts have been made to tailor this monitoring plan to limited external interference and focus on the validation of Project effects predictions.



7 CLOSURE

The outcomes and lessons learned from this proposed plan could be used to help guide future monitoring efforts and further our understanding of industrial effects to SAR lichens in general. This plan has been prepared with the intent to share with NSDNRR for input and feedback on proposed objectives and methodologies.

Please do not hesitate to contact the undersigned with any questions you may have.

Jeff Bonazza, M.Env.Sci.
Project Manager
McCallum Environmental Ltd.



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- NSDNR 2010. Forest Ecosystem Classification for Nova Scotia – Part I: Vegetation Types.



APPENDIX A. FIGURES


Prepared For:



FIGURE 1

Study Area Overview

**Proposed Sporting Mountain Quarry Project
PID 75044156**

 Study Area



Coordinate System: NAD 1983 CSRS UTM Zone 20N
Projection: Transverse Mercator
Datum: North American 1983 CSRS
Units: Meter



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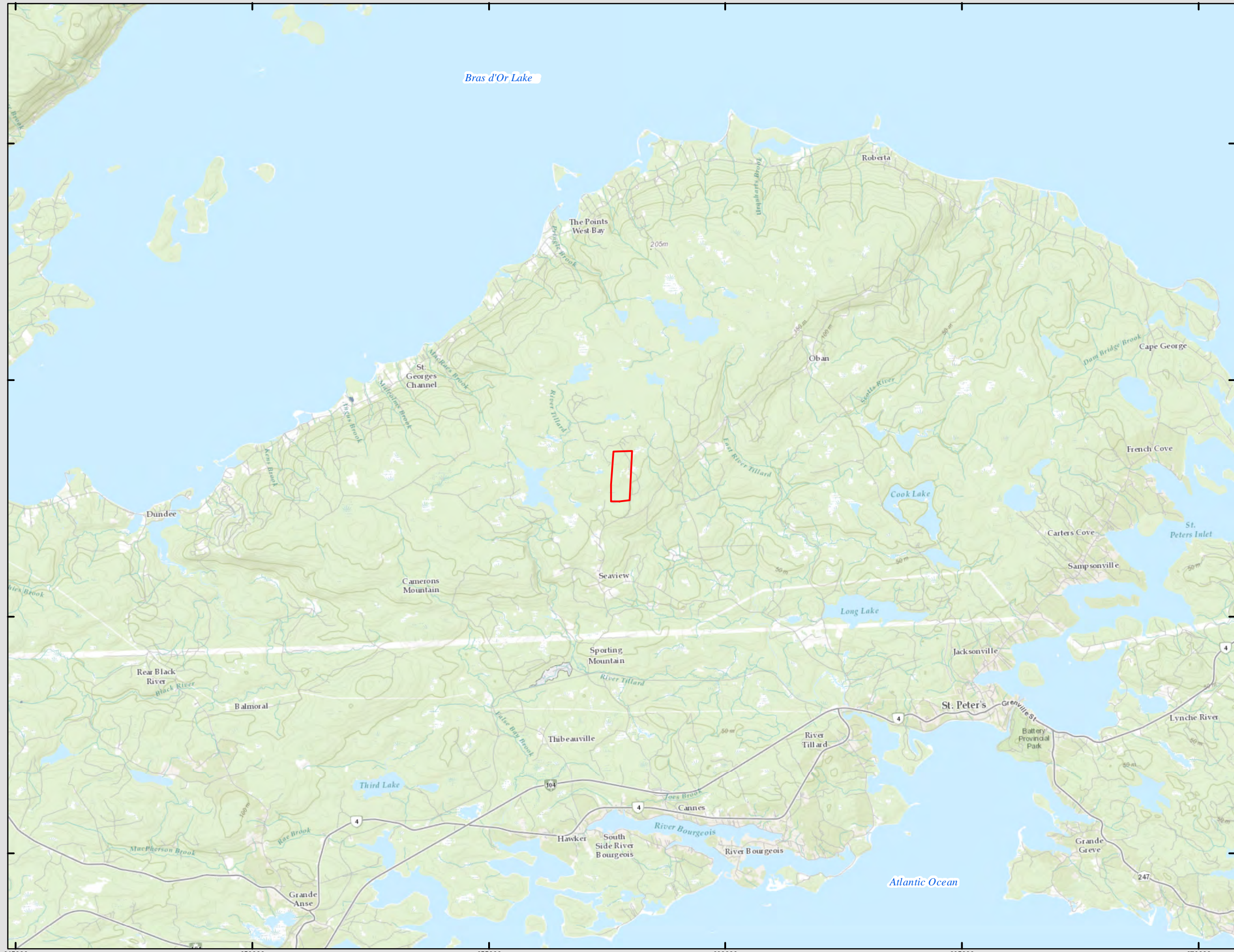
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Date: 2019-11-15



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FIGURE 2

SAR Lichens

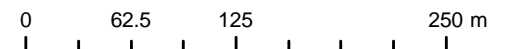
Proposed Sporting Mountain Quarry Project
PID 75044156

- Study Area
 - Revised Expansion Area
 - Field Delineated Watercourse
 - Field Delineated Wetland
- SAR Lichen**
- Blue Felt Lichen
 - Frosted Glass Whiskers Lichen

Note: BlueFelt1 and BlueFelt 2 are the only SAR lichens proposed for monitoring.



Coordinate System: NAD 1983 CSRS UTM Zone 20N
Projection: Transverse Mercator
Datum: North American 1983 CSRS
Units: Meter



1:4,500 Scale when printed @ 11" x 17"

Drawn By: JB
Reviewed By: JG

Date: 2022-07-11



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