Pisces Environmental Consulting Services Ltd.
Robb Trend Coal Mine Expansion Project
Aquatic Ecology Reports (2011-2015)
CEAA Information Request

February 2015

PISCES ENVIRONMENTAL CONSULTING SERVICES LTD.

Table of Contents

Report #1

Pisces Environmental Consulting Services Ltd.

• 25J 37337 Burnt Lake Trail • Red Deer County • Alberta • T4S 2K5 •
• Phone 403-347-5418 • Fax 403-347-0681 •
• www.piscesenvironmental.com •

CVRI
Coal Valley Mine
Bag 5000
Edson, Alberta
T7E 1W1

April 15, 2011

ATTN: Mr. Les LaFleur

RE: Post- construction monitoring of the permanent diversion channel on upper Mercoal Creek for the MP2 development.

Introduction

The Mercoal Phase 2 (MP2) project, part of ongoing mining operations at the Coal Valley Mine, required the permanent diversion (known as diversion D-E) of a portion of Mercoal Creek to facilitate mining. As required by Fisheries and Oceans Canada (DFO), a habitat compensation plan that included enhancement of the constructed channel with a goal of maximizing its productive capacity was developed for the project. In order to meet the requirements of the DFO Section 35(2) *Fisheries Act* Authorization (# ED-04-3170) issued for the project, the mine committed to conducting fish and fish habitat monitoring within the constructed channel. Key components of the monitoring program included:

- Sampling 1, 3, and 5 years following construction of the channel.
- Habitat surveys 1 and 5 years following construction of the channel.

This document presents the year 1 (post construction) monitoring results obtained by Pisces Environmental Consulting Services Ltd. (Pisces).

Background

Baseline investigations of Mercoal Creek found that fish densities were very low in the vicinity of the diversion and that Rainbow Trout (*Oncorhynchus mykiss*) were the only species to occupy this part of the creek (Boorman 2003). Habitat inventory during baseline investigations found that the majority of habitat (>75%) affected by the diversion consisted of Class 3 (<0.5 m) habitat (Boorman 2003). Pool habitat comprised about 2% of the affected habitat and that there was no Class 1 (>1.0 m) habitat in the impacted area (Boorman 2003). Modelling of the habitat suitability of Mercoal Creek for Rainbow Trout (Raleigh et al. 1984) found that both the percent pools and the pool class rating variables were limiting factors (Stemo 2005). As a result, habitat compensation efforts included the construction of pools on every meander and the placement of large woody debris within the constructed pools (Stemo 2005).

Monitoring Results

The 2010 monitoring program included an inventory of the habitat within the diversion channel and fish sampling of constructed and natural habitat in the area. The investigations were completed on September 30, 2010.

Habitat Inventory

The channel was stable and riparian vegetation was becoming established at the time of assessment (see attached photos).

The inventory found that the channel provided an additional 750 m^2 of habitat compared to the pre-disturbance condition. In addition, there was substantially more diversity within the channel in terms of habitat depth as Class 1, 2, and 3 habitat each represented approximately one third of the total area (Table 1). Consistent with the compensation plan there was a substantial increase in pool habitat which accounted for over 50% of the total available habitat. In addition almost one third of the habitat in the enhanced channel consisted of Class 1 (deep) habitat (Table 1).

Table 1. Summary of habitat alteration/loss associated with the diversion D-E of Mercoal Creek based upon the Habitat Classification System (O'Neil and Hildebrand 1986).

Habitat Type	Natural Channel		Diversion Channel		Net Loss/Gain (m^2)
	Area (m^2)	% of Total Available Habitat	Area (m^2)	% of Total Available Habitat	
R3	1122.9	72.4	614.9	26.7	-508.0
R2	332.0	21.4	0.0	0.0	-332.0
F3	63.9	4.1	222.5	9.7	+158.6
F1	0.0	0.0	72.0	3.1	+72.0
P3	23.2	1.5	189.0	8.2	+165.8
P2	8.0	0.5	411.5	17.9	+403.5
P1	0.0	0.0	642.0	27.9	+642.0
RF	1.0	0.04	150.7	6.5	+149.7
Other Features					
LJ	1.4	0.06	0.0	0.0	-1.4
TOTAL	1552.4	100.0	2302.6	100	+750.2

Fish Sampling

The fish sampling program consisted electrofishing and angling surveys.

- Three hundred and fifty-four metres of the diversion channel was electrofished for 1516 seconds of on-time. No fish were captured or observed during this survey.
- Deep portions of 4 pools were angled due to the limited effectiveness of electrofishing within deeper water. No fish were captured or observed during the 1 hour angling survey.
- A 200 metre section of the natural channel downstream of the diversion was electrofished for 1035 seconds of on-time. No fish were captured or observed during this survey.

Summary

Consistent with the Habitat Compensation Plan (Stemo 2005), the constructed diversion channel had substantially more 1st-class pools as compared to the pre-disturbance condition which, based on Habitat Suitability Modelling (Raleigh et al. 1984), has resulted in an increase in the overall habitat quality in this portion of the creek.

Utilization of the diversion channel was not confirmed in 2010 however, fish were also absent in the natural channel downstream of the diversion which suggests that fish densities in the headwaters of Mercoal Creek remain low (as was found during baseline studies (Boorman 2003)).

References

Boorman, J. 2003. Baseline fisheries resource assessment of waterbodies on and adjacent to the proposed mercoal east mine extension. Report of Pisces Environmental Consulting Services Ltd. to Luscar Ltd. Coal Valley Mine. Edson, AB. 35pp. + App.

Raleigh, R.F., T. Hickman, R.C. Solomon, and P.C. Nelson. 1984. Habitat suitability information: Rainbow Trout. U.S. Department of the Interior Fish and Wildlife Service. FWS/OBS-82/10.60. 64 pp.

Stemo, E. 2005. Coal Valley Mine Mercoal Phase 2 Extension Fish Habitat Compensation. Report of Pisces Environmental Consulting Services Ltd. to Luscar Ltd. Coal Valley Mine. Edson, AB. 10pp. + App.

Closure

I trust this meets your information requirements at this time. If you have any questions please contact our office at your convenience.

Sincerely,

<original signed by> <original signed by>

Jason Machney, BSc.
Fisheries Biologist

Erik Stemo, P.Biol
Senior Fisheries Biologist

Pisces Environmental Consulting Services Ltd.

Attch.

	
Photo 1. Downstream (d/s) view near downstream end of diversion channel (dc).	Photo 2. Looking u/s at an anchored tree within the diversion channel ~260 m u/s of the d/s end of the dc.
	
Photo 3. Looking d/s at a P3 (Class 3 Pool) approximately 422 m u/s of the d/s end of the dc.	Photo 4. Looking u/s at the u/s tie-in of the diversion channel.
	
Photo 5. Looking downstream from near the u/s end of the diversion channel.	Photo 6. View of one of the larger pools within the diversion channel.

Photo 7. View of the typical habitat within the diversion channel.

Photo 8. View of the typical habitat within the diversion channel.

Photo 9. View of the typical habitat within the diversion channel.

	
Photo 13. Looking downstream at the outlet channel with surface connection.	Photo 14. Looking upstream at outlet channel from downstream tie-in.

Report #2

AQUATIC MONITORING PROGRAM FOR END PIT LAKES IN THE HEADWATERS OF THE EMBARRAS RIVER, 2011-2012

Prepared for: Coal Valley Resources Inc. Edson, Alberta
April 2013

PISCES ENVIRONMENTAL CONSULTING SERVICES LTD.

AQUATIC MONITORING PROGRAM FOR END PIT LAKES IN THE HEADWATERS OF THE EMBARRAS RIVER, 2011-12

Prepared For:
Coal Valley Resources Inc.
Edson Alberta

Prepared by:
Pisces Environmental Consulting Services Ltd.
Red Deer, Alberta

<original signed by>

Joe Sonnenberg
Senior Fisheries Technician

<original signed by>

Erik Stemo, P.Biol.
Senior Fisheries Biologist

April 2013

Table of Contents

List of Tables

List of Figures

1.0 INTRODUCTION

In August 2004, Fisheries and Oceans Canada (DFO) issued *Fisheries Act* Authorization ED-03-3080 to Coal Valley Resources Incorporated (CVRI) for the diversion of the Embarras River to facilitate mining in the Mercoal Phase 1 (MP1) area. Part of the final reclamation strategy for the MP1 extension included the development of an end pit lake system that would support a self-sustaining native fish population. Key to the fish habitat compensation plan for this diversion was the implementation of a study to assess the viability of the end pit lakes once they were constructed. CVRI completed the physical works to reclaim the aquatic ecosystem in 2010 and monitoring was initiated in 2011. This document presents results of monitoring conducted by Pisces Environmental Consulting Services Ltd. (Pisces) from summer 2011 to spring 2012.

1.1. OBJECTIVES

The 2011-12 monitoring program was designed to evaluate the initial development of the aquatic ecosystem of the Embarras End Pit Lake system in consideration of the following:

- Requirements specified in the DFO Authorization;
- End Pit Lake Working Group (EPLWG) Guideline performance evaluation/criteria; and
- Alberta Environment and Sustainable Resource Development (AESRD) objectives for End Pit Lake closure landscape.

The primary objectives of the program are listed below. Additional study parameters will be assessed in future years as the lake system develops.

- Describe physical and chemical limnological characteristics of the End Pit Lakes;
- Assess fish population in Embarras River downstream of the Lake System;
- Assess benthic macroinvertebrate populations in End Pit Lakes and Embarras River;
- Assess zooplankton and phytoplankton communities in the End Pit Lakes;
- Assess macrophyte communities in the End Pit Lakes.

2.0 STUDY AREA

The Embarras End Pit Lake system is located in the extreme headwaters of the Embarrass River in 25-47-21-W5 (Figure 2.1). The Embarras River flows into the McLeod River approximately 86 kilometres downstream of the lakes, which in turn flows into the Athabasca River near Whitecourt, Alberta. Historically, fish densities in the upper Embarras River were low and pre-mining investigations of this part of the river found fish habitat potential to be limited (Boorman 2003). Habitat diversity within this area was considered to be marginal and substrates were comprised almost exclusively of fines (Boorman 2003). However, Rainbow Trout (*Oncorhynchus mykiss*), Bull Trout (*Salvelinus confluentus*) and Brook Trout (*Salvelinus fontinalis*) were found just downstream of the proposed MP1 pit area during baseline investigations (Boorman 2003).

The Embarras End Pit Lake system consists of three lakes and approximately 1100 metres of constructed connecting channels (Figure 2.1). The naming convention for the lakes is as follows:

- Upper Embarras Lake (Pit 142E);
- Middle Embarras Lake (Pit 122); and
- Lower Embarras Lake (Pit 122).

The Embarras River enters the Upper Lake from a natural beaver pond via a constructed inlet channel that is approximately 30 metres long. There are approximately 500 metres of connecting channel between the Upper and Middle Lakes including the haulroad culvert crossing that is located just upstream of the Middle Lake. Between the Middle Lake and Lower Lake there is approximately 150 metres of connecting channel and there is approximately 400 metres of constructed channel downstream of the Lower Lake. A fish exclusion weir has been constructed at the bottom of this constructed channel to preclude Brook Trout from entering the end pit lake system. Photos of the lake and connection channels are presented in Appendix A.

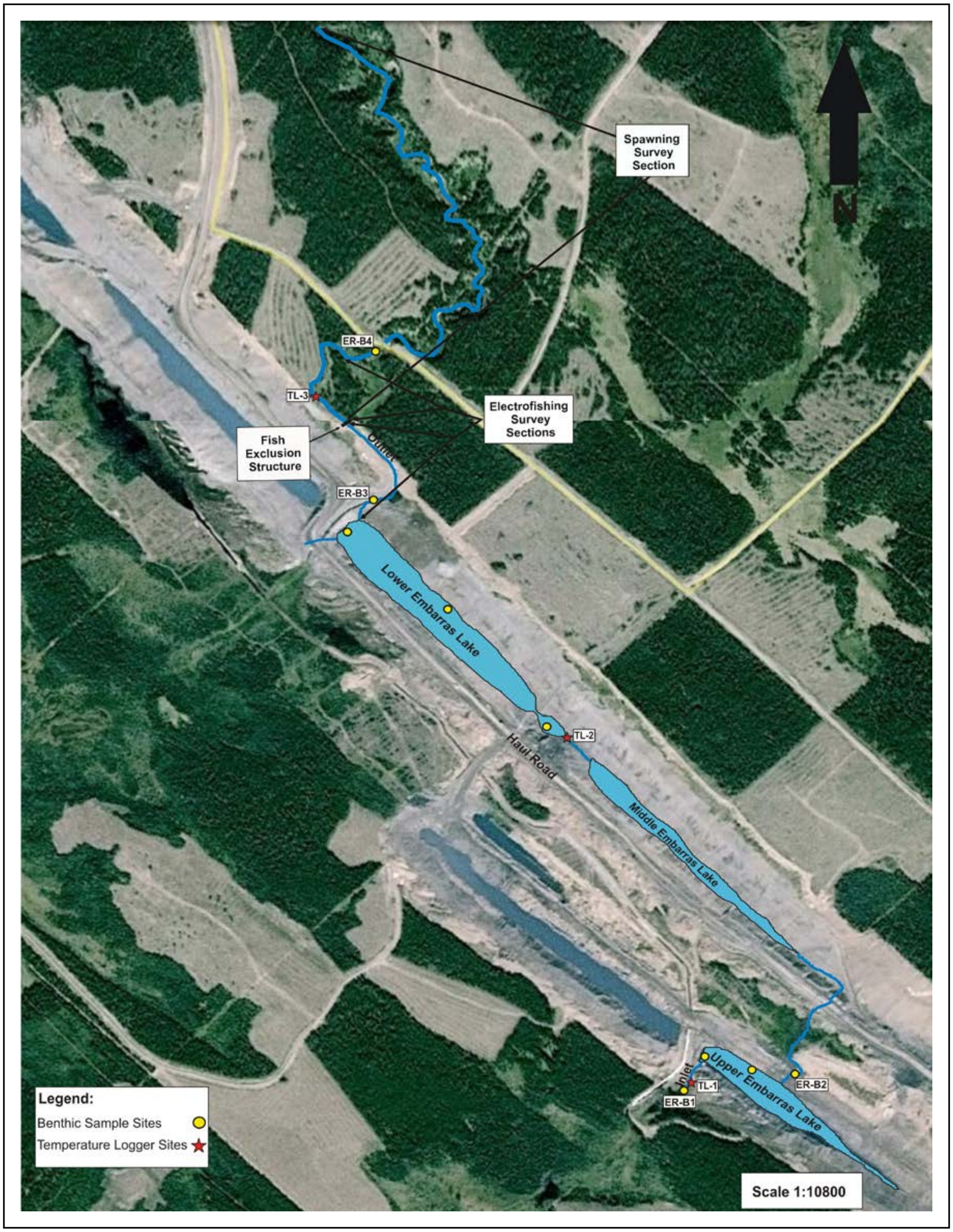


Figure 2.1. Study area and location of lakes.

3.0 METHODS

3.1. LENTIC HABITAT

3.1.1. Physical Characteristics

The basic morphology of each lake was determined based on field investigations and information provided by Sherritt Coal.

3.1.2. Limnology

A limnology station was established near the middle of each lake. Temperature, dissolved oxygen, and electrical conductivity were measured seasonally (summer, fall, winter, spring with a YSI model 85 meter at one metre intervals to a maximum depth of 30 metres. Water transparency was measured with a 20-centimetre Secchi disk during open water sampling.

3.1.3. Water Quality

In August 2011 water samples were obtained from the epilimnion and hypolimnion of the Upper and Lower Lakes using a Kemmerer bottle. Samples for chlorophyll analysis were taken from the photic zone. All samples were sent to Exova Laboratories in Edmonton, Alberta for analysis of select water quality variables (Table 3.1).

3.1.4. Benthic Invertebrates

Benthic macroinvertebrate sampling stations were established at random in the littoral zone of the Upper and Lower Lakes in October 2011. A 0.023 square metre Eckman grab sampler was used to obtain substrate samples at depths of 1.8 to 6.1 metres. Five replicate samples were taken, washed through a 583 μm sized sieve, stored and preserved with 85% ethanol. All benthic collections were submitted to an independent contractor for taxonomic analysis. Sample processing consisted of sorting, identifying and enumerating benthic invertebrates (Appendix B).

3.1.5. Zooplankton

In August 2011, five sample sites were established on both the Upper and Lower Lakes with one site located at or near the centre of the lake and the four remaining samples located in each of four quadrants. Vertical hauls were made at each site using a No. 20 Wisconsin net. The net was lowered to critical depth or near bottom of the lake and raised at 0.5 to 1.0 metres per second. The sample was rinsed into a jar, preserved with 95% ethanol and shipped to a qualified independent contractor for identification, enumeration, and population density calculations (Appendix C).

Table 3.1. Water chemistry variables measured in the Embarras End Pit Lake System in 2011-12 and Provincial and Federal water quality objectives.

Variable	Units	Surface Water Quality Objectives	
		Provincial[1]	Federal[2]
pH		6.5-8.5	6.5-9.0
EC	µMHOS/cm		
TDS	mg/L		
TSS	NTU		
T. Alkalinity	mg/LCACO$_3$		
Carbonate	mg/L		
Bicarbonate	mg/L		
Calcium	mg/L		
Magnesium	mg/L		
Sodium	mg/L		
Potassium	mg/L		
Hardness	mg/LCACO$_3$		
Chloride	mg/L		
Sulphate	mg/L		
Nitrate	mg/L as N		
Nitrite	mg/L as N		0.06
TKN	mg/L as N		
TP	mg/L as P	0.05	
Chlorophyll a (*)	µg/L		
Arsenic	mg/L	0.01	0.005
Antimony	mg/L		
Aluminium	mg/L	1	0.1 @ pH> 6.5
Barium	mg/L		
Beryllium	mg/L		
Bismuth	mg/L		
Boron	mg/L	0.5	
Cadmium	mg/L	0.01	0.0008(**) 0.0013(***) 0.0018(****(
Chromium	mg/L	0.05	0.02
Cobalt	mg/L		
Copper	mg/L	0.02	0.002(**) 0.003(***) 0.004(****)
Iron	mg/L	0.3	0.3
Lead	mg/L	0.05	0.002(**) 0.004(***) 0.007(****)
Lithium	mg/L		
Manganese	mg/L	0.05	
Mercury	mg/L	0.0001	0.0001
Molybdenum	mg/L		
Nickel	mg/L		0.065(**) 0.11(***) 0.15(****)
Selenium	mg/L	0.01	0.001
Silicon	mg/L		
Silver	mg/L	0.05	0.0001
Strontium	mg/L		
Sulphur	mg/L		
Thallium	mg/L		
Titanium	mg/L		
Uranium	mg/L		
Vanadium	mg/L		
Zinc	mg/L	0.05	0.03

1 Alberta Environment (1999)
2 Canadian Council of Ministers of Environment (2006)
Elements/Metals as Total
(*) Chlorophyll measured in photic zone (composite sample)
(**) @Hardness 60-120 mg/L CaCO$_3$, (***) @ Hardness 120-180mg/L CaCO$_3$, (****) @ Hardness > 180mg/L CaCO$_3$

3.1.6. Phytoplankton

Three composite samples were taken randomly from undisturbed areas of the epilimnion near the limnology station in the Upper and Lower lakes. Sampling was completed in August 2011. All samples were transferred to one litre amber bottles and shipped to an independent contractor for analysis.

3.1.7. Aquatic Macrophytes

A survey of the submergent and emergent aquatic macrophyte community in the lakes was conducted during August investigations. Aquatic macrophytes were identified to species and the abundance of each species was approximated in square metres (m^2).

3.2. LOTIC HABITAT

3.2.1. Spawning Surveys

Spawning surveys were conducted in connecting channels and in the natural channel downstream of the Lake system during the spring and fall. Spawning surveys targeting Brook Trout and Bull Trout were conducted on October 5th 2011 while surveys targeting Rainbow Trout were completed in May 2012 (Figure 2.1). The location of spawning activity was noted and the number and appropriate size of the fish on redds was recorded. To be confirmed as a positive redd the redd need to exhibit the typical depression and tail spill mound associated with salmonid spawning sites. A redd was considered to be a possible redd if there was evidence of disturbed stream bed gravels but the distinct pit and tail spill associated with characteristics of a positive redd were absent.

3.2.2. Fish Capture

Single pass electrofishing surveys using a Smith Root LR24 electrofisher were completed in connecting channels and in the natural channel downstream of the Lake system in August and October 2011 (Figure 2.1). All fish captured were identified to species, measured to fork length (mm) and weighted (g).

3.2.3. Benthic Invertebrates

Benthic invertebrate sampling sites were established at four locations on the Embarras River including: one upstream of the lakes, two within the constructed connecting channels, and one downstream of the lake system (Figure 2.1). Sample sites were selected to maintain a consistency of substrate across sites. Habitat at all sites was erosional, consisting of riffle and run habitat. Water velocity and mean depth was measured at three locations along an established transect within the sampling area and substrate composition was recorded at each site.

Three replicate samples were collected at each site using a Neill-Hess cylinder (250 micron mesh). Samples were transferred to jars, preserved with 85% ethanol and transported to a qualified independent contractor for analysis.

3.2.4. Temperature Regime

StowAway®TidbitTM temperature data loggers (Onset Computer Corporation) were installed in the Embarras River at three locations within the end pit lake system. One was located upstream of the lakes, one was located in the connecting channel between the Middle and Lower Lake, and one was located in the channel downstream of Lower Lake near the fish exclusion weir (Figure 2.1). The data loggers recorded a water temperature on an hourly basis between June 9th, 2011 and October 5th, 2011.

4.0 RESULTS

4.1. LOWER EMBARRAS LAKE

4.1.1. Morphometric Data

Morphometric data are summarized in Table 4.1. A bathymetric map of the lake showing benthic, zooplankton, and limnological sampling sites is presented on Figure 4.1.

Table 4.1. Morphometric data for Lower Embarras Lake.

Parameter	Value
Area (ha)	6.6
Volume (m^3)	483 000
Maximum length (m)	853
Maximum width (m)	111
Maximum depth (m)	18
Mean depth (m)	7.34
Surface elevation (m)	1430
Percent Littoral (<3m deep)	30%

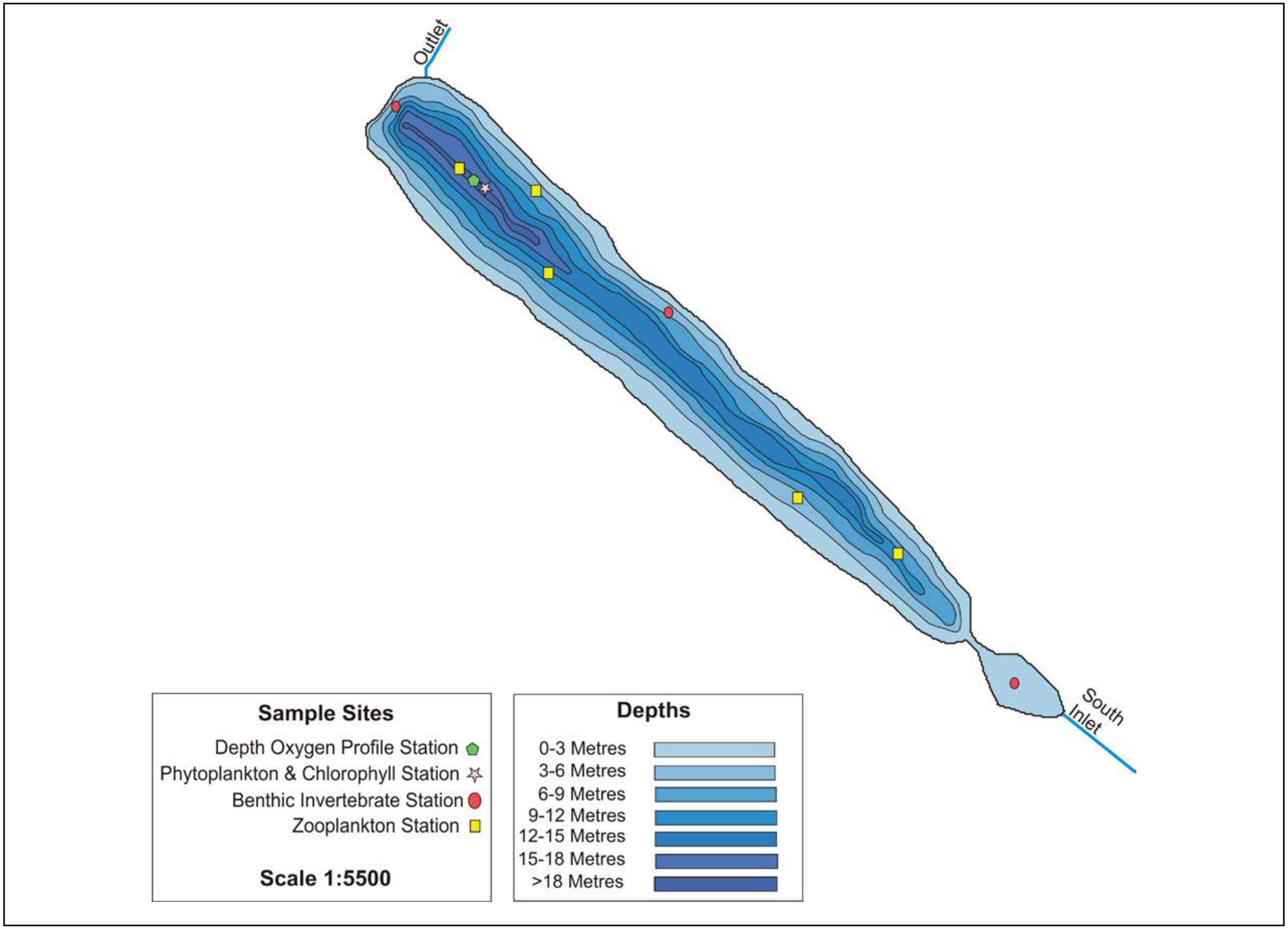


Figure 4.1. Bathymetry and Sample Locations on Lower Embarras Lake.

4.1.2. Physical and Chemical Conditions

Seasonal values for the Secchi disc transparency in Lower Embarras Lake are presented in Table 4.2.

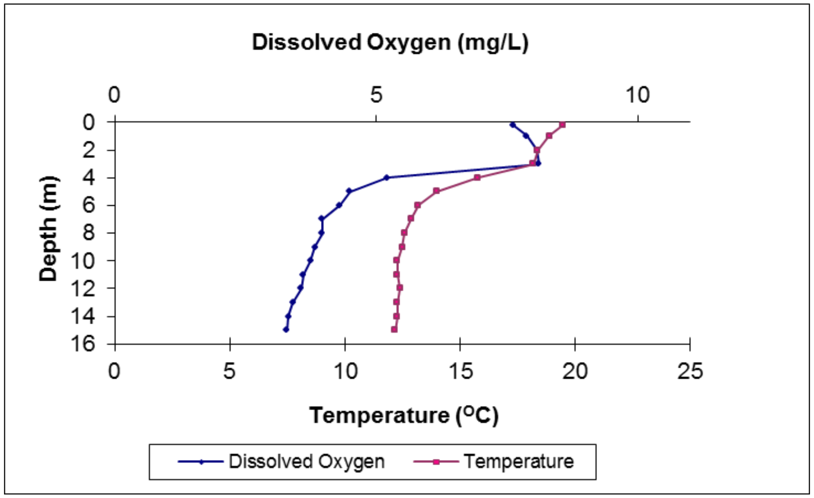
Table 4.2. Secchi disc transparency for Lower Embarrass Lake.

Date/ Season	Secchi Depth (m)	Climatic Conditions
17-Aug-11 (Summer)	1.3	Overcast- light rain
06-Oct-11 (Fall)	1.7	Overcast
26-May-12 (Spring)	1.9	Clear, strong wind

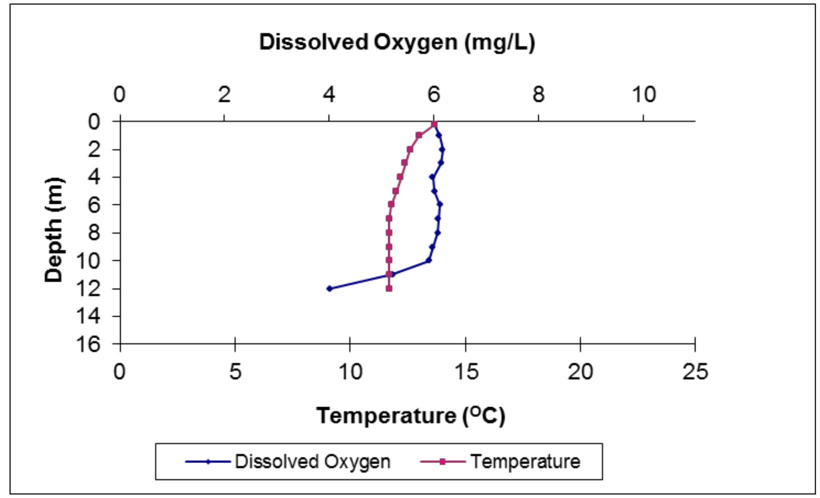
The lake was thermally stratified in the summer with the thermocline situated between 4 and 7 metres (Figure 4.2). Lake temperatures were relatively consistent through the water column in the fall ranging from all most 14^{O}C at the surface to just less than 12^{O}C near lake bottom. The lake was covered by approximately 0.70 metres of ice and 0.05 metres of snow when surveyed in February; surface temperatures had decreased to 0.6^{O}C while temperatures below 10 metres were relatively constant around 4^{O}C. The lake was beginning to stratify in the spring; temperatures ranged from 10.7^{O}C at the lake surface to 6.2^{O}C at the lake bottom with the thermocline situated between 6 and 8 metres.

The Lower Embarras Lake exhibited a clinograde oxygen profile. Oxygen concentrations were lower in the hypolimnion compared to the epilimnion in the summer and winter and were relatively constant within the water column in the spring and fall (Figure 4.2).

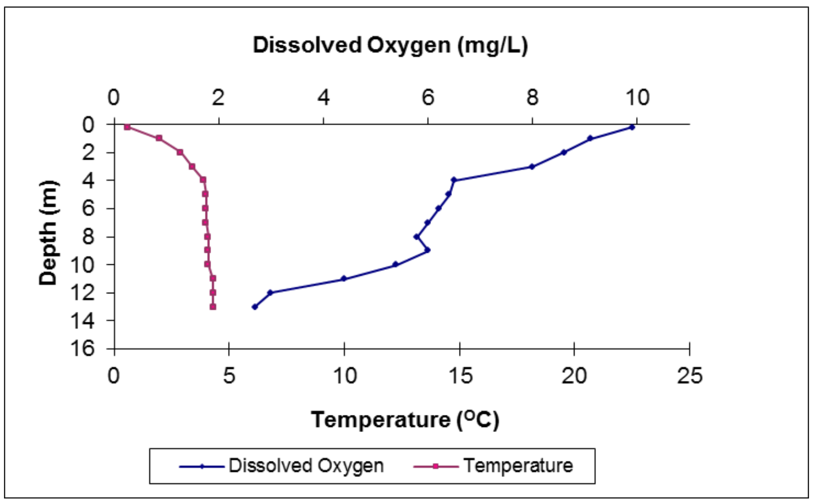
Specific conductivity varied seasonally but values were generally higher in the hypolimnion compared to the epilimnion in each season (Figure 4.3). The lowest conductivity values occurred during the spring and summer sampling period while the highest values were recorded during the winter.



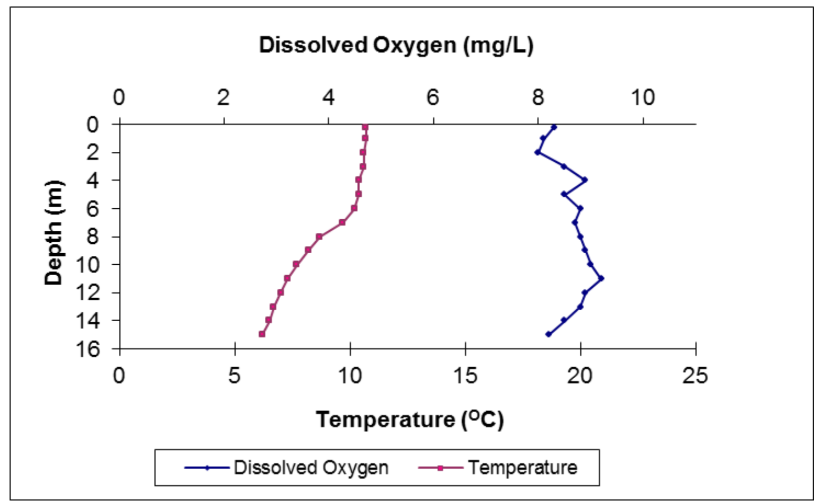
Summer



Fall



Winter



Spring

Figure 4.2. Oxygen and Temperature Profiles for Lower Embarras Lake.

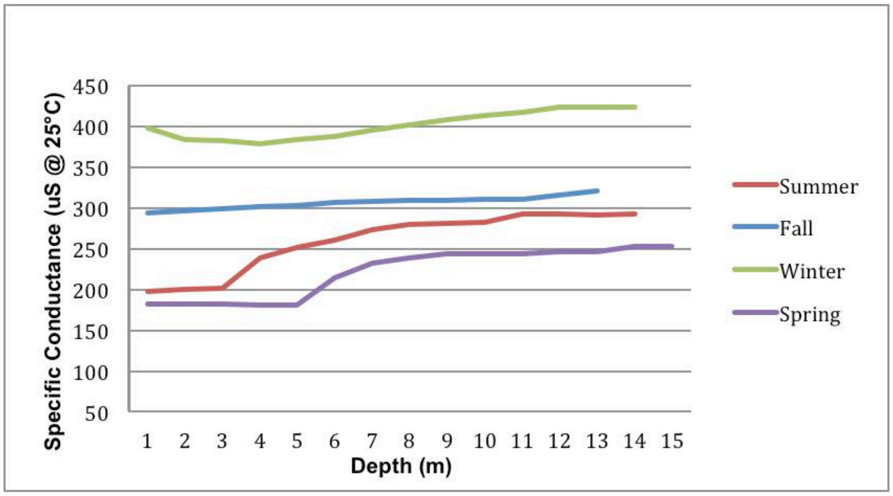


Figure 4.3. Conductivity Profiles for Lower Embarras Lake.

Alkalinity and pH values indicate that the lake was well buffered and non-acidic (Table 4.3). Water in the lake was of a bicarbonate type with an ionic hierarchy of Ca^{+} >Na^{+} > Mg^{+} > K^{+} (cations) and HCO_3^{-} > SO_4^{-} : Cl^{-}. (anions). Two variables, iron (hypolimnion and epilimnion), and aluminum (hypolimnion and epilimnion). exceeded Canadian Council of Ministers of the Environment guidelines (CCME 2006) (Table 4.3). In addition, manganese (epilimnion and hypolimnion) exceeded Provincial guidelines (Alberta Environment 1999).

Table 4.3. Water quality data for Lower Embarras Lake.

Parameter	Units	Epilimnion	Hypolimnion
Kjeldahl Nitrogen	mg/L	0.19	0.07
Phosphorus	mg/L	<0.05	<0.05
Organic Carbon	mg/L	8.2	6.3
Calcium	mg/L	26.0	40.0
Iron	mg/L	0.85	1.09
Magnesium	mg/L	5.6	9.0
Manganese	mg/L	0.112	0.098
Potassium	mg/L	1.2	1.8
Silicon	mg/L	4.15	4.92
Sodium	mg/L	9.8	11.8
Sulfur	mg/L	9.0	14.5
Mercury	mg/L	<0.0001	<0.0001
Aluminum	mg/L	0.71	1.21
Antimony	mg/L	<0.0002	0.0002
Arsenic	mg/L	0.0019	0.0009
Barium	mg/L	0.090	0.109
Beryllium	mg/L	<0.0001	<0.0001
Bismuth	mg/L	<0.0005	<0.0005
Boron	mg/L	0.016	0.023
Cadmium	mg/L	0.00002	0.00005
Chromium	mg/L	0.0014	0.0024
Cobalt	mg/L	0.0005	0.0008
Copper	mg/L	0.002	0.003
Lead	mg/L	0.0004	0.0008
Lithium	mg/L	0.004	0.005
Molybdenum	mg/L	0.004	0.004
Nickel	mg/L	0.0035	0.0045
Selenium	mg/L	<0.0002	<0.0002
Silver	mg/L	0.00002	<0.00003
Strontium	mg/L	0.243	0.408
Thallium	mg/L	<0.00005	<0.00005
Tin	mg/L	0.004	0.004
Titanium	mg/L	0.0118	0.0528
Uranium	mg/L	0.0010	0.0020
Vanadium	mg/L	0.0016	0.0035
Zinc	mg/L	0.003	0.005
Solids	mg/L	<1	<1
pH		7.90	7.74
Electrical Conductivity	µS/cm at 25 C	214	313
Chloride	mg/L	0.5	0.5
Nitrate - N	mg/L	0.3	0.56
Nitrite - N	mg/L	0.012	<0.005
Nitrate and Nitrite - N	mg/L	0.31	0.56
Sulfate (SO4)	mg/L	28	45.6
Hydroxide	mg/L	<5	<5
Carbonate	mg/L	<6	<6
Bicarbonate	mg/L	98	142
P-Alkalinity	mg/L	<5	<5
T-Alkalinity	mg/L	80	116
Total Dissolved Solids	mg/L	120	180
Hardness	mg/L	89	138
Ionic Balance	%	102	100

* composite sample
- exceedences are shaded

4.1.3. Benthic Invertebrates

Diptera were numerically dominant in the assemblage and other taxa were comparatively rare (Table 4.4). A total of 6 taxa were present.

Table 4.4. Benthic Invertebrate Composition for Lower Embarras Lake.

Taxon	Density (per 0.023 m^2) Replicate			Mean #Organisms/Sample
	1	2	3	
Plecoptera				
Perlodidae				
Isoperla sp.	4			1.3
Dipters				
Ceratopogonidae				
Ceratopogoninae		2		0.7
Chironomidae				
Orthocladiinae		19	16	11.7
Tanypodinae		4		1.3
Tanytarsini		39		13
Crustacea				
Copepoda				
Cyclopoida	4	16		6.7
Total	8	80	16	34.7
Total taxa	2	5	1	2.7

4.1.4. Zooplankton

The zooplankton community was comprised of 10 taxa in 2011-2012; Rotifers were numerically dominant while Cyclopoids, Cladocerans, Calanoids, and Cilophora comprised the remainder of the zooplankton community (Table 4.5).

Table 4.5. Zooplankton Abundance for Lower Embarras Lake.

Taxa	Density per m^3					
	Replicate #					Mean #Organisms
	1	2	3	4	5	
Calanoid						
Leptodiaptomus sicilis	555	205	364	449	251	365
Calanoid copepodid	476	614	468	374	201	4267
Calanoid *nauplii*	5774	0	0	9775	0.0	3110
Cladocera						
Daphnia pulex	4837	716	2498	2320	201	2114
Others (Cilophora)						
Vorticella sp	0	0	0	9775	0	1955
Cyclopoid						
Dicyclops bicuspidatus	2537	3682	1822	5315	3518	3375
Cyclopoid copepodid	8246	6853	5673	6930	8085	7157
Cyclopoid *(nauplii)*	11547	6278	5282	19551	7140	9965
Rotifera						
Polyathra dolicoptera Idelson	0	0	0	0	7140	1785
Total	33972	18348	16107	54489	26536	30253
Total Taxa	7	6	6	8	7	6.8

4.1.5. Phytoplankton

Phytoplankton collections in Lower Embarras Lake found a total of 17 taxa present (Table 4.6). The chlorophyll *a* concentration for the lake was 0.550 mg/m^3.

Table 4.6. Phytoplankton Abundance for Lower Embarras Lake.

Genus/Species	Cell/Colony Density (cells/mL)
Bacillariophyta	
Achnanthes minutissima	0.62
Cymbella minuta	0.31
Navicula sp.	0.31
Nitzschia acicularis	2.99
Synedra sp. smaller	4.43
Cryptophyta	
Cryptomonas reflexa	7.86
Katablepharis ovalis	1.55
Rhodomonas	72.52
Chrysophyta	
D. divergens statospore	0.31
Kephyrion sp	111.94
Chlorophyta	
Ankistrodesmus setigera	51.90
Characium sp.	1.24
Oocystis sp.	35.87
Sphaerocystis schroeteri	26.75
Cyanophyta	
Aphanothece clathrata	36.80
Lyngbya limnetica	31.54
Phormidium	2.17
Total	389.1
Total Taxa	17

4.1.6. Aquatic Macrophytes

No submergent and/or floating leaf macrophytes were observed during the survey of the lake conducted in August.

4.2. MIDDLE EMBARRAS LAKE

4.2.1. Morphometric Data

Morphometric data are summarized in Table 4.7. A bathymetric map delineating sample sites is presented on Figure 4.4.

Table 4.7. Morphometric data for Middle Embarras Lake.

Parameter	Value
Area (ha)	3.0
Volume (m^3)	102000
Maximum length (m)	794
Maximum width (m)	62
Maximum depth (m)	10
Mean depth (m)	3.4
Surface elevation (m)	1443
Percent Littoral (<3m deep)	55

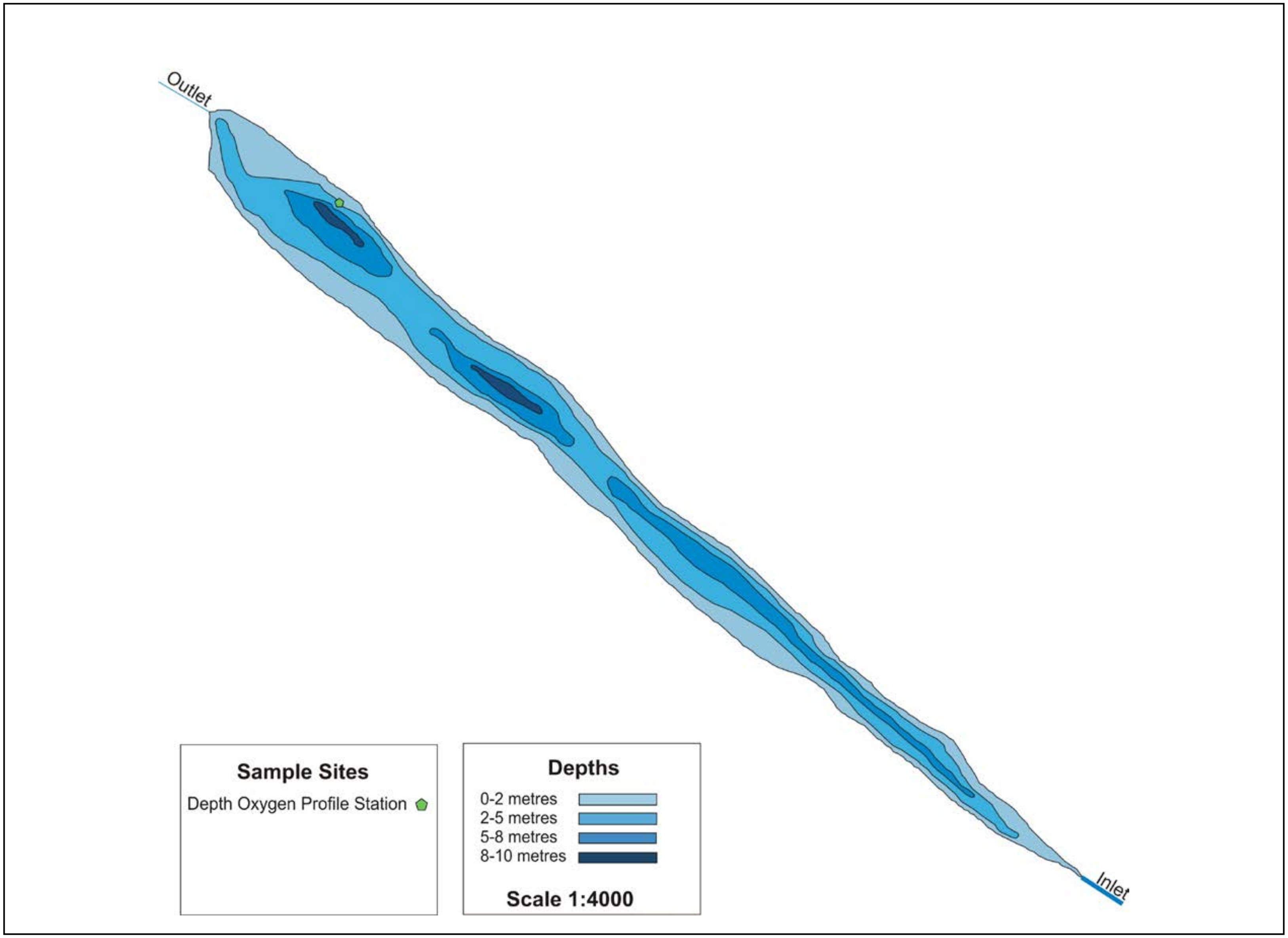


Figure 4.4. Bathymetry and Sample Locations on Middle Embarras Lake.

4.2.2. Physical and Chemical Conditions

Seasonal values for the Secchi disc transparency in Middle Embarrass Lake are presented in Table 4.8.

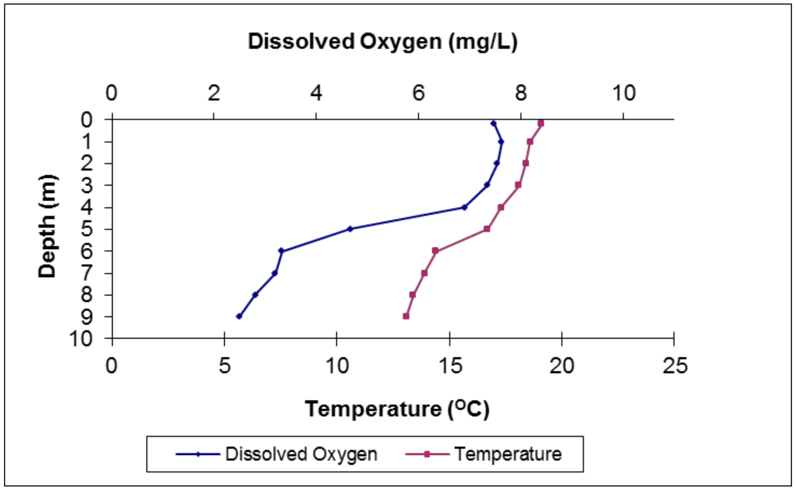
Table 4.8. Secchi disc transparency for the Middle Embarras Lake.

Date/ Season	Secchi Depth (m)	Climatic Conditions
17-Aug-11 (Summer)	0.5	Overcast, rain
5-Oct-11 (Fall)	0.5	Overcast
26-May-12 (Spring)	1.9	Clear, moderate wind.

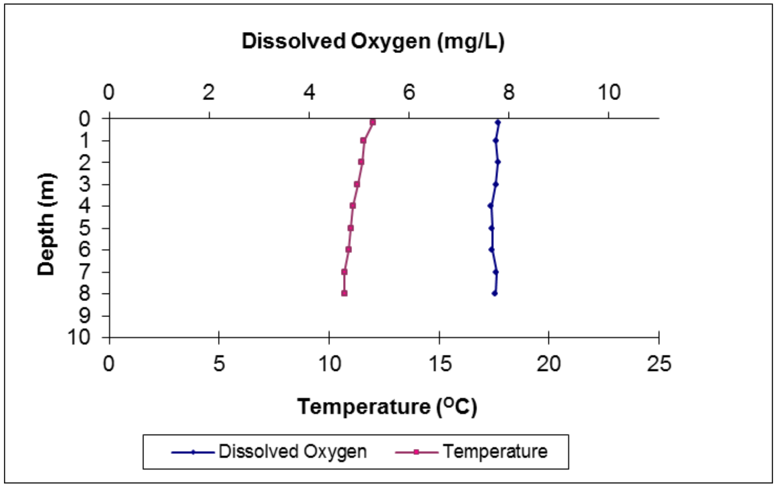
The seasonal temperature profiles obtained during the year indicated that the lake was thermally stratified during the summer with the thermocline situated between 4 and 6 metres (Figure 4.5). Isothermal conditions were present in the fall with temperatures in water column ranging from 12^{O}C near the surface to just under 11^{O}C at a depth of 8 metres. The lake was covered by approximately 0.61 metres of ice and 0.12 metres of snow when surveyed in February; surface temperatures had decreased to 0.4^{O}C while temperatures through the water column were at or near 4^{O}C. In the spring temperatures ranged from 10.5^{O}C at the surface to 6.1^{O}C near lake bottom (9 m depth) with the thermocline situated between 4 and 5 metres.

The Middle Embarras Lake exhibited a clinograde oxygen profile. Oxygen concentrations were lower in the hypolimnion compared to the epilimnion in the summer and winter and were relatively constant within the water column in the spring and fall (Figure 4.5).

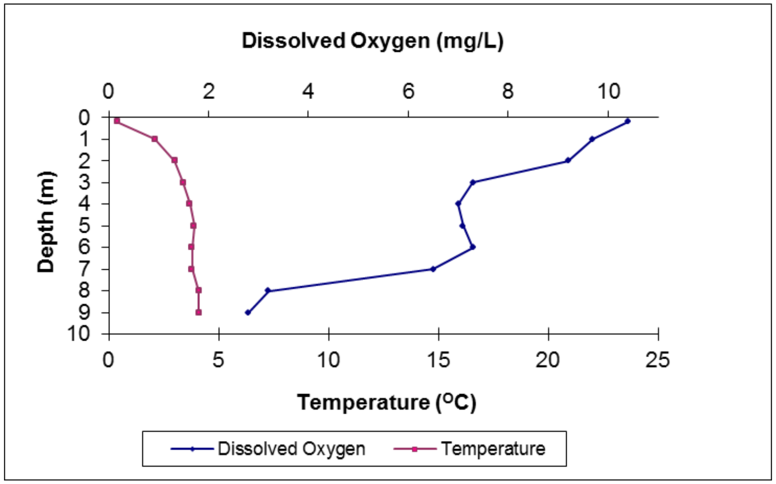
Specific conductivity within the water column was fairly constant during seasonal sampling events (Figure 4.6). However, the conductivity within the lake increased from spring season to winter season.



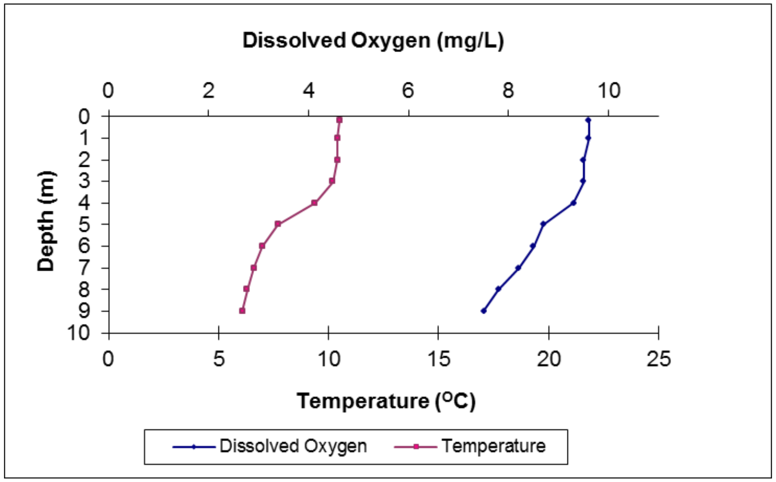
Summer



Fall



Winter



Spring

Figure 4.5. Oxygen and Temperature Profiles for Middle Embarras Lake.

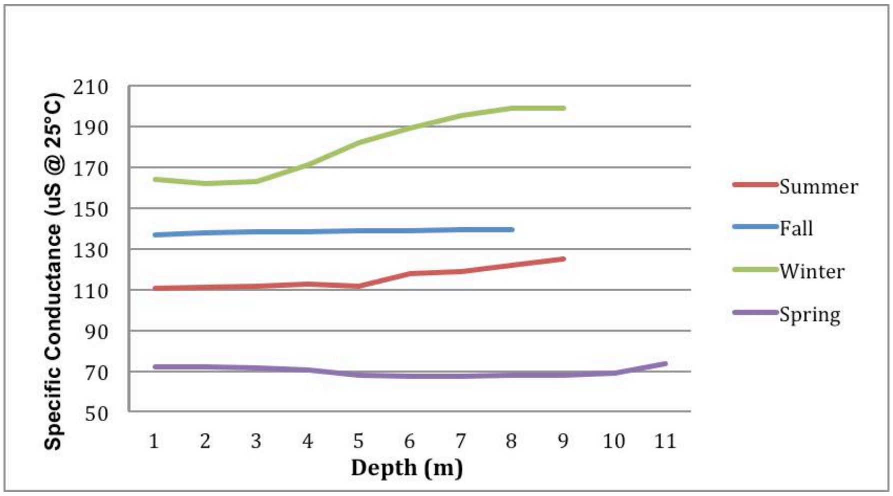


Figure 4.6. Conductivity Profiles for Middle Embarras Lake.

4.2.3. Aquatic Macrophytes

No submergent and/or floating leaf macrophytes were observed during the survey of the conducted in August.

4.3. UPPER EMBARRAS LAKE

4.3.1. Morphometric Data

Morphometric data are summarized in Table 4.9. A bathymetric map of the lake showing benthic, zooplankton, and limnological sampling sites is presented in Figure 4.7.

Table 4.9. Morphometric data for Upper Embarras Lake.

Parameter	Value
Area (ha)	5.0
Volume (m^3)	160 000
Maximum length (m)	851
Maximum width (m)	110
Maximum depth (m)	8.0
Mean depth (m)	3.2
Surface elevation (m)	1450
Percent littoral ((<3m deep)	56

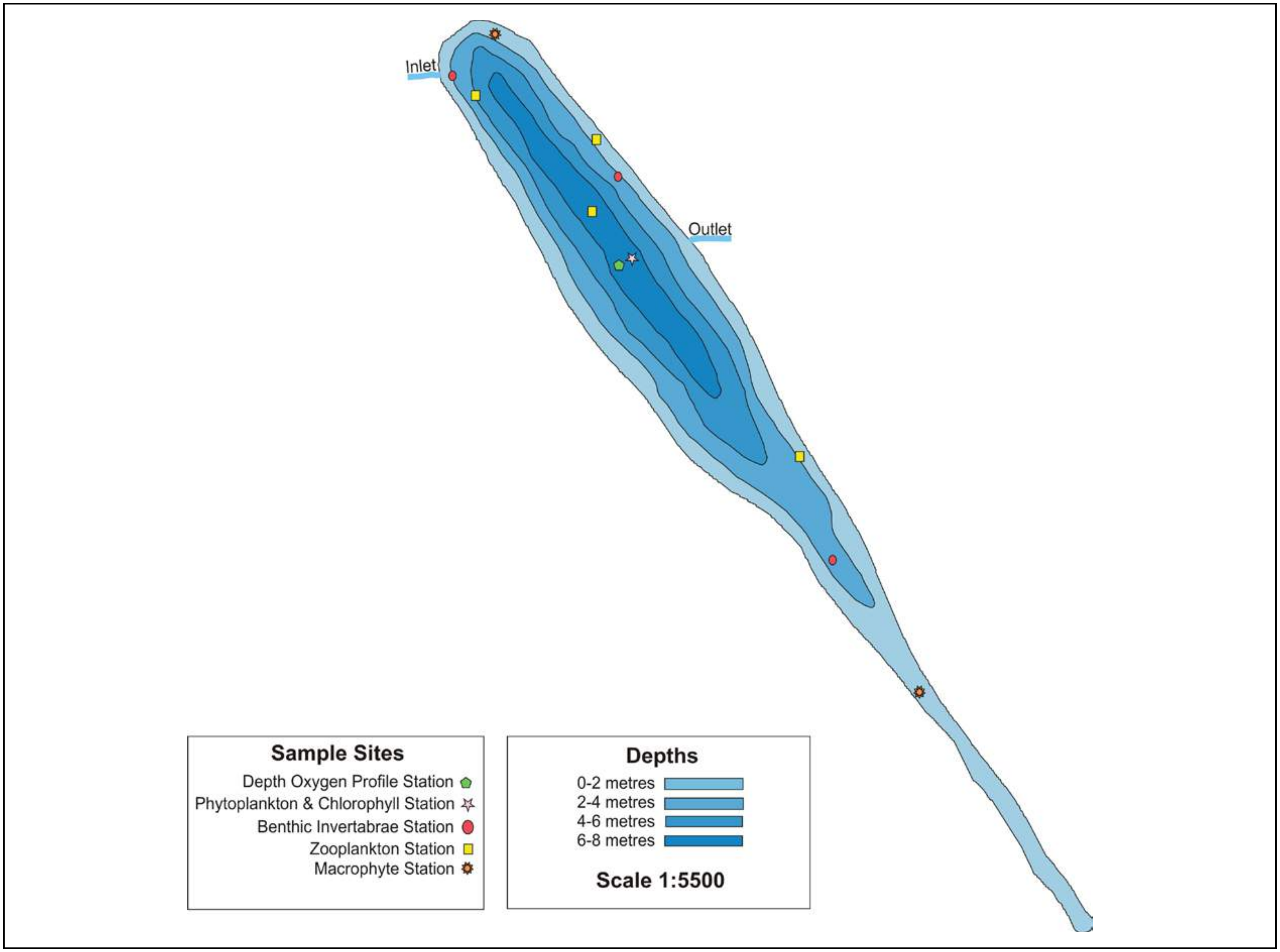


Figure 4.7. Bathymetry and Sample Locations on Upper Embarras Lake.

4.3.2. Physical and Chemical Conditions

The Secchi disc transparency in Upper Embarras Lake varied over the course of the sampling period (Table 4.10).

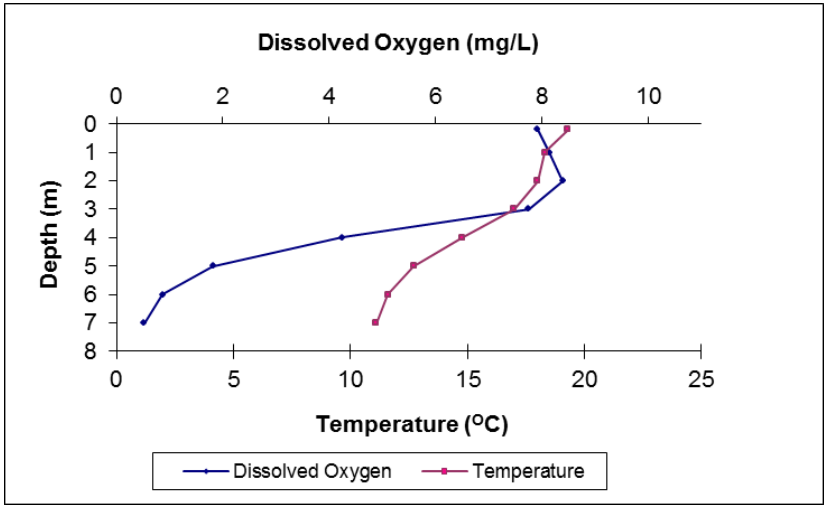
Table 4.10. Secchi disc transparency for Upper Embarras Lake.

Date/ Season	Secchi Depth (m)	Climatic Conditions
16-Aug-11 (Summer)	2.8	Partly overcast.
05-Oct-11 (Fall)	3.0	Partly sunny.
26-May-12 (Spring)	1.9	Sunny, moderate wind

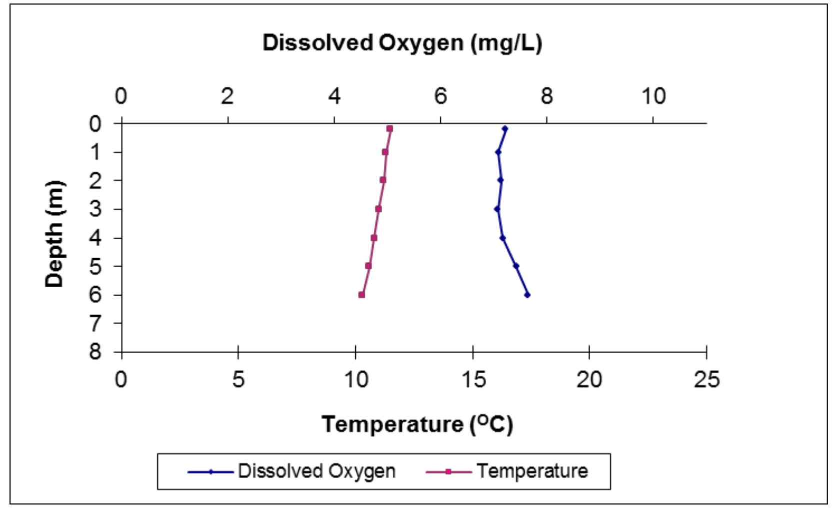
The lake was thermally stratified during the summer with temperatures ranging from about 19^{O}C near the surface of the lake to 11^{O}C at 7 m depth (Figure 4.8). Isothermal conditions persisted in the fall with temperatures near 11^{O}C throughout the water column. The lake was covered by approximately 0.67 m of ice and 0.06 m of snow when assessed in February 2012; water temperatures increased with depth from 1.0 ^{O}C at the ice surface to 4.2 ^{O}C near the lake bottom. Thermal stratification was evident in the spring with the thermocline present between 3 and 5 metres.

The Upper Embarras Lake exhibited a clinograde oxygen profile in general (Figure 4.8). Dissolved oxygen concentrations were lower in the hypolimnion than the epilimnion during the summer and winter and it appeared that the lake had already stratified when sampled in the spring. Oxygen concentrations were relatively constant within the water column in the fall.

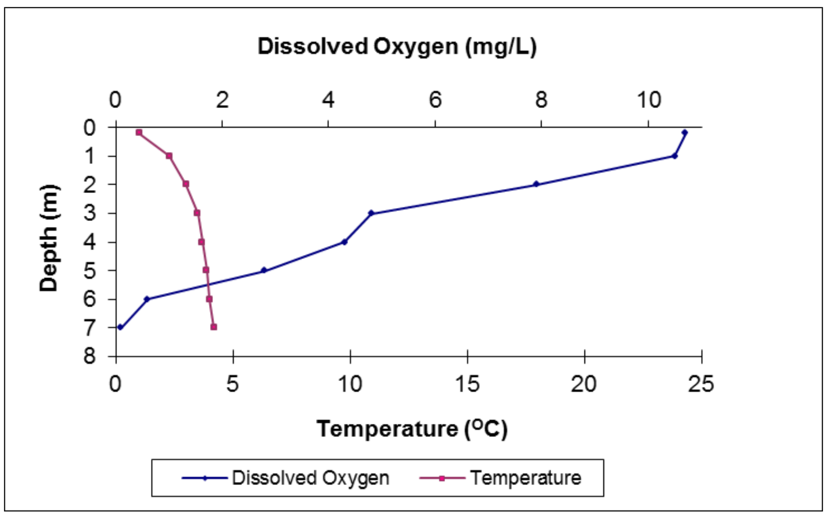
The specific conductivity of the lake water increased with depth in all seasons (Figure 4.9). In general, conductivity within the lake increased from the spring season to winter season.



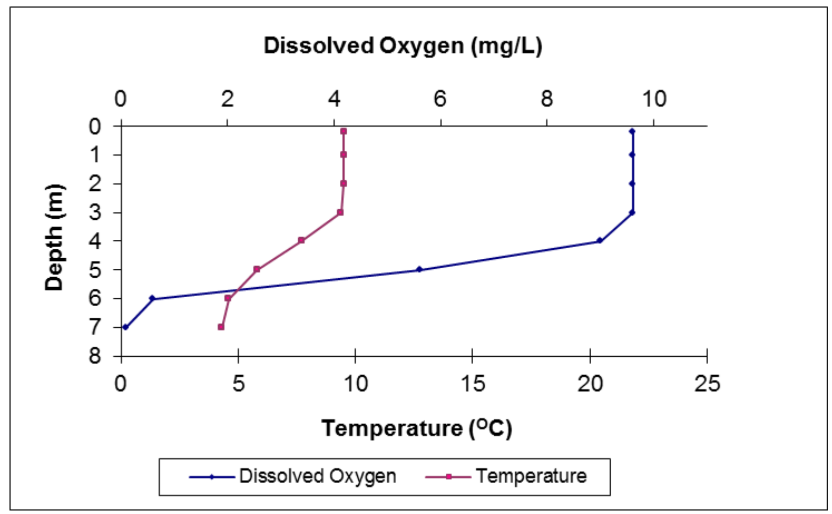
Summer



Fall



Winter



Spring

Figure 4.8. Oxygen and Temperature Profiles for Upper Embarras Lake.

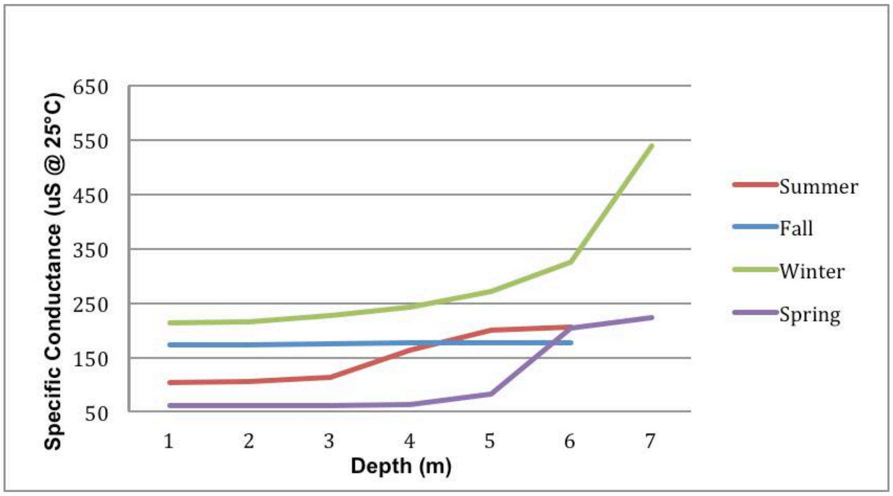


Figure 4.9. Conductivity Profiles for Upper Embarrass.

Alkalinity and pH values indicate that the lake was well buffered and non-acidic (Table 4.11). Water in the lake was of a bicarbonate-sodium type with an ionic dominance of Ca^+ > Na^+ > Mg^+ > K^+ (cations) and HCO_3^- > SO_4^- > Cl^-. (anions). With the exception of iron (epilimnion only), and manganese (hypolimnion only), all parameters were within the water quality guidelines specified by CCME and the Province of Alberta (Table 4.11).

Table 4.11. Water Quality Data for Upper Embarras Lake.

Parameter	Units	Epilimnion	Hypolimnion
Kjeldahl Nitrogen	mg/L	0.27	0.24
Phosphorus	mg/L	<0.05	<0.05
Organic Carbon	mg/L	7.5	7.6
Calcium	mg/L	13.5	24.1
Iron	mg/L	0.39	0.23
Magnesium	mg/L	2.6	4.9
Manganese	mg/L	0.036	0.197
Potassium	mg/L	0.4	0.9
Silicon	mg/L	3.73	3.82
Sodium	mg/L	5.7	9.5
Sulfur	mg/L	1.9	4.7
Mercury	mg/L	<0.0001	<0.0001
Aluminum	mg/L	0.05	0.07
Antimony	mg/L	<0.0002	<0.0002
Arsenic	mg/L	0.0006	0.0010
Barium	mg/L	0.040	0.092
Beryllium	mg/L	<0.0001	<0.0001
Bismuth	mg/L	<0.0005	<0.0005
Boron	mg/L	0.01	0.017
Cadmium	mg/L	0.00001	<0.00001
Chromium	mg/L	<0.0005	0.0008
Cobalt	mg/L	<0.0001	0.0003
Copper	mg/L	0.001	<0.001
Lead	mg/L	0.0001	<0.0001
Lithium	mg/L	0.003	0.006
Molybdenum	mg/L	<0.001	0.003
Nickel	mg/L	0.0010	0.0015
Selenium	mg/L	<0.0002	0.0003
Silver	mg/L	<0.00001	<0.00001
Strontium	mg/L	0.108	0.232
Thallium	mg/L	<0.00005	<0.00005
Tin	mg/L	0.002	0.006
Titanium	mg/L	0.0008	0.0010
Uranium	mg/L	<0.0005	0.0007
Vanadium	mg/L	0.003	0.002
Zinc	mg/L	0.003	0.002
Solids	mg/L	<1	<1
pH		7.76	7.57
Electrical Conductivity	µS/cm at 25 C	111	201
Chloride	mg/L	0.5	<0.4
Nitrate - N	mg/L	<0.01	0.03
Nitrite - N	mg/L	<0.005	<0.005
Nitrate and Nitrite - N	mg/L	<0.01	0.03
Sulfate (SO4)	mg/L	6.0	15.0
Hydroxide	mg/L	<5	<5
Carbonate	mg/L	<6	<6
Bicarbonate	mg/L	64	107
P-Alkalinity	mg/L	<5	<5
T-Alkalinity	mg/L	53	88
Total Dissolved Solids	mg/L	62	110
Hardness	mg/L	45	83
Ionic Balance	%	100	104

* composite samples
- exceedences are shaded

4.3.3. Benthic Invertebrates

Sampling for benthic invertebrates was conducted in littoral habitat (Figure 4.7). Diptera were numerically dominant and accounted for four of the seven taxa sampled (Table 4.12). Other groups were present in very low numbers.

Table 4.12. Benthic Macroinvertebrate Composition for Upper Embarras Lake.

Taxon	Density (per 0.023 m^2) Replicate			Mean #Organisms/Sample
	1	2	3	
Dipters				
Ceratopogonidae				
Ceratopogoninae			4	1.3
Chironomidae				
Orthocladiinae	22	4	10	12
Tanytarsini	43	4	82	43
Empididae				
Simuliidae		4		1.3
Crustacea				
Ostracoda				
Cyprididae	4			1.3
Cladocera				
Daphnia sp.	5		4	3
Pelecypoda				
Sphaeriidae				
Pisidium sp.	1			0.3
Total	75	12	100	62.3
Total taxa	5	3	4	7

4.3.4. Zooplankton

Eleven taxa were found in the Upper Embarras Lake; Rotifera were numerically dominant while Cyclopoida, Cladocerans, and Calanoida comprised the remainder of the zooplankton community (Table 4.13).

Table 4.13. Zooplankton Abundance for Upper Embarrass Lake.

Taxa	Density per m³					
	Replicate #					Mean #Organisms
	1	2	3	4	5	
Calanoida						
Leptodiaptomus sicilis	30	0	0	0	0	6
Calanoid copepodid	0	0	0	34	0	7
Cladocera						
Daphnia pulex	1091	2614	3546	2481	1026	2152
Bosmina longirostris	0	0	0	0	89	18
Cyclopoid						
Dicyclops bicuspidatus	1970	1352	1696	1937	2365	1864
Cyclopoid copepodid	3636	2073	2813	5335	3034	3378
Cyclopoid *(nauplii)*	23368	0	7282	18195	0	9769
Rotifera						
Ascomorpha sp	0	0	0	18195	22724	8183
Polyathra dolicoptera Idelson	0	10517	0	0	0	2103
Polyathra euryptera Wierzejski	7790	0	0	0	7140	2986
Synchaeta	15579	0	0	0	11362	5388
Total	53464	16556	15337	46177	47740	35854
Total Taxa	7	4	4	6	7	5.6

4.3.5. Phytoplankton

Phytoplankton collections in Upper Embarras Lake revealed a total of 18 taxa (Table 4.14). Chrysophyta were dominant while other types were less common. The chlorophyll *a* concentration for the lake was 0.518 mg/m^3.

Table 4.14. Phytoplankton Abundance for Upper Embarras Lake.

Genus/Species	Cell/Colony Density (cells/mL)
Bacillariophyta	
Diatoma sp.	0.67
Cryptophyta	
Cryptomonas reflexa	15.89
Katablepharis ovalis	35.63
Rhodomonas	26.10
Chrysophyta	
Chrysochromulina parva	1.00
Dinobryon divergens	224.49
D. divergens statospore	10.96
Kephyrion sp	1.34
Mallomonas sp.	0.34
Pyrrophyta	
Peridinium sp	0.34
Chlorophyta	
Ankistrodesmus setigera	2.01
Characium sp.	1.00
Monoraphidium	0.34
Sphaerocystis schroeteri	2.34
Unidentified colonial	0.67
Cyanophyta	
Lyngbya limnetica	9.03
Oscillatoria sp.	3.01
Phormidium	2.34
Total	337.49
Total Taxa	18

4.3.6. Aquatic Macrophytes

Aquatic macrophytes were present in Upper Embarras Lake in the summer of 2011; Narrow leaf pondweed (*Potamogeton strictifolius*), and broad leaf pondweed *(Potamogeton natans*) were sparsely distributed within the lake. The majority of macrophyte development had occurred along the north and south shores of Upper Embarras Lake in water less than two metres deep.

4.4. LOTIC HABITAT

4.4.1. Spawning Surveys

Spawning surveys conducted during the fall indicated that Brook Trout spawning had commenced by October 5th. Four redds and four possible redds were identified downstream of the fish exclusion weir (Table 4.15). No evidence of fall spawning was observed upstream of the weir.

Spawning surveys conducted in late May found two possible Rainbow Trout redds downstream of the fish exclusion weir and one possible redd upstream of the exclusion structure in the connecting channel between the Middle and Upper Lake (Table 5.15). No spawning was observed during subsequent spawning surveys conducted in June (Table 4.15).

Table 4.15. Summary of Spawning Survey Results.

Survey Date	Downstream of Fish Exclusion Structure	Upstream of Fish Exclusion Structure
October 5th-6th 2011	4 BKTR redds, 4 possible	No activity observed
May 26th, 2012	2 possible RNTR redds	1 possible redd upstream of middle lake
June 1st, 2012	No spawning observed, 3 large RNTR attempting to move upstream at weir	No spawning observed
June 21st, 2012	No spawning observed.	No spawning observed.

4.4.2. Fish Capture

Electrofishing surveys of the constructed channel upstream of the fish exclusion structure resulted in the capture of Rainbow Trout in both August and October (Table 4.16). In addition, fish were observed rising in the Upper Embarras Lake during summer field investigations.

Electrofishing surveys of the Embarras River downstream of the exclusion structure captured both Brook Trout and Rainbow Trout (Table 4.16). Brook Trout were more common than Rainbow Trout in August while Rainbow Trout outnumbered Brook Trout during the fall sampling. A record of sampling effort and individual fish capture data is presented in Appendix D.

Table 4.16. Summary of Fish Capture Results for the Embarras Lake System in 2011.

Sample Section	Date	Species	n	Fork Length (mm)			Weight (g)		
				Mean	Min	Max	Mean	Min	Max
u/s of exclusion structure	18-Aug-11	RNTR	25	66.0	53	78	3.0	1	6
	5-Oct-11	RNTR	1	106	-	-	18	-	-
d/s of exclusion structure	18-Aug-11	RNTR	21	133.3	56	247	39.8	3	176
		BKTR	50	171.3	71	226	64.8	4	145
	5-Oct-11	RNTR	20	140.8	83	262	40.9	4	223
		BKTR	10	161.0	82	208	50.1	5	88

4.4.3. Benthic Invertebrates

The number of taxa present was highest at ER-B4 and lowest at ER-B2 (table 4.17). Total abundance of invertebrates ranged considerably between sites, with the highest numbers at ER-B1 and the lowest at ER-B2. Chironomidae were numerically dominant at all sites but were particularly common at ER-B1 where they comprised almost 90% of the total sample. Generally, ER-B1, B2, and B3 all had a relatively low proportion of EPT (Ephemeroptera, Plecoptera, Trichoptera) counts compared to ER-B4. Oligochaeata were highest at ER-B3 and lowest at ER-B1 and Nematodes were only present at ER-B1 and B2.

Table 4.17. Summary of Benthic Invertebrate Sampling Results from Lotic Sites.

Taxon	Mean Count from 3 Replicates (per 0.1m^2)			
	ER-B1	ER-B2	ER-B3	ER-B4
Ephemeroptera				
Baetidae				
Baetis sp.	12.0	23.0	57.7	457.7
Callibaetis sp.			43.0	
Ephemerellidae				
Serratella sp.	6.5	1.0		132.3
Heptageniidae				
Cinygmula sp.	10.0			49.0
Leptophebiidae				
Paraleptophlebia sp.			15.5	11.0
Siphlonuridae				
Parameletus.sp.	8.0	1.0		20.5
Plecoptera				
Chloroperlidae				21.0
Nemouridae				
Zapada sp.	2.0	1.0		106.0
Visoka sp.				23.7
Perlodidae				50.7
Megarcys sp.				6.5
Isoperla sp.			1.0	1.0
Isogenoides sp.				12.0
Capniidae	1.0		5.0	30.0
Trichoptera				
Brachycentridae				

Table 4.17. Continued

Brachycentrus sp.	2.0			11.0
Glossosomatidae				
Glossosoma sp.			1.0	9.5
Limnephilidae				
Dicosmoecus sp.	1.5	1.7		
Hydroptilidae				
Hydroptila sp.			1.0	10.5
Phryganeidae				
Phryganea sp.			1.0	
Rhyacophilidae				
Rhyacophila sp			4.0	14.0
Hydropsychidae				
Cheumatopsyche sp.			1.0	
Diptera				
Ceratopogonidae				
Ceratopogoninae	16.0			10.0
Chironomidae				
Orthocladiinae	215.3	454.3	524.3	142.7
Tanypodinae	18.5			11.0
Tanytarsini	3279.0	477.7	96.7	19.5
Chironomini	1.0		26.7	1102.0
Pupae	4.0	8.0		10.0
Empididae			1.0	2.0
Simuliidae	98.3	305.7	399.3	20.5
Pupae	2.0	32.5	3.0	
Tipulidae				
Limoniinae				
Dicranota sp.	4.3		7.3	32.0
Hexatoma sp.			1.0	8.0
Tipulinae				
Tipula sp.				5.0
Anthomyiidae	1.5	1.0	5.3	2.0
Psychodidae				
Pericoma/Telmatoscopus				5.5
Coleoptera				
Elmidae				55.3
adult				5.0
Dytiscidae			25.7	
adult			34.0	
Hemiptera				
Corixidae (adult)			4.0	
Nematoda	9.0	1.0		
Oligochaeta				
Naididae				
Specaria sp.	18.3	37.0	174.7	30.0
Arachnida				
Acari				
Hydrarachnidia	23.0		18.3	39.5
Crustacea				
Copepoda				
Cyclopoida	110.0	7.0	21.0	120.0
Calanoida		20.0	115.3	
Ostracoda				
Cyprididae	4.0	4.0		14.5
Cladocera				
Daphnia sp.	151.7	153.0	446.3	
Pelecypoda				
Sphaeriidae				
Sphaerium sp.		1.0		
Pisidium sp.				
Gastropoda				
Limnaeidae			1.5	
Hirudinea				
Erpobdellidae	7.0	5.7		4.0
Glossiphoniidae	29.0	2.7	1.0	18.0
Hydrozoa		267.7	30.7	
Total (average of 3 replicates)	4035.0	1805.8	2067.3	2622.8
Total Taxa	26	21	30	38

4.4.4. Temperature Regime

Temperature data collected in the Embarras Lake System in 2011 is presented in Figure 4.10. Overall, water temperatures in the Embarras River downstream of the lakes averaged approximately 2^{0}C warmer than upstream of the lakes.

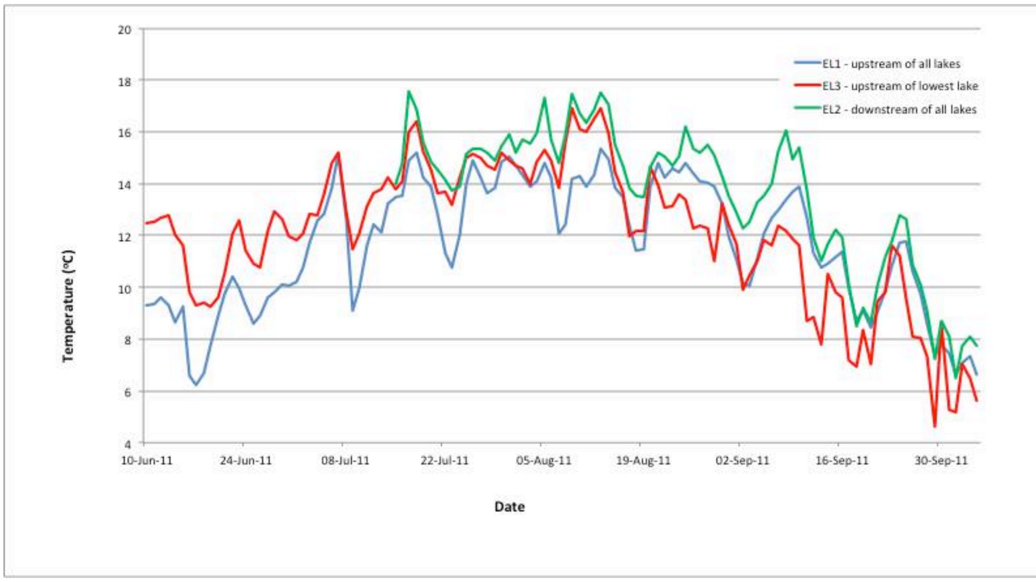


Figure 4.10. Mean Daily Temperatures in the Embarras River in 2011.

5.0 DISCUSSION

Results from monitoring conducted during the 2011-12 program represent the initial stages of lake development post reclamation and were undertaken to provide baseline information on the existing physical, chemical, and biological conditions in the lakes and connecting channels.

5.1. LENTIC HABITAT

5.1.1. Summary of 2011-12 Monitoring

The inlet and outlets of the lakes were stable (Table 5.1). Side slopes were generally stable and riparian vegetation was beginning to become established but areas of sparse vegetation, particularly on the slopes close to the haulroad, were fairly common.

Table 5.1. Characteristics of Embarras End Pit Lakes in 2011-12.

Parameter		Indicator	Lower Embarras	Middle Embarras	Upper Embarras
Physical		Inlet/Outlet Stability	Stable	Stable	Stable
		Shoreline Erosion	Some Erosion		Stable
Chemical		Circulation	Dimictic	Dimictic	Dimictic
		Water Quality[1] Exceedances	E (Fe, Al) H (Mn)	n/m	E (Fe) H (Mn)
Biological	Benthic Invertebrates	Average Density/Sample	34.7	n/m	62.3
		Total Taxa	6	n/m	8
	Zooplankton	Average Density/m^3	30253	n/m	35854
		Total Taxa	9	n/m	11
	Phytoplankton	Average Density (cells/ml)	389.1	n/m	337.5
		Total Taxa	18	n/m	18
	Aquatic Macrophytes	Present/Absent	Absent	Absent	Present
	Fish	Present/Absent	Present	Present	Present

1. E – epilimnion, H – hypolimnion

Results of the limnological investigations indicate that all three of the Embarras Lakes were dimictic with complete mixing occurring in the spring and fall (Table 5.1). Water in the lakes was of bicarbonate type and did not demonstrate a sodium ion dominance, which may indicate groundwater sources have less impact on these lakes than other end-pit lakes in the area (Brinker 1991, Hatfield, 2008, 2011, Stemo 2005, Pisces 2011). The majority of measured water quality variables did not exceed thresholds for the protection of aquatic life. Iron and aluminum concentrations exceeded CCME water quality guidelines in the Lower Embarras Lake while iron concentrations in the epilimnion of the Upper Embarras Lake also exceeded guideline levels. Both of the sampled lakes had nutrient concentrations corresponding to oligotrophic trophic status as defined in Wetzel (2001).

The benthic invertebrate assemblage within the lakes was typical of the early colonization stage in lake development. Densities were relatively low, there was limited diversity, and populations were dominated by Chironomids.

Zooplankton taxa collected from the Upper and Lower Lakes were common components of zooplankton communities in Alberta. Total taxa counts from each lake ranged from 9 to 11 and average densities ranged from 30,253 to 35,854 individuals per cubic metre (Table 5.1). Rotifers were numerically dominant in the Upper Lake while Cyclopoids were the most abundant group in the Lower Lake.

Chlorophyll *a* concentrations were quite low in both the Upper and Lower Lakes; however, the phytoplankton diversity was quite high. Phytoplankton composition in the Upper Embarras Lake was dominated by Chrysophyta while Chrysophyta, Chlorophyta and Cyanophyta were all dominant in the Lower Lake.

5.1.2. Comparision to Fairfax Lake

Draft guidelines for end pit lake development at coal mine operations were prepared in 2003 by the End Pit Lake Working Group to assist government and industry in designing, managing, monitoring, and evaluating end pit lakes (EPLWG 2003). Evaluation and performance criteria provided in the guideline document are used to assess whether a lake has met or is meeting its intended objective. While the targets/goals used to measure success in terms of physical and chemical parameters are based on specific indicators, the measure of success for biological targets/goals are typically based on comparison to “local lakes”.

There is one local natural lake in the general vicinity of the Coal Valley Mine. Fairfax Lake is a shallow (<5m mean depth) foothills lake (Radford 1979, Luscar 1992), which is generally comparable to the Embarras Lakes (Table 5.2). Overall, the biotic communities of the Embarras Lakes were similar to Fairfax Lake (Table 5.2). Zooplankton and benthic invertebrate diversity was lower in the Embarras Lakes compared to Fairfax Lake but Phytoplankton diversity was higher. Zooplankton and phytoplankton densities were lower but relatively comparable between the lakes while benthic invertebrate densities were notably lower in the Embarras Lakes compared to Fairfax Lake. Aquatic macrophyte communities have only become established in the Lower Embarras Lake

Table 5.2. Characteristics of Embarras Lakes and Fairfax Lake.

Lake	Area (Ha)	Max Depth (m)	Mean Depth (m)	Littoral (% <3 m deep)	Crustacean Zooplankton		Benthos		Phytoplankton		Macrophytes	Fish
					Density (n/l)[1]	# of taxa	Density (n/m[2])	# of taxa	Density (n/ml)	# of taxa	# of taxa	Species
Lower Embarras	6.6	18	7.34	30	30.3	9	1509	6	389.1	18	0	RNTR
Middle Embarras	3.0	10	3.4	55	-	-	-	-	-	-	0	RNTR
Upper Embarras	5.0	8	3.2	56	35.9	11	2709	8	337.5	18	2	RNTR
Fairfax Lake[1]	28.4	7.6	3.2	60[2]	41.3	22	6450	11	522.9	12	-	RNTR/ BKTR

1. Hatfield 2008
2. Derrived from Hatfield 2011

5.2. LOTIC HABITAT

The inlet and outlets of the lakes and the connecting channel were all stable (Table 5.1). Proposed habitat enhancements (i.e. spawning gravel, large woody debris) for the connecting and outlet channels had not yet been constructed but are expected to be installed in 2012 or 2013. Riparian vegetation along the connecting channels was somewhat limited and was not fully established. Habitat within the connecting channels was comprised mainly of shallow run and riffle habitat. However, in October 2011, the channel between the Middle and Lower Lake was dry and the outlet channel downstream of the Lower Lake was dry for approximately 150 m.

During the later stages of construction of the end pit lake system (early 2011) approximately 80 to 100 Rainbow Trout were found to have colonized the Lower Embarras Lake (Dean Woods *Personal Communication*). In September 2011, Alberta Environment and Sustainable Resource Development stocked 208 native Athabasca Rainbow Trout into the Upper Embarras Lake (Ryan Cox *Personal Communication*). The stocked fish ranged in size from 29 mm to 119 mm with a mean length of 80 mm (Ryan Cox *Personal Communication*). Spawning surveys conducted during spring 2011 confirmed Rainbow Trout spawning downstream of the fish exclusion structure and found some evidence to indicate that spawning may be occurring in the connecting channels of the end pit lake system. Fish sampling within the connecting channels during the summer of 2011 (prior to AESRD stocking) resulted in the capture of several Rainbow Trout that ranged in size from 53 mm to 78 mm long. Sonnenberg (2011) noted that growth rates for stream resident Rainbow Trout downstream of end pit lakes were significantly greater that growth rates for Rainbow Trout observed upstream of pit lakes. Considering this information and given the thermal regime of the lake system, it seems possible that egg and fry development was accelerated (due to the slight warming effect of the lakes) such that some of the captured fish represent young of the year (yoy) age class resulting from successful spawning in the spring of 2011.

The fish exclusion structure appears to be effectively precluding the movement of Brook Trout into the Embarras Lake System since Brook Trout were found downstream of the barrier but not upstream.

6.0 CONCLUSIONS AND RECOMMENDATIONS

Monitoring and assessing the progress of young waterbodies towards target values can be complicated by the inherent inability of an immature lake to exhibit functional equivalency to an older system (EPLWG 2003). Over time, young waterbodies typically progress from low nutrient, chemically imbalanced waters to a more fertile, chemically balanced state. The timeline and extent of this transition is variable between lakes. At present the Embarras Lakes appear to be developing towards being productive lakes that are similar to local waterbodies. Initial results indicate that certain parameters have not yet reached target goals while other parameters have (Table 6.1). Continued monitoring will document the development of the lakes and should help identify potential limiting factors. The following observations and recommendations have been made in the interest of maximizing the potential success of the Embarras End Pit Lake system. Additional reclamation and/or enhancement work may be required depending on future monitoring results.

- Unvegetated areas (including the haul road slopes) along the Middle and Lower Embarras Lakes appear to be resulting in sediment inputs into the Lake during the open water season.
- Cover within the Embarras River constructed connecting channels is limited. It is recommended that dense plantings of larger woody species (willows, deciduous trees, and coniferous trees) be installed along reconstructed channels.
- Appropriate sized Gravel (5m to 15mm) should be strategically placed within the constructed channels to create spawning and rearing habitat.
- Large woody debris (conifers with intact limbs) should be anchored at select locations within the constructed channel to provide cover for spawning fish.

Table 6.1. Pit lake evaluation/performance assessment for select chemical and biological parameters for the Embarras Lakes based on End Pit Lake Working Group (2003) guidelines.

Design Factor	Indicator	Parameters	Targets/Goals	Lake	Target/Goal Met?	Rationale
Chemical	Overturn	Summer stratification Fall mixing	Presence of annual summer stratification and fall overturn	All	Yes (dimictic)	• Table 5.1
	Water quality	Water chemistry in lake and discharge	Meet Surface Water Quality Guidelines used in Alberta Chemical end points fall within regional range	Upper Lower	Uncertain	• Table 5.1 • Most parameters are under guidelines. Only manganese and iron exceed Provincial Guideline. • Aluminum and Iron exceeded Federal Guidelines in Lower Lake, only Iron in Upper Lake.
Biological	Biodiversity Biomass Productivity	Benthic Invertebrates	Comparable to local lakes and/or regional fisheries management objectives (not applicable, no comparable local lakes). Comparable to similar natural mountain lakes.	Upper Lower	No	• Table 5.1 • Number of taxa lower than Fairfax Lake • Average densities lower than Fairfax Lake
		Zooplankton		Upper Lower	No Uncertain	• Table 5.1 • Number of taxa present fewer than Fairfax Lake • Average densities lower but comparable to Fairfax Lake
		Phytoplankton		Upper Lower	Yes	• Table 5.1 • Number of taxa present exceeds mean for Fairfax Lake • Average densities exceed mean for Fairfax Lake
		Macrophytes		All Lakes	No	• Table 5.1 • Number of taxa and distribution limited compared to Fairfax Lake.
		Fish (including non-game fish)		Uncertain		• Not applicable, Fairfax requires annual stocking. End goal self-sustaining Rainbow Trout population.

7.0 LITERATURE CITED

Alberta Environment. 1999. Surface Water Quality Guidelines for use in Alberta.

Boorman, J. 2003. Baseline fisheries resources assessment of waterbodies on and adjacent to the proposed Mercoal East extension. Report of Pisces Environmental Consulting Services Ltd. to Luscar Ltd. Coal Valley Mine, Edson, AB. 35 pp. + App.

Brinker. 1991. Lake Creation and Development at a Alberta Foothills Coalmine. Proceedings of the 15th Annual B.C Reclamation Symposium in Kamloops, BC. The Technical and Research Committee on Reclamation.

Canadian Council of Ministers of the Environment. 2006. Canadian Environmental Quality Guidelines: Water Quality Guidelines for the Protection of Aquatic Life. Ottawa, ON.

End Pit Lake Working Group. 2003. Guidelines for lake development at coal mining operations in mountain foothills of the northern east slopes, Report # ESD/LM/00-1, Alberta Environment, Environmental Science.

Hatfield. 2008. Coal Valley Mine: An Evaluation of Existing End-Pit Lakes. Report by Hatfield Consultants for Coal Valley Resources Inc. Edson, AB. 42 pp +App

Hatfield. 2011. An Evaluation of Water Quality in Existing End-Pit Lakes in the Coal Valley Mine Area. Report by Hatfield Consultants for Coal Valley Resources Inc. Edson, AB. 46 pp +App

Luscar Ltd. 1992. Development of sport fisheries in lakes created by coal mining operations in the eastern slopes. Progress Report #2 Limnological characteristics of study lakes. Edmonton, Alberta. 54pp. + App.

Pisces Environmental Consulting Services Ltd. 2011. Limnological surveys of five end pit lakes on the Gregg River Mine, 2009-2010. Prepared for Sherrit Coal, Gregg River Mine. Edmonton, AB. 48 pp. + App.

Radford, D.S. 1979. Alberta's high mountain lakes fisheries management program. MS report. Alberta Energy and Natural Resources, Fish and Wildlife Division, Edmonton, AB, 49 pp. + App.

Sonnenberg, R. 2011. Development of Aquatic Communities in High-Altitude Mine Pit Lake Systems of West-Central Alberta. A Thesis Submitted to the School of Graduate Studies of the University of Lethbridge in Partial Fulfillment of the Requirements for the Degree Master of Science. 175 pp + App

Stemo. E. 2005. Limnological surveys of five end pit lakes on the Gregg River Mine, 2004-05. Report of Pisces Environmental Consulting Services Ltd. to Luscar Ltd. Hinton, AB. 39 pp. + App.

Wetzel. R. G. 2001. Limnology Lake and River Ecosystems. Third Edition.

8.0 PERSONNEL COMMUNICATIONS

Cox, Ryan. December 2012. Fisheries Biologist Foothills Area. Edson, Alberta.

Woods, Dean. December 2012. Reclamation Specialist D&T Woods. Edson, Alberta.

APPENDIX A:

Photos

Lower Embarras Lake August 2011

Middle Embarras Lake August 2011

Upper Embarras Lake August 2012

Embarras Channel Upstream of Lakes in Summer 2011

Upper Embarras Lake Outlet (looking d/s) Spring 2012

Middle Embarras Lake Outlet (looking u/s) Spring 2012

Embarras Fish Exclusion Weir Spring 2012

Looking upstream from Embarrass Exclusion Weir

APPENDIX B:

Benthic invertebrate sample processing methodology

Method Used for Picking Animals and Taxonomy

The picking of animals was performed in accordance with the process developed by Wrona et al. (1982), with slight modifications. This procedure has been used for many years. It provides a good estimate of animal population in aquatic systems based on samples.

The Picking and Sub Sampling Process

The whole sample is washed through double stacked 2 mm and 106 µm meshes. All the animals that remain on the 2 mm mesh (coarse fraction) are picked. The fine fraction from the 106 µm mesh is put into an aeration apparatus and diluted with water until the total sample plus water volume is 1 litre. The sample is aerated, and when well mixed, five 50 mL sub samples are taken out of the aeration apparatus. The entire sub samples are picked using a compound microscope at 10 times magnification for the course fraction and 40 times magnification for the fine fraction. Once picking has been completed, the course and fine fraction are saved for quality assurance. The total of animals in each sub sample is determined for all taxa. After the samples are picked, quality assurance is performed to confirm that no visible animals are left in the sample.

All the animals are classified using the keys: '*Aquatic Invertebrates'* of Alberta by Hugh F. Clifford (1991), '*Ecology and Classification of North American Freshwater Invertebrates'* by James H. Thorp and Alan P. Covich (1991), and '*Fresh Water Invertebrates of the United States'* by Robert W. Pennak (1978).

The complete hierarchical classification through Phylum, Class, Order, Family, Genus, and Species is attempted for all taxa. However, in some cases when parts of the animals are missing, complete classification cannot be performed. In that case, classification was performed to the level recognizable to the taxonomer.

Reference:

Wrona, F.J., Culp, J.M. and Davies, R.W. 1982. *Macroinvertebrate subsampling: a simplified apparatus and approach*. Can. J. Fish. Aquat. Sci. 39:1051-1054

APPENDIX C:

Zooplankton sample processing methodology

Zooplankton were enumerated from three 1-15 ml sub-samples using a dissecting microscope at magnifications 10-50x for macro-zooplankton, and at magnification 100-400x for rotifers and copepod nauplii using Nikon compound microscope.

Macro-Zooplankton were identified using keys from Brooks (1957), Edmondson (1959), Chengalath (1971), Grothe and Grothe (1977), Pennak (1978), and Clifford (1991), The micro-zooplankton were identified using keys from Chengalath (1971), Grothe & Grothe (1977), Stemberger (1979), Clifford (1991) and Thorp & Covich (1991).

Lengths were determined directly on the microscope with a micrometer in the ocular. Generally, lengths were measured for the first 50 individuals of each species or genus observed. Where less than 30 individuals occur, the number measured equaled the average number counted over all sub-samples.

Zooplankton biomass was calculated for each sample. Weights were calculated from published length-weight regressions; general equations for taxa were used where length-weight equations are not available for specific species (Table 1). For each sample, mean individual weights for each species were calculated by averaging estimated weights. Total biomass for each group (species or developmental stage) was calculated as the product of its density and estimated mean individual weight.

Table 1. Length-weight regressions used in calculating zooplankton weights.

Organism	Equation (ug=microgram)	Reference
Copepods (N I-adults)	lnW(ug) = 1.9526 + 2.399 lnL(mm)	Bottrell et al. 1976
Daphnia spp.	lnW(ug) = 1.6 + 2.84' lnL(mm)	Bottrell et al. 1976
Ceriodaphnia spp.	lnW(ug) = 2.8713 + 3.079 lnL(mm)	Bottrell et al. 1976
Scapholeberis spp.	lnW(ug) = 2.5623 +3.338 lnL(mm)	Downing & Rigler 1984
Chydorus sphaericus	lnW(ug) = 4.543 + 3.6360 lnL(mm)	Downing & Rigler 1984
Other Cladocerans	lnW(ug) = 1.7512 + 2.653lnL(mm)	Bottrell et al. 1976
Rotifers	lnW(ug) = -10.3815 + 1.574llnL(mm)	Sternberger & Gilbert. 1987

References

Brooks, J. L. 1957. The systematics of North American daphnia. Mem. Conn. Arts and Sci. 13:1-180.

Bottrell, H.H., A. Duncan, Z.M. Gliwicz, E. Grygierek, A. Herzig, A. Hillbricht-Ilkowska, H. Kurasawa, P Larsson, and T. Weglenska. 1976. A review of some problems in zooplankton production studies. Norw. J. Zoot 24: 419-546.

Chengalath, R.C., C.H. Fernando & M.G. George. 1971. The Planktonic Rotifera of Ontario with keys to genera and species. University of Waterloo Biology Series, Waterloo, ON. 40 p.

Clifford, H. 1991. Aquatic inveterbrates of Alberta. University of Alberta Press. 538 p.

Downing, J.A., and F .H. Rigler. 1984. A manual on methods for the assessment of secondary productivity in fresh waters. Blackwell Scientific Publications. 501 p.

Edmondson, W.T. 1959. Freshwater Biology. 2nd ed. John Wiley and Sons, New York, N.Y.

Grothe, D.W. & D. R. Grothe. 1977. An illustrated key to the planktonic rotifers of the Laurentian Great Lakes. U.S. Environmental Protection Agency, Chicago, IL. 53 p.

Pennak, RW. 1978. Freshwater invertebrates of the United States, 2nd edition. John Wiley and Sons Inc., New York, NY. 803 p.

Stemberger, R.S. 1979. A Guide to Rotifers of the Laurentian Great Lakes. US Envir. Prot. Agency, Envir. Mon. Support Lab, Cincinnati, Ohio. 182 pp.

Stemberger, R.S. & J.J. Gilbert. 1987. Plantonic rotifer defences. In: Kerfoot, W.C. and A. Sih (eds.) Predation: Direct and indirect impacts on aquatic communities. University Press of New England, Hanover, NH. P. 227-239.

Thorp, J.H. & A.P. Covich. 1991. Ecology and classification of North American freshwater invertebrates. Academic Press. 911 p.

APPENDIX D:

Fish Capture Record

Electrofishing Record				
Date:		18-Aug-11		
Stream Name:		Embarrass River		
UTM reference:		503436E, 5882209N, NAD 83, ZN11		
Sample Site:		Upstream of exclusion barrier		
Section length (m):		360m		
Duration (seconds):		2384		
Sample	Species	Fork Length	Weight	Comments
#		(mm)	(g)	
1	RNTR	78	6	
2	RNTR	53	1	
3	RNTR	65	3	
4	RNTR	69	3	
5	RNTR	71	3	
6	RNTR	69	3	
7	RNTR	58	2	
8	RNTR	75	4	
9	RNTR	65	2	
10	RNTR	71	4	
11	RNTR	60	2	
12	RNTR	63	3	
13	RNTR	64	2	
14	RNTR	58	2	
15	RNTR	63	2	
16	RNTR	64	3	
17	RNTR	74	4	
18	RNTR	62	2	
19	RNTR	63	2	
20	RNTR	72	4	
21	RNTR	67	4	
22	RNTR	69	4	
23	RNTR	64	4	
24	RNTR	65	3	
25	RNTR	68	3	

Electrofishing Record				
Date:		18-Aug-11		
Stream Name:		Embarrass River		
UTM reference:		503434E, 5882384N, NAD 83, ZN11		
Sample Site:		Downstream of fish exclusion barrier		
Section length (m):		300		
Duration (seconds):		1902		
Sample	Species	Fork Length	Weight	Comments
#		(mm)	(g)	
1	RNTR	154	34	
2	RNTR	147	33	

3	RNTR	62	3	
4	RNTR	165	59	
5	RNTR	104	10	
6	RNTR	73	4	
7	RNTR	56	3	
8	RNTR	66	3	
9	RNTR	160	43	
10	RNTR	179	75	
11	RNTR	148	34	
12	RNTR	216	136	
13	RNTR	247	176	
14	RNTR	184	79	
15	RNTR	102	12	
16	RNTR	70	4	
17	RNTR	110	14	
18	RNTR	97	8	
19	RNTR	156	36	
20	RNTR	164	50	
21	RNTR	140	20	
22	BKTR	187	76	
23	BKTR	176	62	
24	BKTR	74	4	
25	BKTR	158	46	
26	BKTR	174	57	
27	BKTR	201	85	
28	BKTR	179	70	
29	BKTR	179	62	
30	BKTR	166	58	
31	BKTR	222	129	
32	BKTR	71	4	
33	BKTR	75	4	
34	BKTR	191	76	
35	BKTR	173	61	
36	BKTR	190	73	
37	BKTR	165	60	
38	BKTR	226	130	
39	BKTR	220	145	
40	BKTR	74	4	
41	BKTR	163	47	
42	BKTR	166	61	
43	BKTR	138	30	
44	BKTR	180	64	
45	BKTR	175	60	
46	BKTR	156	47	
47	BKTR	145	37	
48	BKTR	159	74	

49	BKTR	215	117	
50	BKTR	157	45	
51	BKTR	188	79	
52	BKTR	170	57	
53	BKTR	177	64	
54	BKTR	225	131	
55	BKTR	195	85	
56	BKTR	192	81	
57	BKTR	186	74	
58	BKTR	175	62	
59	BKTR	194	83	
60	BKTR	178	57	
61	BKTR	185	72	
62	BKTR	180	69	
63	BKTR	175	50	
64	BKTR	164	49	
65	BKTR	163	45	
66	BKTR	164	51	
67	BKTR	197	95	
68	BKTR	195	92	
69	BKTR	171	58	
70	BKTR	178	56	
71	BKTR	160	44	

Electrofishing Record				
Date:		5-Oct-11		
Stream Name:		Embarrass Creek		
UTM reference:		503573E, 5882051N, NAD83, ZN11		
Sample Site:		Upstream of fish exclusion barrier.		
Section length (m):		300		
Duration (seconds):		1240		
Sample #	Species	Fork Length (mm)	Weight (g)	Comments
1	RNTR	106	18	

Electrofishing Record				
Date:		5-Oct-11		
Stream Name:		Embarrass River		
UTM reference:		503434E, 5882384N, NAD 83, ZN11		
Sample Site:		D/S of outfall Structure		
Section length (m):		300		
Duration (seconds):		367		
Sample #	Species	Fork Length (mm)	Weight (g)	Comments
1	RNTR	262	223	
2	RNTR	170	52	
3	RNTR	163	42	
4	RNTR	124	21	
5	RNTR	98	9	
6	RNTR	218	102	
7	RNTR	171	54	
8	RNTR	133	25	
9	RNTR	88	8	
10	RNTR	140	31	
11	RNTR	172	57	
12	RNTR	148	32	
13	RNTR	146	30	
14	RNTR	97	7	
15	RNTR	181	66	
16	RNTR	154	36	
17	RNTR	93	8	
18	RNTR	88	4	
19	RNTR	83	5	
20	RNTR	86	6	
21	BKTR	196	81	
22	BKTR	208	88	
23	BKTR	185	62	
24	BKTR	181	64	
25	BKTR	180	62	
26	BKTR	183	61	
27	BKTR	145	26	
28	BKTR	163	46	
29	BKTR	90	6	
30	BKTR	82	5	

Report #3

Pisces Environmental Consulting Services Ltd.

•Unit 118, 239 Spruce Street• Red Deer County • Alberta • T4E 1B4•
• Phone 403-347-5418 • Fax 403-347-0681•
•www.piscesenvironmental.com•

August 21, 2013

CVRI
Coal Valley Mine
Bag 5000
Edson, Alberta
T7E 1W1

ATTN: Megan Hill

RE: Recommendations for channel enhancement in the Embarras Lakes End Pit Lake System.

1.0 Introduction

Pisces Environmental Consulting Services Ltd. (Pisces) is conducting ongoing fisheries monitoring in the Embarras Lakes end-pit lake system located in 25-47-21-W5. As requested, the following summarizes Pisces' recommendations for habitat enhancement of the connecting channels in the Embarras Lakes End Pit Lake System. Information provided is based on data gathered from site investigations conducted in May, June, and July 2013 as well as water temperature monitoring and habitat utilization studies that have been ongoing since 2011.

2.0 Background

In August 2004, Fisheries and Oceans Canada (DFO) issued Fisheries Act Authorization ED-03-3080 to Coal Valley Resources Incorporated (CVRI) for the diversion of the Embarras River to facilitate mining in the Mercoal Phase 1 (MP1) area. Part of the final reclamation strategy for the MP1 extension included the development of an end pit lake system that would support a self-sustaining native fish population.

The Embarras End Pit Lake system is located in the extreme headwaters of the Embarrass River in 25-47-21-W5. The Embarras River flows into the McLeod River approximately 86 kilometers downstream of the lakes, which in turn flows into the Athabasca River near Whitecourt, Alberta. Historically, fish densities in the upper Embarras River were low and pre-mining investigations of this part of the river found fish habitat potential to be limited (Boorman 2003). Habitat diversity within this area was considered to be marginal and substrates were comprised almost exclusively of fines (Boorman 2003). However, Rainbow Trout (Oncorhynchus mykiss), Bull Trout (Salvelinus confluentus) and Brook Trout (Salvelinus fontinalis) were found just downstream of the proposed MP1 pit area during baseline investigations (Boorman 2003).

The Embarras End Pit Lake system consists of three lakes and approximately 1100 metres of constructed connecting channels. The naming convention for the lakes is as follows:

- Upper Embarras Lake (Pit 142E);
- Middle Embarras Lake (Pit 122); and
- Lower Embarras Lake (Pit 122).

The Embarras River enters the Upper Lake from a beaver pond via a constructed inlet channel that is approximately 30 metres long (Upper Embarras Channel). There are approximately 500 metres of connecting channel between the Upper and Middle Lakes (Middle Embarras Channel B) including the haulroad culvert crossing that is located just upstream of the Middle Lake. Between the Middle Lake and Lower Lake there is approximately 150 metres of connecting channel (Middle Embarras Channel A) and there is approximately 400 metres of constructed channel downstream of the Lower Lake (Lower Embarras Channel). A fish exclusion weir has been constructed at the bottom of this constructed channel to preclude Brook Trout from entering the end pit lake system.

3.0 Recommendations

Recommendations for habitat enhancements in the constructed channels include placement of instream habitat features as well as stabilization and vegetation of streambanks. Optimally a Qualified Aquatic Environment Specialist (QAES) would be onsite to provide advice and feedback during the construction of the habitat enhancements. As summary of these recommendations and suggested enhancement locations are provided in Tables 1 to 4. Additional are provided in Sections 3.1 to 3.4 and Figures 1 to 26.

Table 1. Lower Embarras Channel (exclusion weir to Lower Embarras Lake)

Site	Location (UTM's)	Enhancement Details
Figure 1	0503422 5882249	Vegetate, tree cover installations
Figure 2	503463 5882217	Vegetate, tree cover installations
Figure 3	503495 5882187	Vegetate, gravel addition, tree cover installations
Figure 4	503513 5882166	Vegetate, gravel addition, tree cover installations
Figure 5	503544 5882127	Vegetate, tree cover installations
Figure 6	503566 5882092	Vegetate, tree cover installations
Figure 7	503563 5882058	Vegetate to maximize future shade
Figure 8	503544 5882028	Stabilize, vegetate, tree cover and gravel installations
Figure 9	503510 5882022	Stabilize, vegetate, tree cover installations
Figure 10	503492 5882014	Stabilize, vegetate, tree cover and gravel installations

Table 2. Middle Embarras Channel A (Lower Embarras Lake to Middle Embarras Lake)

Site	Location (UTM's)	Enhancement Details
Figure 11	504077 5881362	Vegetate with willows and conifers.
Figure 12	504112 5881343	Vegetate, gravel addition, tree cover installations

Table 3. Middle Embarras Channel B (Middle Embarras Lake to Upper Embarras Lake)

Site	Location (UTM's)	Enhancement Details
Figure 13	504746 5880771	Vegetate with willows and conifers.
Figure 14	504793 5880736	Vegetate with willows and conifers.
Figure 15	504863 5880695	Vegetate, gravel addition, tree cover installations
Figure 16	504791 5880616	Vegetate with willows and conifers.
Figure 17	504787 5880581	Supplemental tree/ willow plantings
Figure 18	504787 5880581	Supplemental tree/ willow plantings
Figure 19	504746 5880465	Supplemental tree/ willow plantings, substrate enhancement (if possible)
Figure 20	504746 5880465	Vegetate, substrate enhancement (if possible)
Figure 21	504756 5880427	Vegetate with willows and conifers.
Figure 22	504733 5880400	Vegetate, gravel addition, tree cover installations

Table 4. Upper Embarras Channel (upstream of Upper Embarras Lakes

Site	Location (UTM's)	Enhancement Details
Figure 23	504521 5880434	Vegetate with willows and conifers.
Figure 24	504497 5880409	Vegetate, gravel addition, tree cover installations
Figure 25	504497 5880409	Vegetate, gravel addition, tree cover installations
Figure 26	504364 5880240	Vegetate, gravel addition, tree cover installations

3.1 Lower Embarras Channel

Pisces recommends the following components be incorporated into the reclamation plans for the Lower Embarras Channel. Additional details are shown on Figures 1 to 10. Existing water temperature data suggests that an important design consideration for this channel reach is to maximize stream shading. In addition, observations in 2012 and 2013 suggest lake resident fish are moving downstream past the fish exclusion weir; recommended channel enhancements (improve cover, holding habitat and spawning habitat) are intended to reduce these losses.

- Streambank cover should be installed along the reclaimed channel. Willows and/or other deciduous plantings should be established as close to the stream as possible. Coniferous tree seedling should also be established where feasible to promote long-term stream shading that will mimic natural channel conditions in the area. Plantings should be relatively dense where warranted with riparian planting densities averaging at least one tree per meter of bank. Faster growing species such as willows, aspen or balsam poplar should be considered in addition to conifers along this channel reach in order to maximize stream shading as quickly as possible. Willows should only be planted near the water, as establishment will likely be difficult at drier locations.

- Large woody debris (conifers with intact limbs anchored or embedded into the banks and protruding into the channel or brush piles) should be placed within the reclaimed channel to provide cover for fish where channel conditions allow. Bushy conifers at least three metres tall with intact root wads (if feasible) should be installed where indicated (Figures 1-10). If possible, instream conifer placements should be anchored utilizing boulders or cable/ posts. Perpendicular installations should aim to maximize stream shade area; the largest tree's that can be handled practically would be optimal. The recommended location of these habitat features could be changed slightly to accommodate the materials available for the enhancement works.
- Though successful spawning is occurring within the channel reach salmonid spawning habitat enhancements should be undertaken (Figure 3, 4, 8, and 10). These enhancements should include placement of appropriately sized gravels, and habitat suited for rearing of juvenile salmonids. The gravel should be 5 to 30 mm in size and preferably rounded rather than crushed with sharp edges. A diversity of gravel size will be appropriate as the Embarras Lakes are occupied by adult Rainbow Trout of varying size. Gravel depths should exceed 0.30 meters to increase the longevity of the enhancements since the surrounding area is unlikely to provide for much natural recruitment of this type of substrate.
- Areas of instability within the Embarras River constructed channel have been identified (Figure 8-10). Bank re-contouring should be completed with the aim of reducing slopes and reducing erosion so vegetation can be established. If re-contouring and planting is not feasible CVRI may want to consider riprap placement in problem areas. Currently, sediment is being generated from these unstable areas predominantly during spring rainstorms when Rainbow Trout reproduction is occurring. Stabilizing these areas will help protect incubating Rainbow Trout eggs and rearing fry that could be present in the connective channel.

Figure 1. Looking upstream

Figure 2. Looking upstream

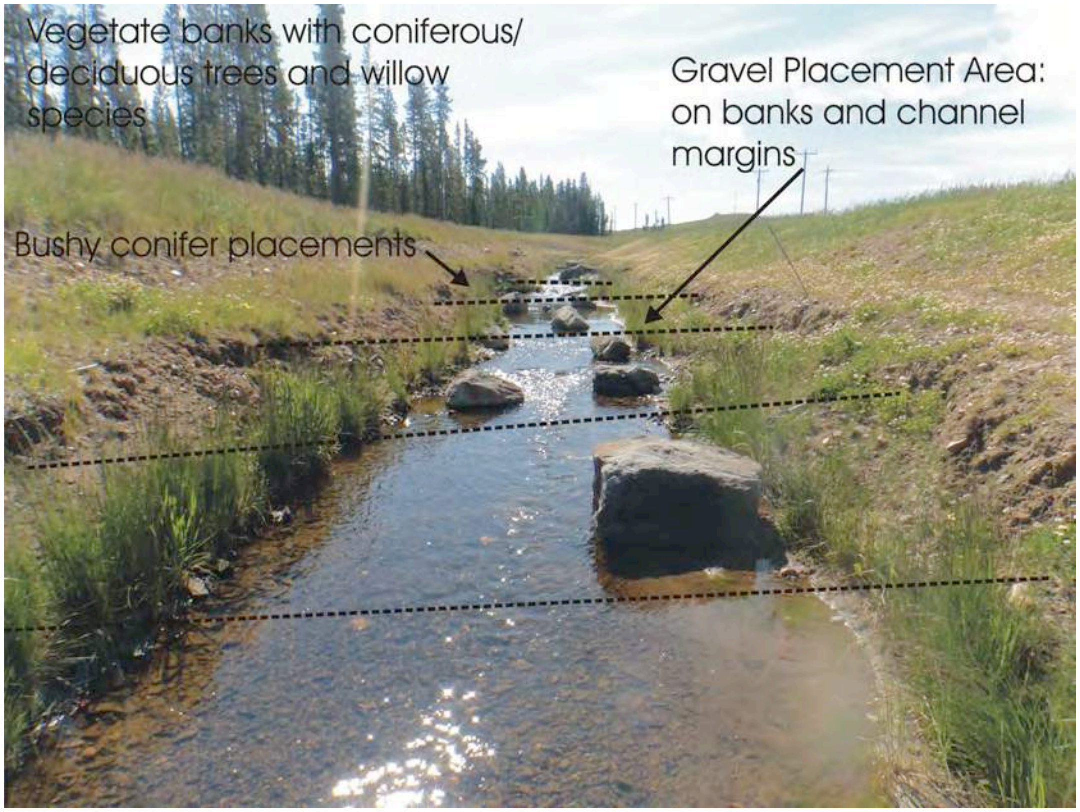


Figure 3. Looking upstream

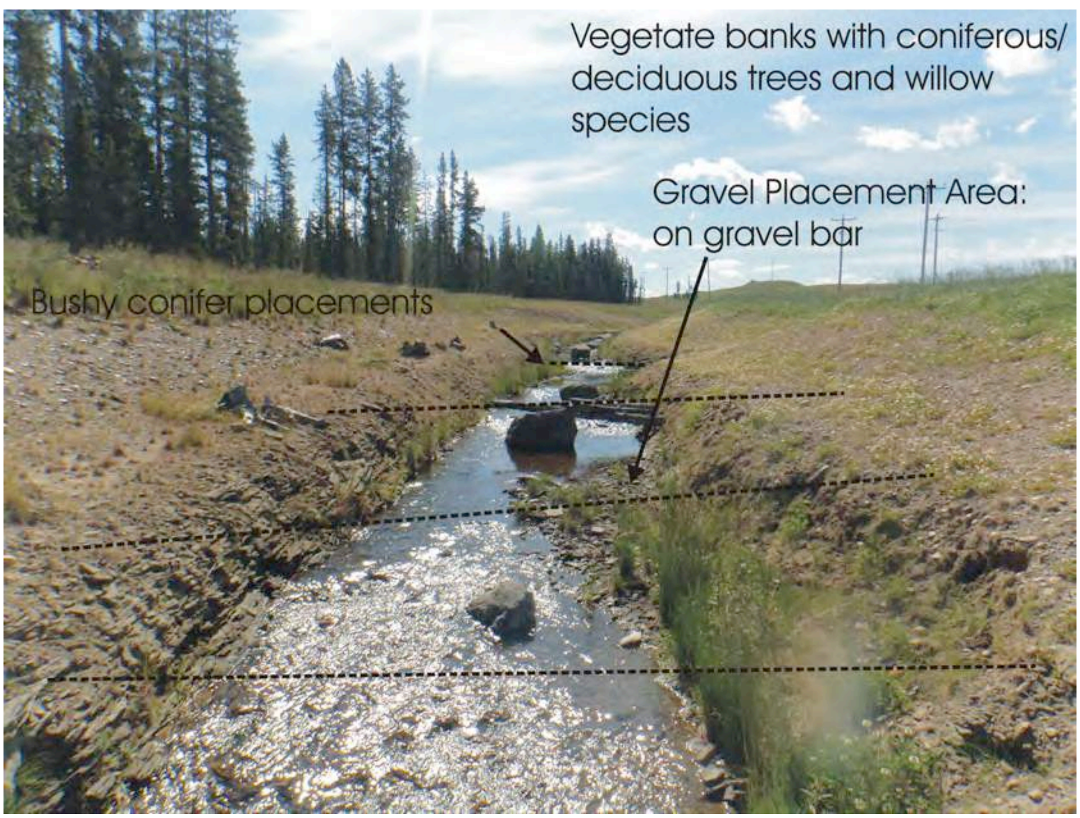


Figure 4. Looking upstream

Figure 5. Looking upstream

Figure 6.Looking upstream

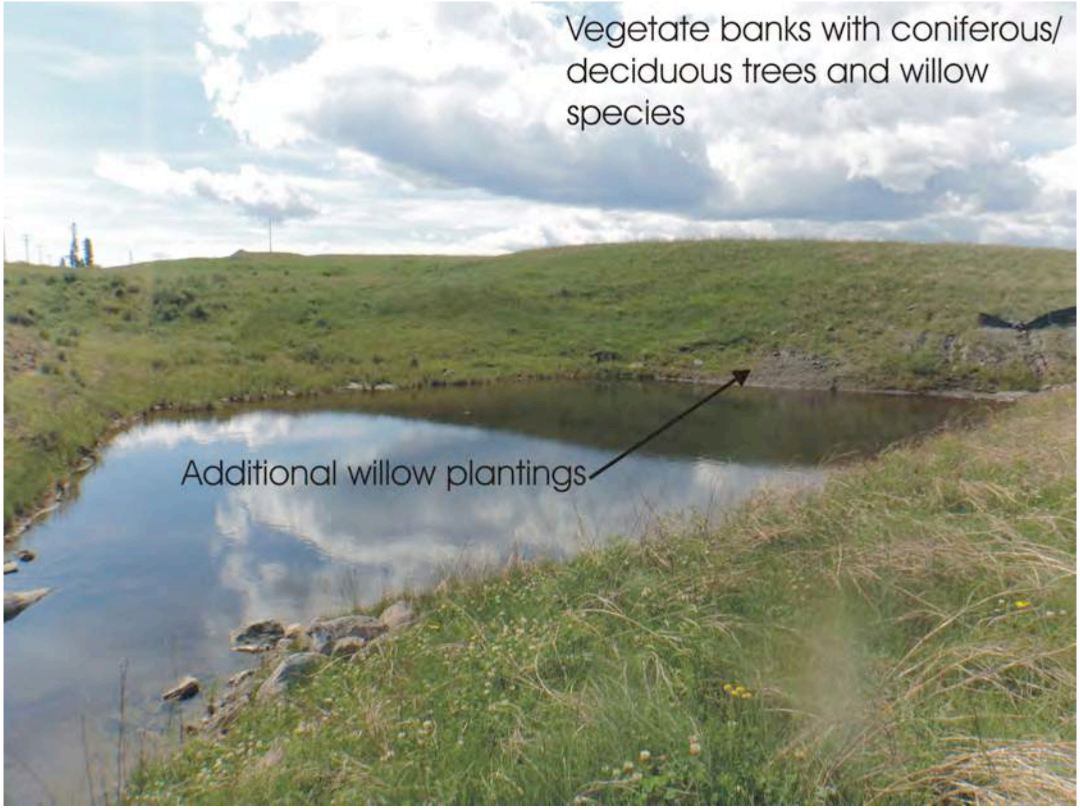


Figure 7. Looking upstream

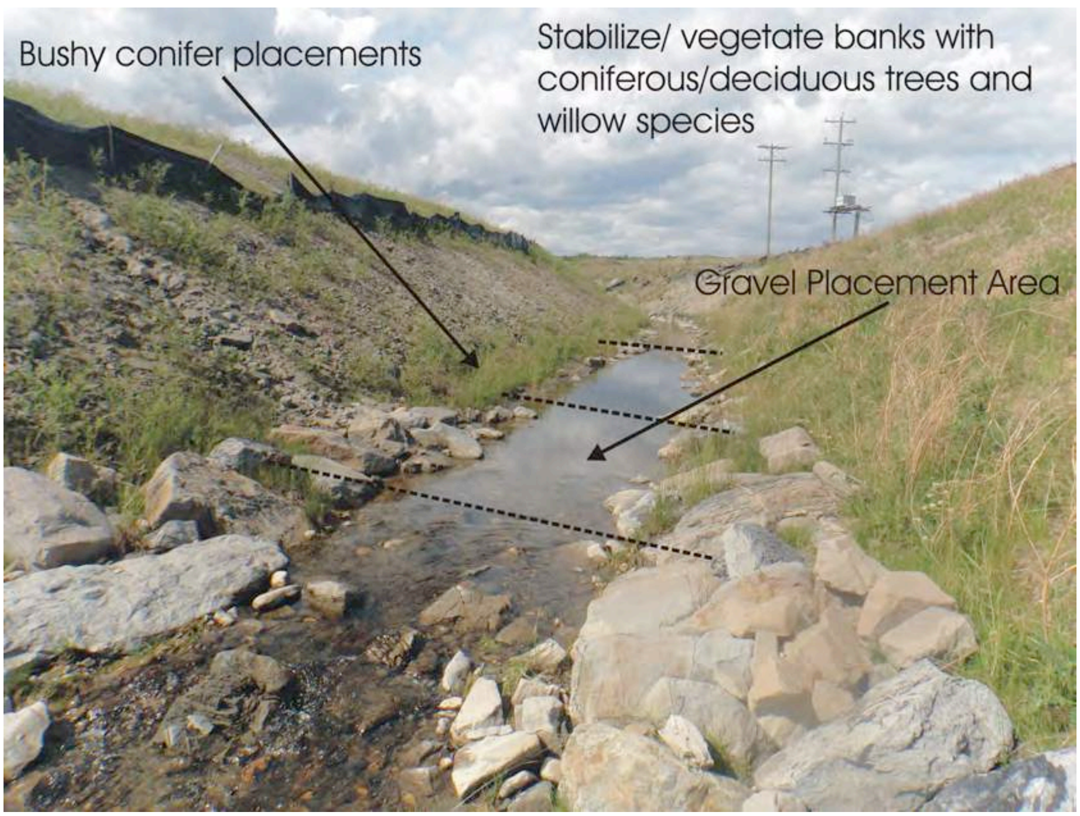


Figure 8. Looking upstream

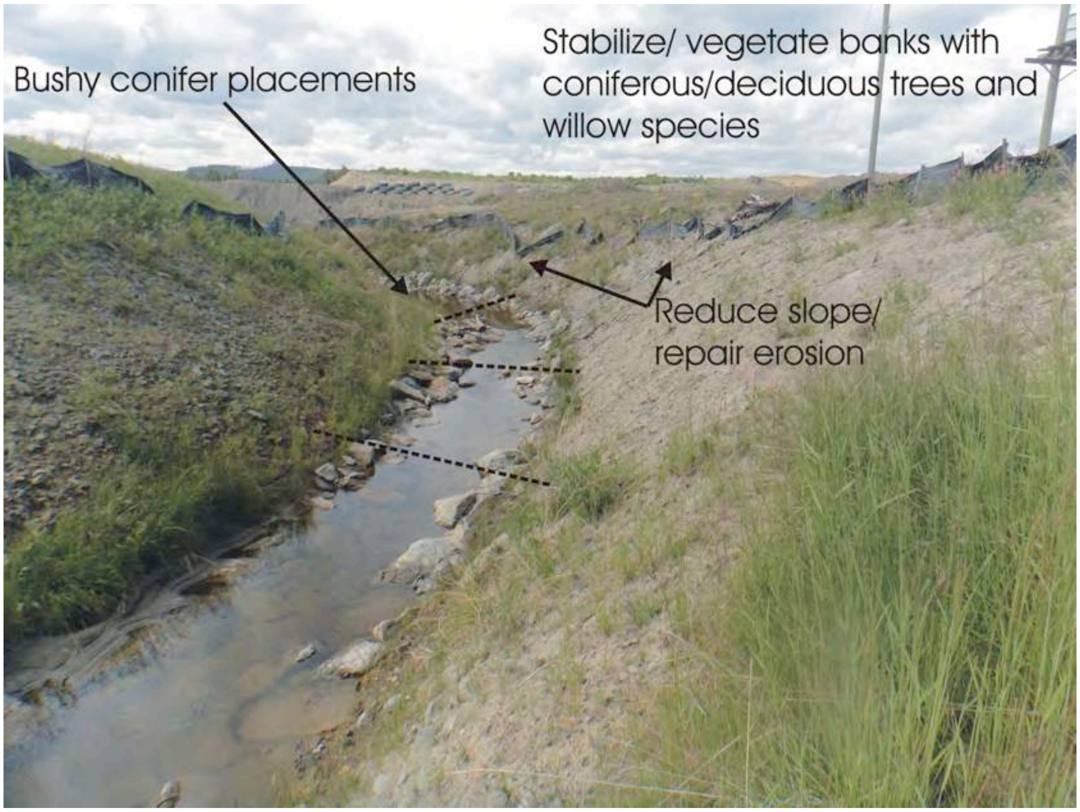


Figure 9. Looking upstream

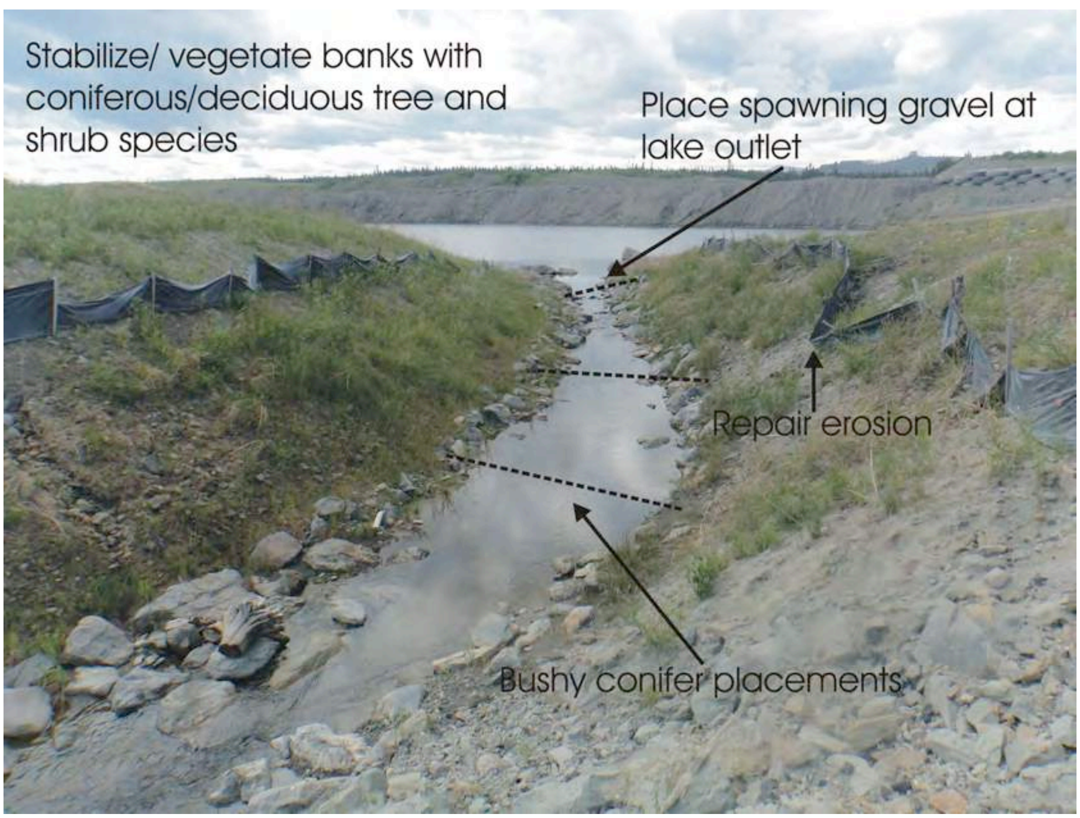


Figure 10. Looking upstream

3.2 Middle Embarras Channel A

Pisces recommends the following components be incorporated into the reclamation plans for the Middle Embarras A Channel. Additional details are shown on Figures 11 and 12. Existing water temperature data suggests that an important design consideration for this channel reach is to maximize stream shading. The substrate and cover enhancements are expected to promote the long-term success of the Embarras Lakes System.

- Streambank cover should be installed along the reclaimed channel. Willows and/or other deciduous plantings should be established as close to the stream as possible. Coniferous tree seedling should also be established where feasible to promote long-term stream shading that will mimic natural channel conditions in the area. Plantings should be relatively dense where warranted with riparian planting densities averaging at least one tree per meter of bank. Faster growing species such as willows, aspen or balsam poplar should be considered in addition to conifers along this channel reach in order to maximize stream shading as quickly as possible.
- Though successful spawning is likely occurring within the channel reach salmonid spawning habitat enhancements should be undertaken (Figure 11 and 12). These enhancements should include placement of appropriately sized gravels, and installation of woody debris cover at the outlet of the Middle Embarras Lake. The gravel should be 5 to 30 mm in size and preferably rounded rather than crushed with sharp edges; a diversity of gravel size will be appropriate as the Embarras Lakes are occupied by adult Rainbow Trout of varying size. Gravel depths should exceed 0.30 meters to increase the longevity of the enhancements since the surrounding area is unlikely to provide for much natural recruitment of this type of substrate.

Figure 11. Looking upstream

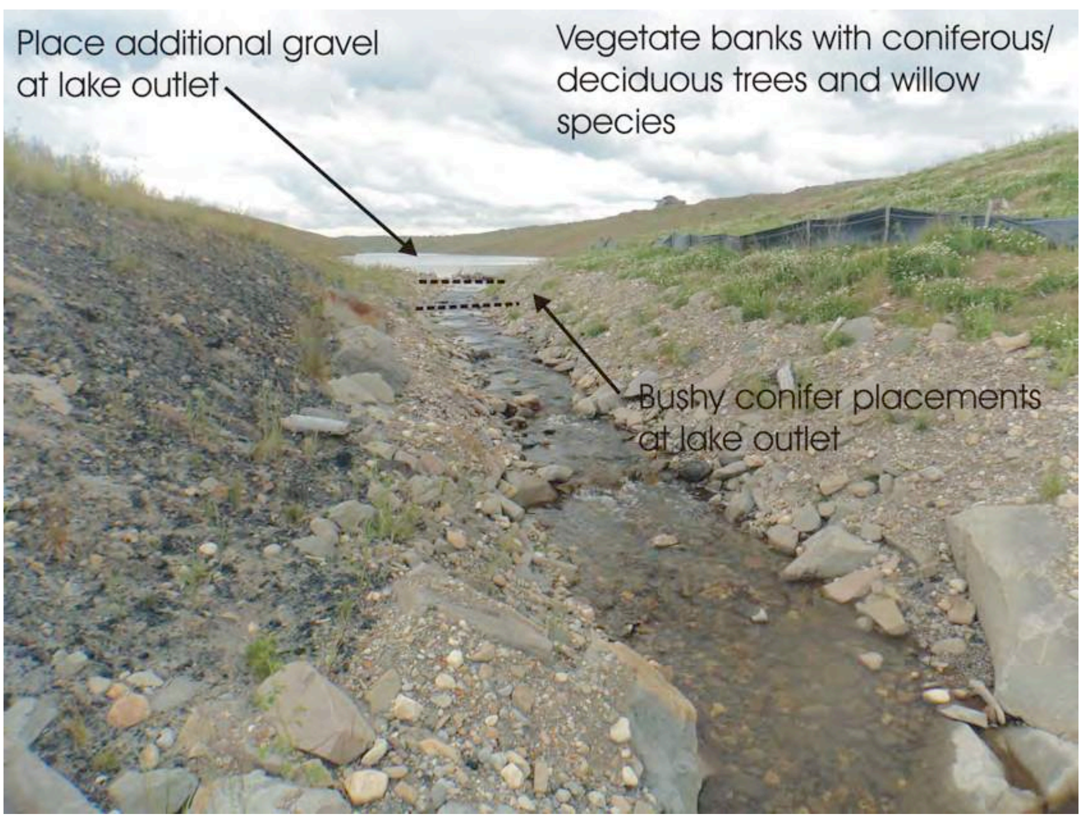


Figure 12. Looking upstream.

3.3 Middle Embarras Channel B

Pisces recommends the following components be incorporated into the reclamation plans for the Middle Embarras B Channel. Additional details are shown on Figures 13 and 22. Existing water temperature data indicates that this channel reach has exhibited a near optimal thermal regime for Rainbow Trout in 2012 and 2013. The focus of recommended enhancements is to maximize habitat use and promote the long-term success of the Embarras Lakes System. The goal of the enhancement work is to maintain and improve fry production, reduce fish egg mortality, and increase the suitability of the habitat for juvenile rearing. In addition, the vegetation of streambanks and surrounding slopes is expected to improve overall habitat conditions.

- Streambank cover should be installed along the reclaimed channel. Willows and/or other deciduous plantings should be established as close to the stream as possible. Coniferous tree seedling should also be established where feasible to promote long-term stream shading that will mimic natural channel conditions in the area. Plantings should be relatively dense where warranted with riparian planting densities averaging at least one tree per meter of bank. Faster growing species such as willows, aspen or balsam poplar should be considered in addition to conifers along this channel reach in order to maximize stream shading as quickly as possible. Fine material may be required in the margins of riprap areas in order to establish riparian vegetation.
- If possible, conifer placements should be anchored utilizing boulders or cable/ posts. Perpendicular installations should aim to maximize stream shade area. Cover enhancements within this channel will provide habitat for spawning and rearing fish. Enhancements at the outlet of the Upper Embarras Lake should also prevent ungulate trampling of incubating Rainbow Trout eggs that is suspected to have occurred in 2012 and 2013.
- Although successful spawning is occurring within this channel reach and monitoring indicates near optimal temperature regimes for Rainbow Trout reproduction, additional enhancements directed at improving salmonid spawning habitat are recommended. These enhancements should include placement of appropriately sized gravels, and habitat suited for rearing of juvenile salmonids. The gravel should be 5 to 30 mm in size and preferably rounded rather than crushed with sharp edges; a diversity of gravel size will be appropriate as the Embarras Lakes are occupied by adult Rainbow Trout of varying size. Gravel depths should exceed 0.30 meters to increase the longevity of the enhancements since the surrounding area is unlikely to provide for much natural recruitment of this type of substrate.

Figure 13. Looking upstream

Figure 14. Looking upstream

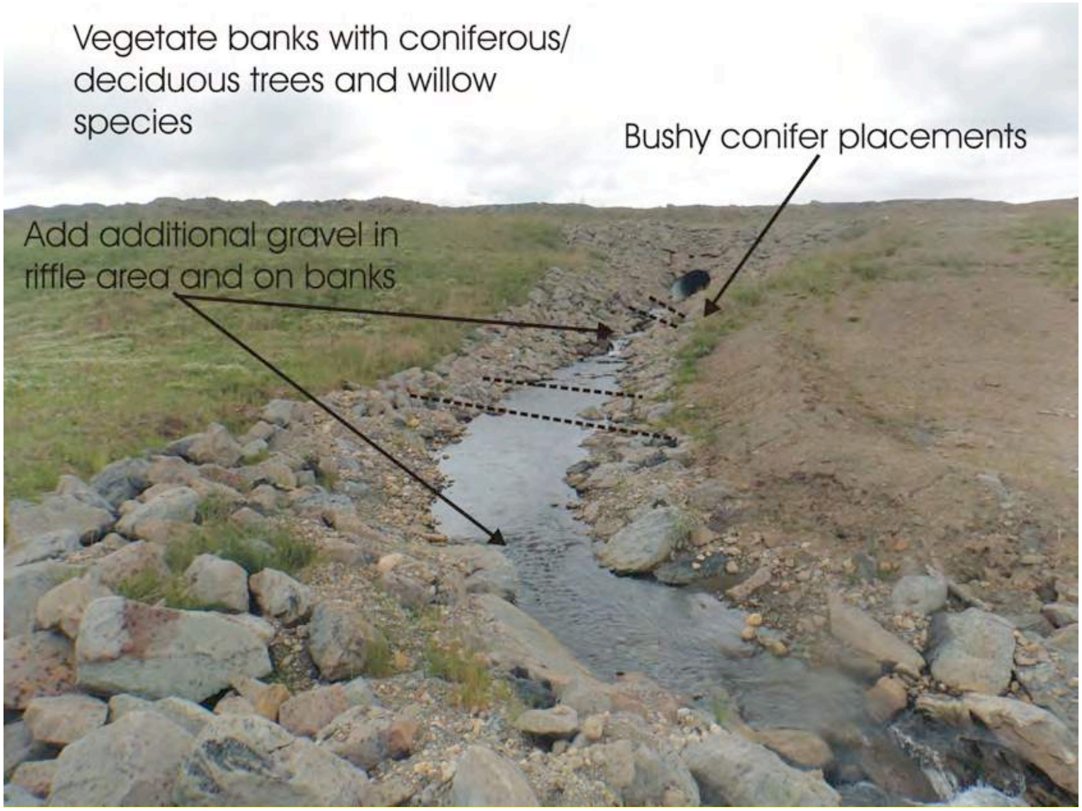


Figure 15. Looking upstream

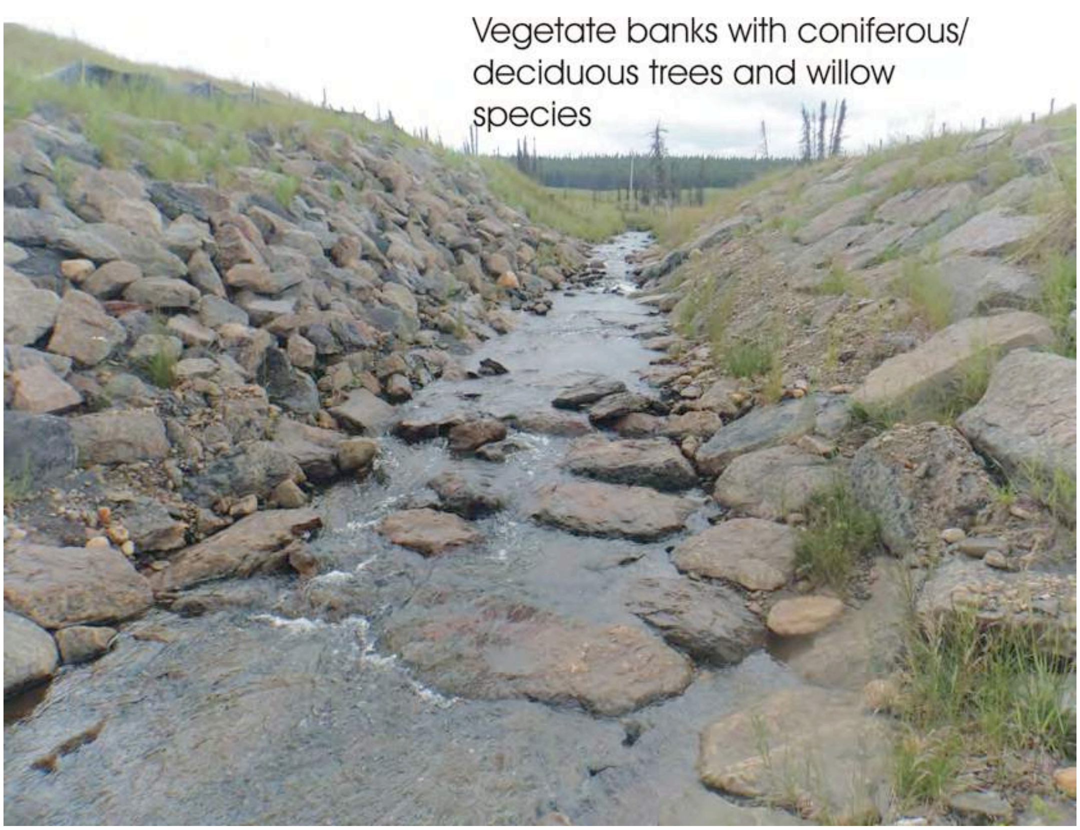


Figure 16. Looking upstream

Figure 17. Looking upstream

Figure 18. Looking upstream

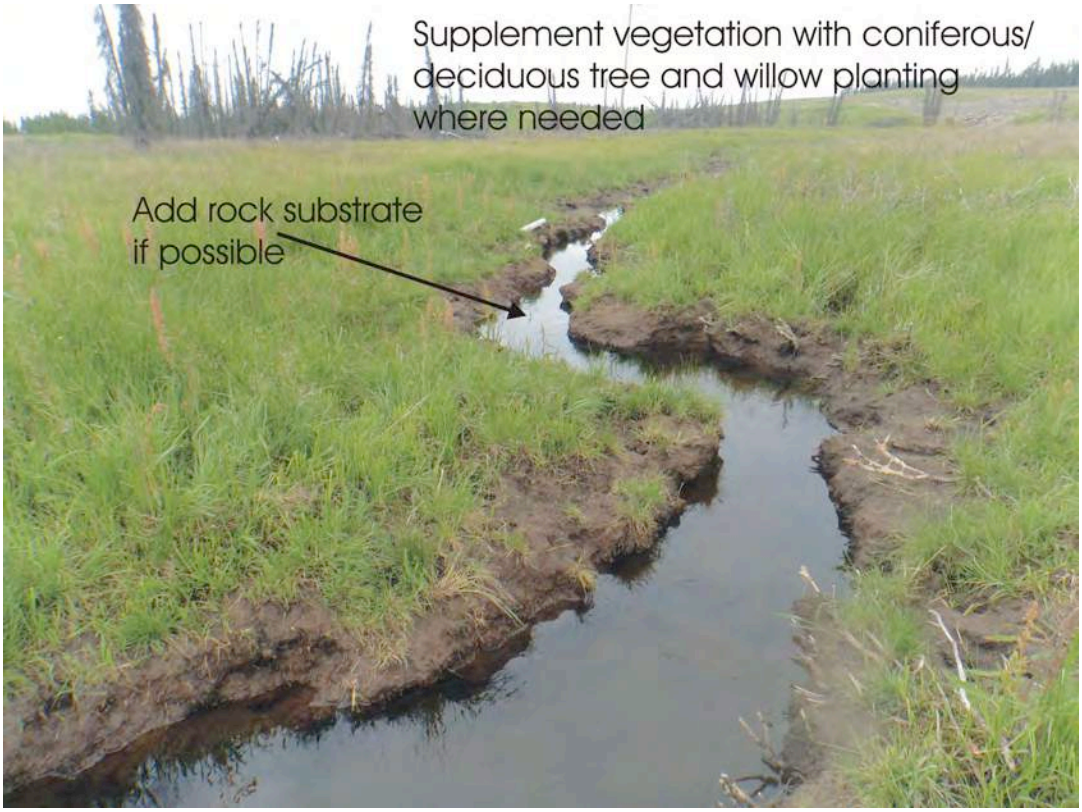


Figure 19. Looking downstream.

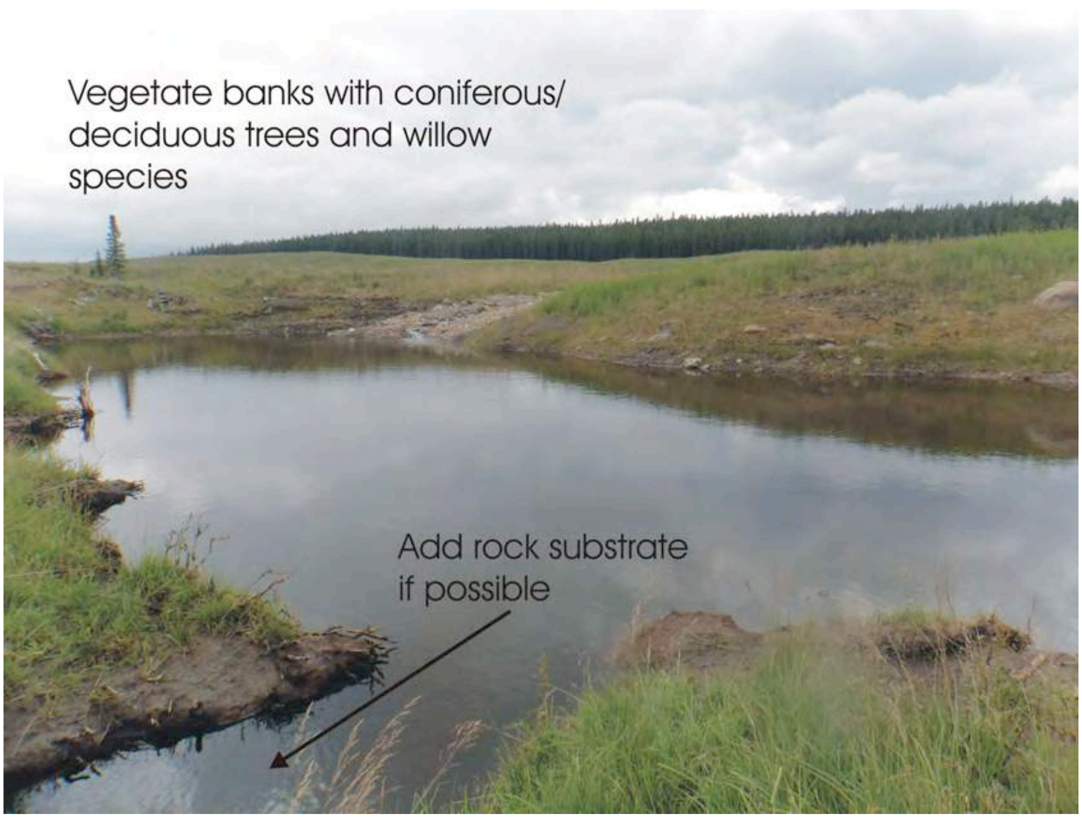


Figure 20. Looking upstream

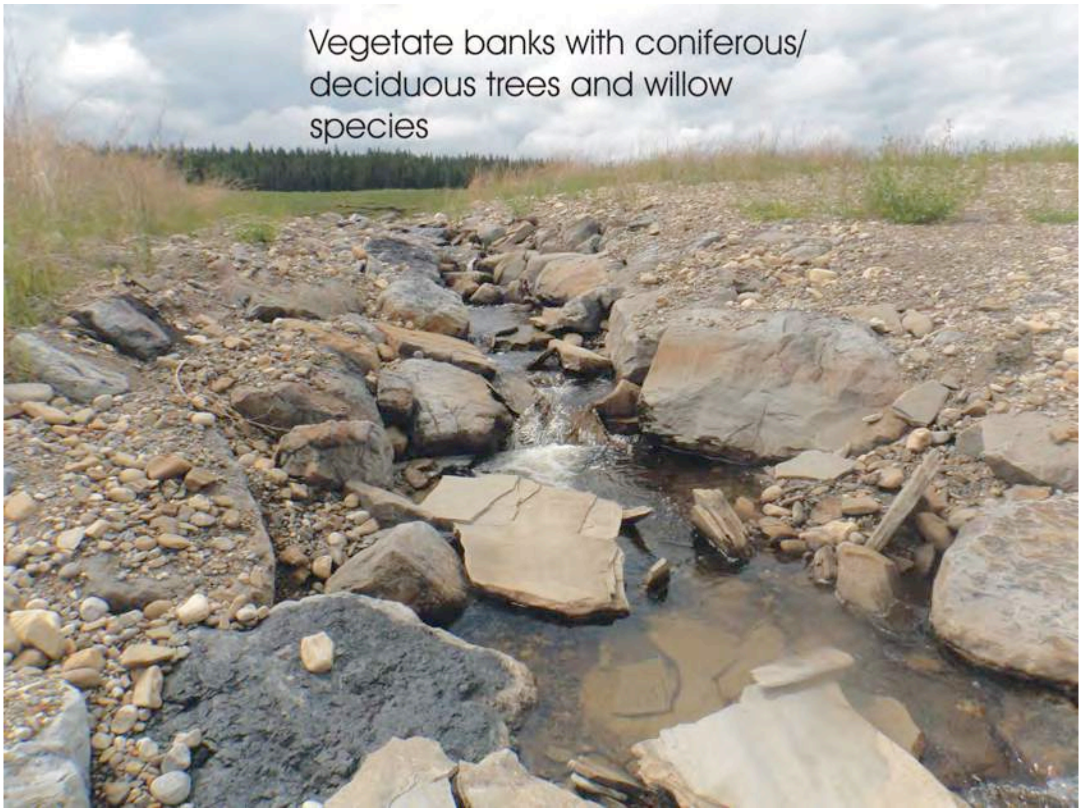


Figure 21. Looking upstream

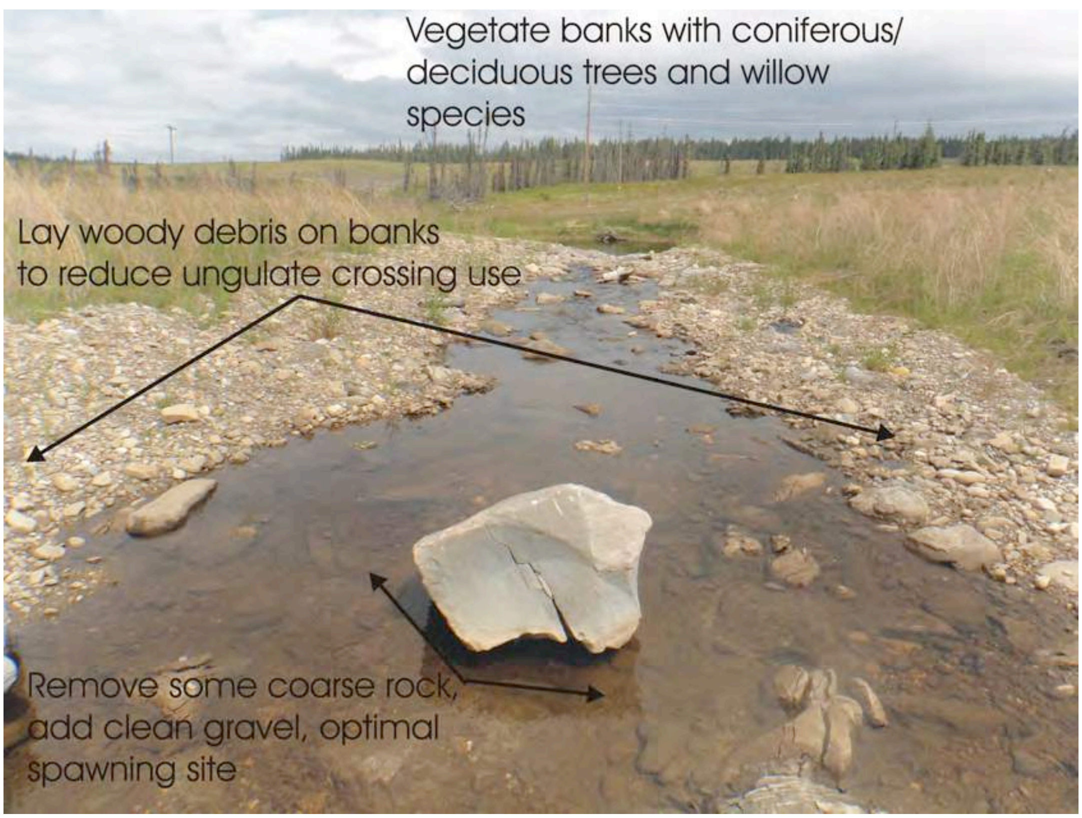


Figure 22. Looking downstream

3.4 Upper Embarras Channel

Pisces recommends the following components be incorporated into the reclamation plans for the Upper Embarras Channel. Additional details are shown on Figures 23 and 26. Existing water temperature data indicates that while channel reach is relatively cold (especially upstream of the beaver pond), it is likely suitable for Rainbow Trout reproduction during most years. However, the enhancement of habitat in this channel reach may provide a thermal refuge that would likely be beneficial during warmer than average years.

- Streambank cover should be installed along the reclaimed channel. Willows and/or other deciduous plantings should be established as close to the stream as possible. Coniferous tree seedling should also be established where feasible to promote long-term stream shading that will mimic natural channel conditions in the area. Plantings should be relatively dense where warranted with riparian planting densities averaging at least one tree per meter of bank.
- Perpendicular woody cover installations should aim to maximize stream shade area and as large of trees as possible should be utilized. Enhancements within this channel will benefit Rainbow Trout by providing cover for adults during spring spawning.
- Although successful spawning is likely occurring within this channel reach additional habitat enhancements are recommended. The Upper Embarras Channel is consistently colder than the other channel reaches and may be of particular importance for Rainbow Trout spawning during abnormally warm years. Enhancements should include placement of appropriately sized gravels, and habitat suited for rearing of juvenile salmonids. The gravel should be 5 to 30 mm in size and preferably rounded rather than crushed with sharp edges; a diversity of gravel size is appropriate since the Embarras Lakes are occupied by adult Rainbow Trout of varying size. Gravel depths should exceed 0.30 meters to increase the longevity of the enhancements since the surrounding area is unlikely to provide much natural recruitment of this type of substrate.

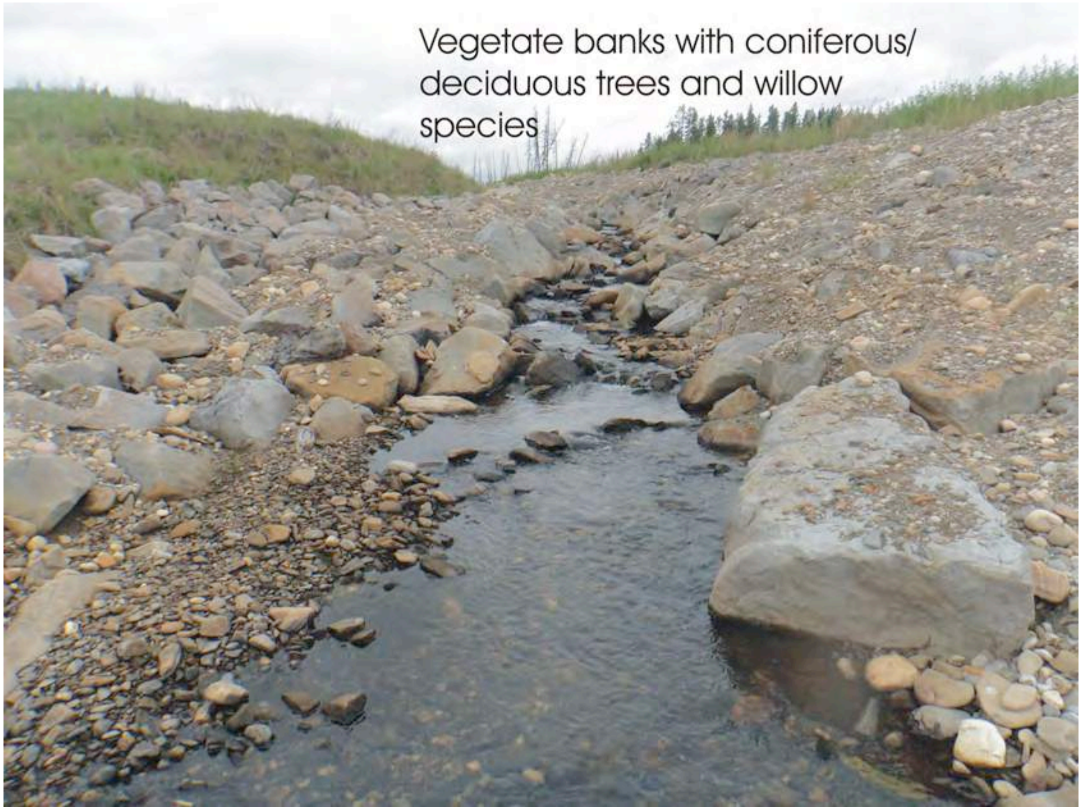


Figure 23. Looking upstream

Figure 24. Looking upstream

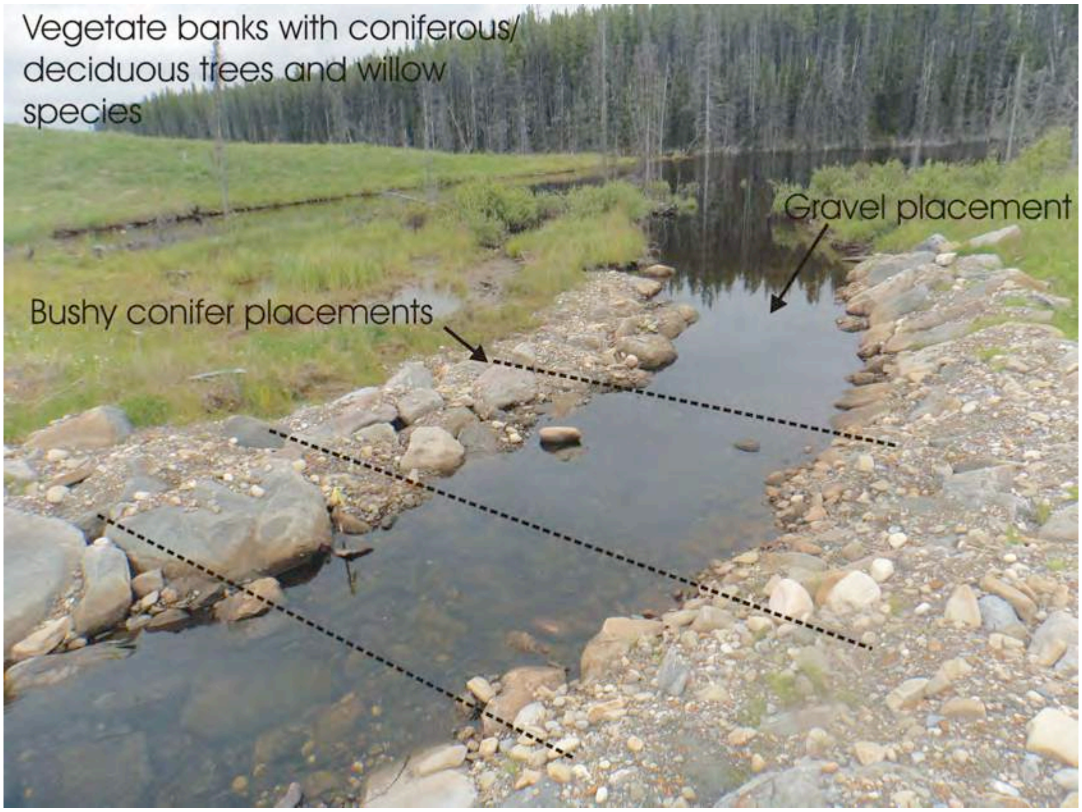


Figure 25. Looking upstream

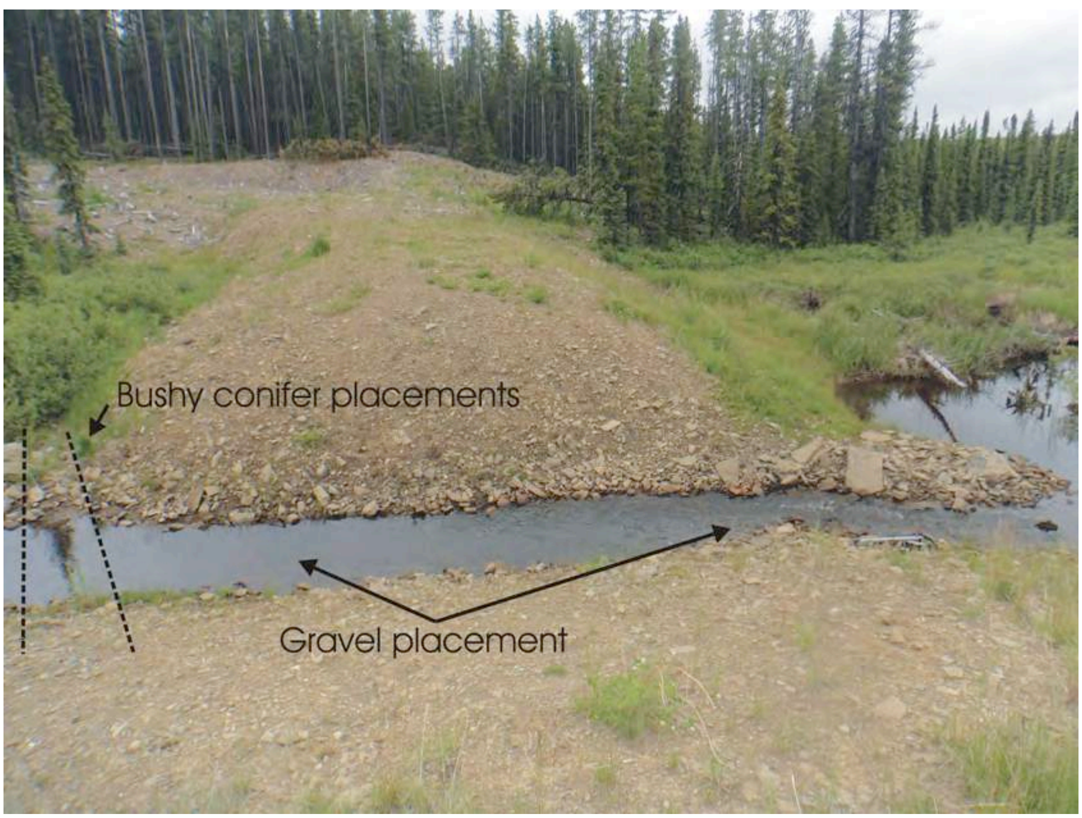


Figure 26. Looking from right upstream bank.

4.0 Other Considerations

Dependent on final reclamation objectives and the direction of AESRD there may be potential to create a seasonal or permanent connection between the Upper Embarras Lake and the Pit 142W Lake. The water level of Pit 142W Lake has not risen above the outflow channel elevation since final channel work was completed (Figure 27), under the current configuration the lake would likely require stocking if a fishery end use is desired. However, adjustment to the channel grade could be attempted to allow for seasonal recruitment of fish from the Embarras system. Alternatively, the possibility of this pit undergoing a change in final surface elevation so it could be connected via a permanent channel could be investigated if CVRI and/or AESRD wish to reduce the number of lakes that will require stocking in the future. A channel between this lake and the beaver pond upstream of the Embarras Lakes could also be investigated if connectivity is a desired end use and water surface elevations were appropriate. However, providing a surface connection to Pit 142W should likely not be completed until it is confirmed that the Rainbow Trout currently in the Embarras End Pit Lake System are native Athabasca Rainbow Trout.

Figure 27. Existing channel between Pit 142W Lake and Upper Embarras Lake.

While we recognize that the haulroad between Pit 122W and the Lower Embarras Lakes is still active there may be merit in exploring the possibility of developing a final reclamation plan that involves construction of a connecting channel between the lakes. Depending on fisheries objectives this may provide an opportunity to reduce the need for long-term fish stocking in the area.

5.0 Closure

I trust this meets your information requirements at this time. If you have any questions regarding the foregoing please contact our office at your convenience.

Sincerely,

<original signed by>

<original signed by>

Joe Sonnenberg, B.Sc.
Fisheries Biologist

Erik Stemo, P. Biol.
Senior Fisheries Biologist

Pisces Environmental Consulting Services Ltd.

References

Boorman, J. 2003. Baseline fisheries resources assessment of waterbodies on and adjacent to the proposed Mercoal East extension. Report of Pisces Environmental Consulting Services Ltd. to Luscar Ltd. Coal Valley Mine, Edson, AB. 35 pp. + App.

Report #4

Pisces Environmental Consulting Services Ltd.

•Unit 118, 239 Spruce Street• Red Deer County • Alberta • T4E 1B4•
• Phone 403-347-5418 • Fax 403-347-0681•
•www.piscesenvironmental.com•

March 19, 2013

CVRI
Coal Valley Mine
Bag 5000
Edson, Alberta
T7E 1W1

ATTN: Mr. Les LaFleur

RE: 2012 post-construction monitoring of the permanent diversion channel on upper Mercoal Creek for the MP2 development.

Introduction

The Mercoal Phase 2 (MP2) project, part of ongoing mining operations at the Coal Valley Mine, required the permanent diversion (known as diversion D-E) of a portion of Mercoal Creek to facilitate mining. As required by Fisheries and Oceans Canada (DFO), a habitat compensation plan that included enhancement of the constructed channel with a goal of maximizing its productive capacity was developed for the project. In order to meet the requirements of the DFO Section 35(2) *Fisheries Act* Authorization (# ED-04-3170) issued for the project, the mine committed to conducting fish and fish habitat monitoring within the constructed channel. Key components of the monitoring program included:

- Sampling 1, 3, and 5 years following construction of the channel.
- Habitat surveys 1 and 5 years following construction of the channel.

This document presents Year 3 (post construction) monitoring results obtained by Pisces Environmental Consulting Services Ltd. (Pisces).

Background

Baseline investigations of Mercoal Creek found that fish densities were very low in the vicinity of the diversion and that Rainbow Trout (*Oncorhynchus mykiss*) were the only species to occupy this part of the creek (Boorman 2003). Habitat inventory during baseline investigations found that the majority of habitat (>75 %) affected by the diversion consisted of Class 3 habitat (<0.5 m depth, Boorman 2003). Pool habitat comprised about 2 % of the affected habitat and there was no Class 1 habitat (>1.0 m depth) in the impacted area (Boorman 2003). Modeling of the habitat suitability of Mercoal Creek for Rainbow Trout (Raleigh et al. 1984) found that both the percent pools and the pool class rating variables were limiting factors (Stemo 2005). As a result, habitat compensation efforts included the construction of pools on every meander and the placement of large woody debris within the constructed pools (Stemo 2005).

Monitoring Results

The 2012 monitoring program included sampling of the compensation area as well as the natural channel adjacent to the compensation area. In addition, channel stability, general habitat conditions, and instream sedimentation was also assessed. The investigations were completed on August 14, 2012.

Habitat Condition

The channel was mostly stable and vegetated at the time of the 2012 assessment; some channel instability and erosion had occurred within the reconstructed channel (see attached photos).

The habitat inventory completed in 2010 found that the channel provided an additional 750 m^2 of habitat compared to the pre-disturbance condition. In 2012, habitat conditions were judged to be very similar to what was present in 2010. A full assessment of habitat within the study area is scheduled for 2014.

The August 14^{th}, 2012 assessment included measurement of water quality parameters within the compensation channel (Table 1). No water quality factors were judged to be limiting for fish at the time of assessment though flows were considered to be low.

Table 1. Select Water Quality Measurements of Mercoal Creek on August 14^{th}, 2012

Dissolved Oxygen (mg/l)	7.44
Temp (^{0}C @ time)	12.6 @ 10:00
Cond (uS)	423.3
Discharge (m^3/s)	0.0135

Fish Sampling

The 2012 fish sampling program consisted of electrofishing and angling surveys:

- 350 metres of the diversion channel was electrofished for 1381 seconds of on-time. No fish were captured or observed during this survey.
- Deep portions of 4 pools were angled due to the limited effectiveness of electrofishing within deeper water. No fish were captured or observed during 2 hours of total angling effort.
- A 200 metre section of the natural channel downstream of the diversion was electrofished for 996 seconds of on-time. No fish were captured or observed during this survey.

Summary

Consistent with the Habitat Compensation Plan (Stemo 2005), the constructed diversion channel still had substantially more Class 1 pools in 2012 as compared to the pre-disturbance condition. Based on Habitat Suitability Modelling (Raleigh et al. 1984), compensation efforts have resulted in an increase in the overall habitat quality within this portion of Mercoal Creek.

Utilization of the diversion channel was not confirmed in 2010 or 2012, however fish were also absent in the natural channel downstream of the diversion which suggests that fish densities in the headwaters of Mercoal Creek remain low (as was found during baseline studies (Boorman 2003)).

References

Boorman, J. 2003. Baseline fisheries resource assessment of waterbodies on and adjacent to the proposed mercoal east mine extension. Report of Pisces Environmental Consulting Services Ltd. to Luscar Ltd. Coal Valley Mine. Edson, AB. 35pp. + App.

Raleigh, R.F., T. Hickman, R.C. Solomon, and P.C. Nelson. 1984. Habitat suitability information: Rainbow Trout. U.S. Department of the Interior Fish and Wildlife Service. FWS/OBS-82/10.60. 64 pp.

Stemo, E. 2005. Coal Valley Mine Mercoal Phase 2 Extension Fish Habitat Compensation. Report of Pisces Environmental Consulting Services Ltd. to Luscar Ltd. Coal Valley Mine. Edson, AB. 10pp. + App.

Closure

I trust this meets your information requirements at this time. If you have any questions please contact our office at your convenience.

Sincerely,

<original signed by>

Joe Sonnenberg
Fisheries Technician

<original signed by>

Ricki-Lynn Boorman, P.Biol
Senior Fisheries Biologist

Pisces Environmental Consulting Services Ltd.

Attch.

	
Photo 1. Looking across at anchored tree within the diversion channel.	Photo 2. Looking downstream at typical habitat within the diversion channel.
	
Photo 3. View of typical habitat within the diversion channel.	Photo 4. Looking at partially exposed bank along diversion channel.
	
Photo 5. Looking at large pool with anchored trees.	Photo 6. View of typical habitat within the diversion channel.

	
Photo 7. Looking at large pool with anchored trees.	Photo 8. Looking at small pool with anchored trees.

Report #5

Pisces Environmental Consulting Services Ltd.
•Unit 118, 239 Spruce Street• Red Deer County • Alberta • T4E 1B4•
• Phone 403-347-5418 • Fax 403-347-0681•
•www.piscesenvironmental.com•

May 27, 2013

CVRI
Coal Valley Mine
Bag 5000
Edson, Alberta
T7E 1W1

ATTN: Megan Hill

RE: Mercoal Tributary 3 (MET-3) channel re-establishment and fisheries enhancement site visit.

Introduction

As requested, Fisheries Biologists from Pisces Environmental Consulting Services Ltd. (Pisces) completed a site visit and reconnaissance of the MET3 channel construction site. The purpose of the visit was to assess current conditions in consideration of potential habitat enhancements that could be constructed site. The document presents a brief summary of results from the site visit and also includes general recommendations regarding potential habitat enhancement opportunities.

Background

CVRI's Mercoal West Development required diversion of Mercoal Tributary #3 (MET-3) to facilitate mining. Following coal extraction, CVRI is required by DFO authorization ED-09-2664A to:

- Re-construct the channel of MET-3;
- Construct fish habitat features in the restored channel of MET3;
- Monitor the channel and constructed habitat following construction to ensure specifications in the authorization have been met.

CVRI removed the MET-3 Diversion and re-established flow within a reconstructed channel early in 2013. Pisces staff conducted a site visit on May 22nd, 2013 to assess the reclamation area ahead of final planting and channel enhancement. Prior to mining, MET-3 was composed of shallow run habitat and provided seasonal habitat for salmonid species (Pisces 2008).

Site Conditions

Discharge in MET-3 on May 22nd, 2013 was extremely low. Conditions in the Coal Valley area were dry in general and flows were observed to be low throughout the area. Only a portion of the constructed channel had a surface hydraulic connection and a significant length of channel was dry (see attached photos).

Near the downstream end of the diversion channel MET-3 was receiving substantial discharge from an end-pit lake/pond area. The outlet channel was approximately 40 meters long with a 3 meter wetted width. The discharge from the outlet channel was measured at 0.08 m^3/s while discharge in MET-3 (upstream of where the lake/pond outlet entered MET3) was less than 0.005 m^3/s at the time of assessment. Our understanding from initial mine plans was that these standing waterbodies were not supposed to be accessible to fish but in our estimation there was no sufficient barrier that would exclude fish from moving into the lake/pond.

Photos depicting habitat conditions within the constructed MET-3 channel and the end pit lake/pond outflow are attached.

Recommendations

The MET-3 channel still requires final fish habitat feature installation and re-vegetation. Pisces recommends the following components be incorporated into the final reclamation design:

- Surface hydraulic connectivity should be established in the constructed channel. This may require removal of some of the larger rock that was used to line the channel.
- Streambank cover should be installed along the reclaimed channel. Willows/ deciduous plantings should be established as close to the stream as possible. Coniferous tree seedling should also be established where feasible to promote long-term stream shading that will mimic natural channel conditions in the area.
- Large woody debris (conifers with intact limbs anchored or embedded into the banks and protruding into the channel) should be placed within the reclaimed channel to provide cover for fish where channel conditions allow. The shallow nature of MET-3 limits the potential for instream habitat enhancement within the reconstructed channel area.
- The creation of salmonid spawning habitat within the end-pit lake/pond outflow channel should include placement of appropriately sized gravels, and habitat suited for rearing of juvenile salmonids. The gravel should be 5 to 15 mm in size and preferably rounded rather than crushed with sharp edges. Gravel enhancement in this channel would be expected to benefit MET-3 as some substrate would be expected to move downstream during future flood events.

Additional recommendations and input can be provided at the request of CVRI. Optimally, a Qualified Aquatic Environment Specialist (QAES) would be onsite to provide feedback and expertise during channel configuration and enhancement.

References

Pisces. 2008. Coal Valley Mine Mercoal West and Yellowhead Tower Extension Project. Aquatic Resources Environmental Impact Assessment. Prepared for CVRI by Pisces Environmental Consulting Services Ltd. 120 pp+ App

Closure

I trust this meets your information requirements at this time. If you have any questions regarding the foregoing please contact our office at your convenience.

Sincerely,

<original signed by>

____

Joe Sonnenberg,
Fisheries Biologist

Pisces Environmental Consulting Services Ltd.

Attch.

Photos

	
Photo 1. Looking upstream at MET-3 channel from upstream end of restored channel.	Photo 2. Looking downstream at restored channel from MET-3. Note: lack of surface connection
	
Photo 3. MET-3 Restored channel overview (looking downstream).	Photo 4. MET-3 Restored channel where surface connectivity resumes (looking downstream).

	
Photo 5. Looking downstream at lower restored MET-3 channel.	Photo 6. Looking upstream at outlet channel from end-pit lake/pond system.
	
Photo 7. Looking upstream at end pit lake/pond system.	Photo 8. Looking downstream at end pit lake/pond outflow and MET-3 confluence.

Report #6

Pisces Environmental Consulting Services Ltd.
•Unit 118, 239 Spruce Street• Red Deer County • Alberta • T4E 1B4•
• Phone 403-347-5418 • Fax 403-347-0681•
•www.piscesenvironmental.com•

August 16, 2013

CVRI
Coal Valley Mine
Bag 5000
Edson, Alberta
T7E 1W1

ATTN: Megan Hill

RE: Recommendations for Mercoal Tributary 3 (MET-3) channel re-establishment and habitat enhancement.

Introduction

As requested, Pisces Environmental Consulting Services Ltd. (Pisces) conducted investigations of Mercoal Tributary 3 (MET-3) to assess current conditions to facilitate development of a habitat enhancement plan. This document presents detailed recommendations regarding potential habitat enhancement opportunities following site visits and assessments completed in May and July 2013.

Background

CVRI's Mercoal West Development required diversion of MET-3 to facilitate mining. DFO issued Authorization ED-0902664A for the project; the Authorization states that CVRI is required to implement the following measures once coal extraction has been completed.

- Re-construct the channel of MET-3;
- Construct fish habitat features in the restored channel of MET3;
- Monitor the channel and constructed habitat following construction to ensure specifications in the Authorization have been met.

CVRI removed the MET-3 Diversion and re-established flow within a reconstructed channel early in 2013. Pisces staff conducted site visits on May 22nd, 2013 and July 13th, 2013 to assess the reclamation area ahead of final riparian planting and channel enhancement. Prior to mining, MET-3 was composed of shallow run habitat and provided seasonal habitat for salmonid species (Pisces 2008).

Recommendations

Pisces recommends the following components be incorporated into the reclamation plans for the MET-3 channel. Optimally, a Qualified Aquatic Environment Specialist (QAES) would be onsite to provide advice and feedback during the construction of the habitat enhancements. Table 1 provides general information regarding the location of proposed enhancement works while photos of proposed enhancement sites are provided in Figures 1 to 10.

- Surface hydraulic connectivity should be established in the constructed channel. This may require removal of some of the larger rock that was used to line the channel (Figure 7 and 9). Pools created in these areas should be excavated to 1.0 meter deep if possible (to increase habitat diversity).
- Streambank cover should be installed along the reclaimed channel. Willows (or other deciduous plantings) should be established as close to the stream as possible. Coniferous tree seedling should also be established where feasible to promote long-term stream shading that will mimic natural channel conditions in the area. Plantings should be relatively dense where warranted with riparian planting densities averaging at least one tree per meter of bank. Fine material (soil) may need to be placed within riprap gaps to provide suitable planting substrate.
- Large woody debris (conifers with intact limbs anchored or embedded into the banks and protruding into the channel or brush piles) should be placed within the reclaimed channel to provide cover for fish where channel conditions allow. Bushy conifers ranging from three to five metres tall with intact root wads (if feasible) should be installed where indicated (Figures 1-12). Perpendicular installations (Figure 4) should aim to maximize stream shade area. If possible, instream conifer placements should be anchored utilizing boulders or cable/ posts.
- OPTIONAL - There is opportunity to create salmonid spawning habitat within the end-pit lake/pond outflow channel (Figure 11 and 12). This would involve placement of gravels (preferably rounded rather than crushed with sharp edges) in the 5 to 15 mm size range.

Table 1. Basic description and location of proposed habitat enhancements on MET-3.

Site	Location (UTM’s)	Enhancement Details
Figure 1	492724 5891268	Vegetate with willows and conifers.
Figure 2	492730 5891282	Vegetate, gravel addition, tree cover installations
Figure 3	492733 5891302	Vegetate, gravel addition, tree cover installations
Figure 4	492725 5891334	Vegetate, gravel addition, tree cover installations
Figure 5	492740 5891370	Vegetate, excavate pool, tree cover installations
Figure 6	492746 5891385	Vegetate with willows and conifers
Figure 7	492759 5891425	Improve connectivity
Figure 8	492759 5891425	Vegetate with willows and conifers
Figure 9	492768 5891440	Vegetate, improve connectivity
Figure 10	492736 5891452	Vegetate with willows and conifers

As previously noted in the letter from Pisces to CVRI on May 27, 2013 (J. Sonnenberg to M. Hill), Pisces noted that a nearby end-pit lake/pond outlets into MET-3 in the near vicinity of the constructed channel. It is our understanding that these standing waterbodies were not supposed to be accessible to fish but it appears that there is currently no sufficient barrier that would exclude fish. Given the current scenario Pisces has identified two options (both likely subject to consultation with regulators):

- Construct a barrier to preclude fish from accessing the lake/pond. However, fish were observed within the lake area during the assessment and CVRI might need to consider this factor if lake drawdown or backfilling is to occur.
- Develop the lake/pond to support fish. There is potential for a vegetated island and adjacent littoral area near the lake outlet that could provide excellent juvenile salmonid rearing and feeding habitat. The enhancements featured on the end-pit lake outflow channel (Figure 11 and 12) are included but may not be necessary depending on final reclamation plans and end use objectives.

Closure

I trust this meets your information requirements at this time. If you have any questions regarding the foregoing please contact our office at your convenience.

Sincerely,

<original signed by>

Joe Sonnenberg, B.Sc.
Fisheries Biologist
Author

<original signed by>

Erik Stemo, P.Biol
Senior Fisheries Biologist
Review

References

Pisces. 2008. Coal Valley Mine Mercoal West and Yellowhead Tower Extension Project. Aquatic Resources Environmental Impact Assessment. Prepared for CVRI by Pisces Environmental Consulting Services Ltd. 120 pp+ App

Figure 1.

Figure 2.

Figure 3.

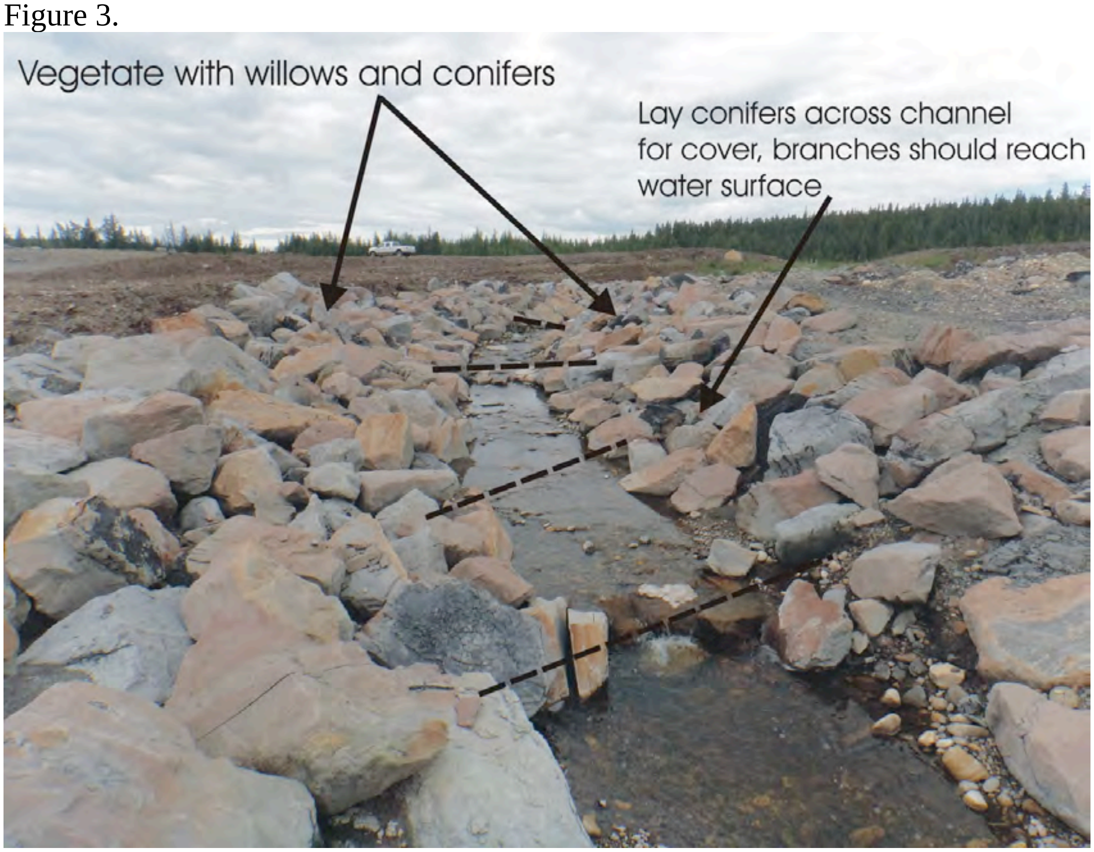


Figure 4.

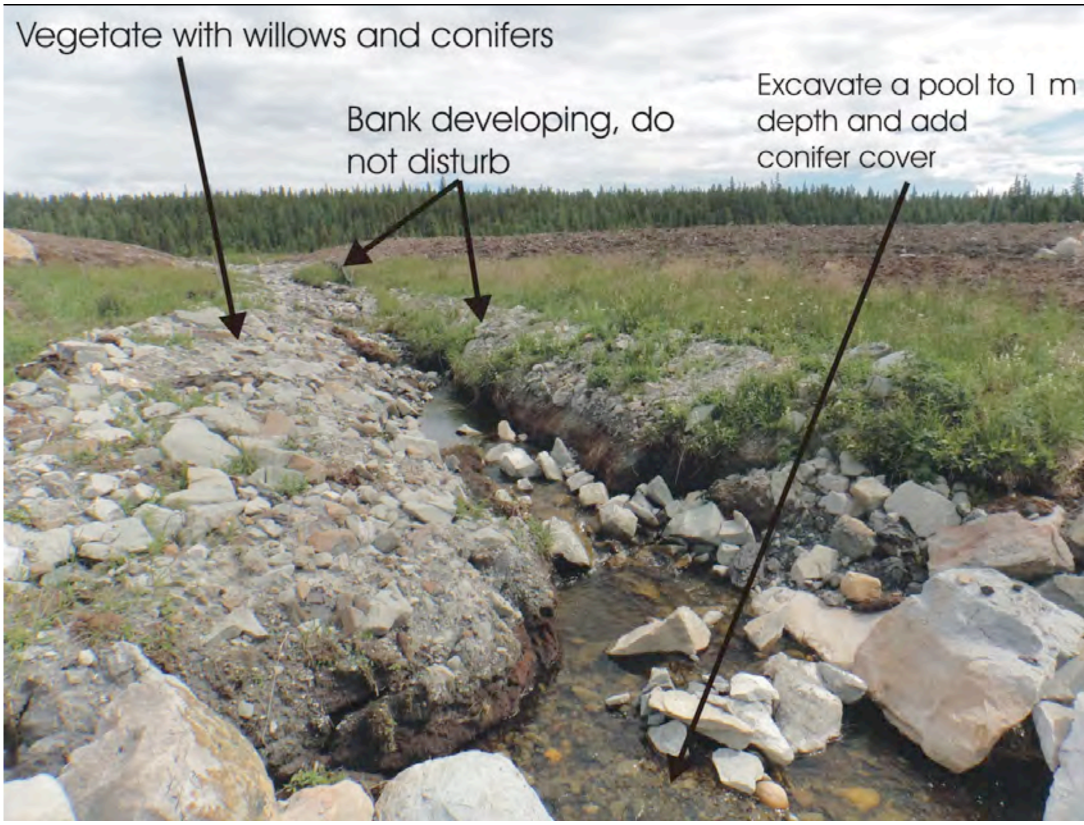


Figure 5.

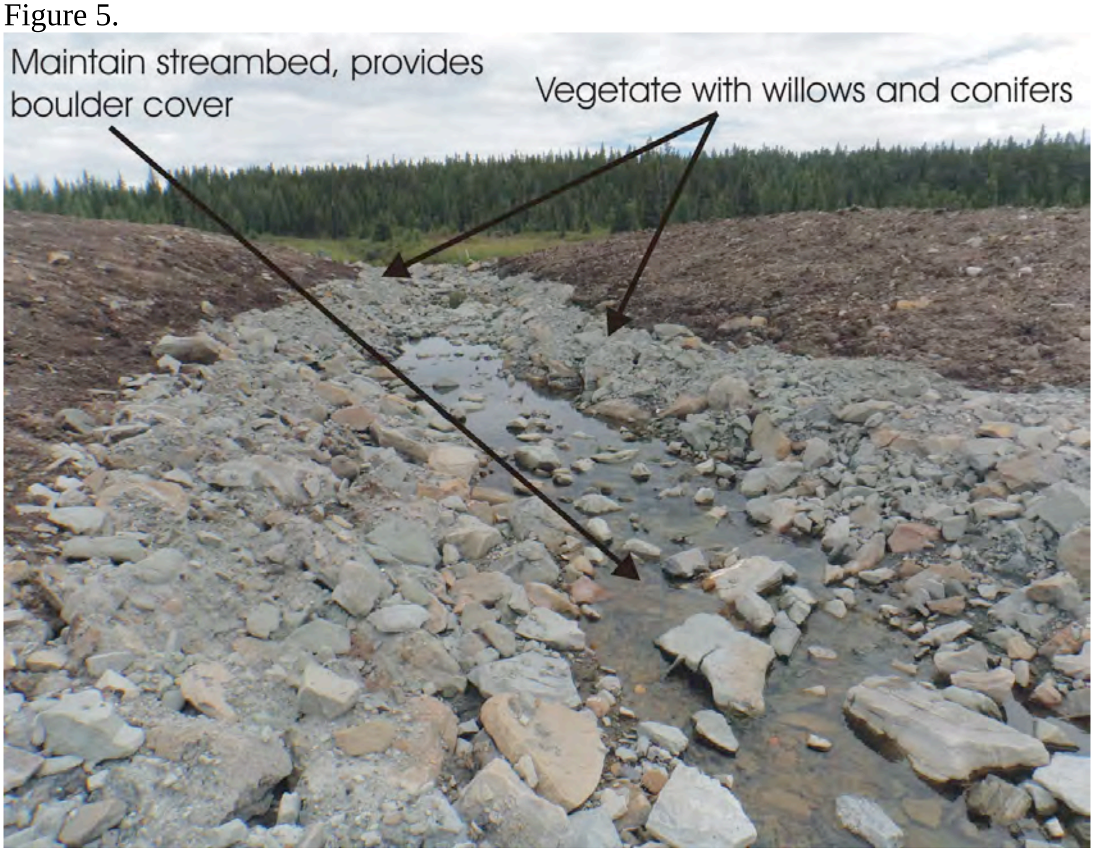


Figure 6.

Figure 7.

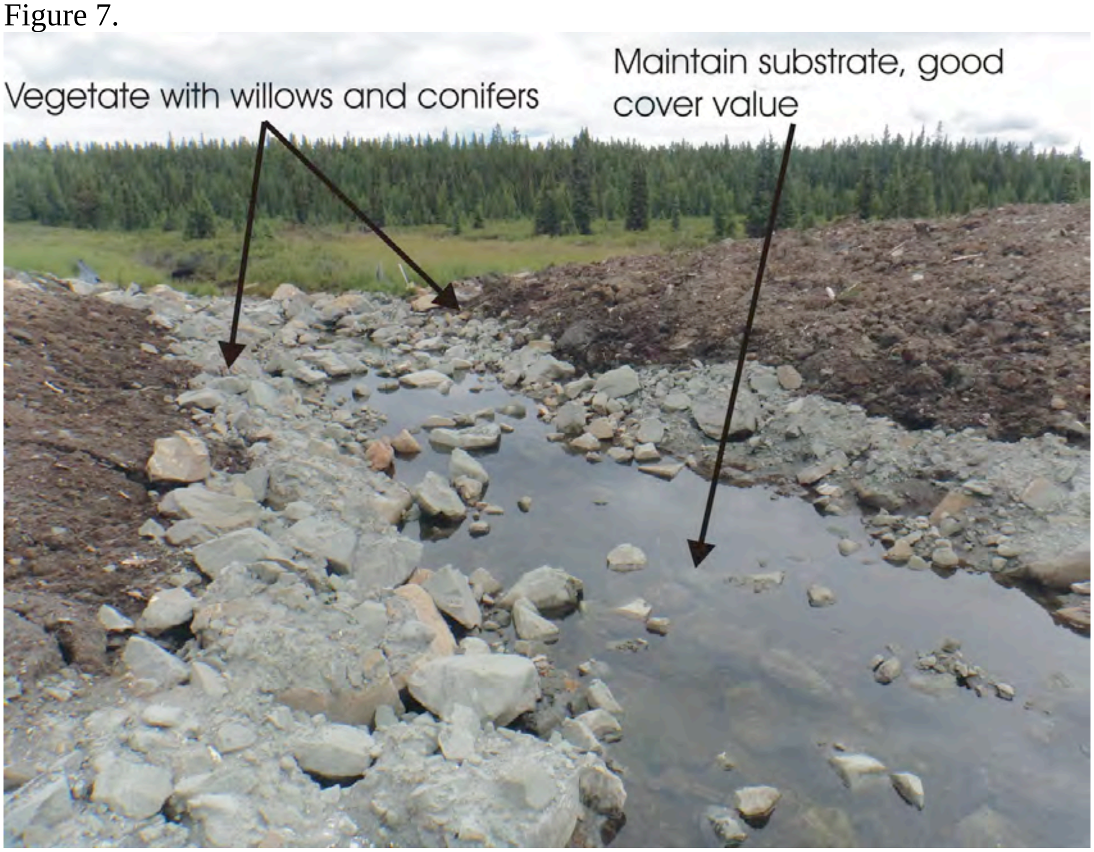


Figure 8.

Figure 9.

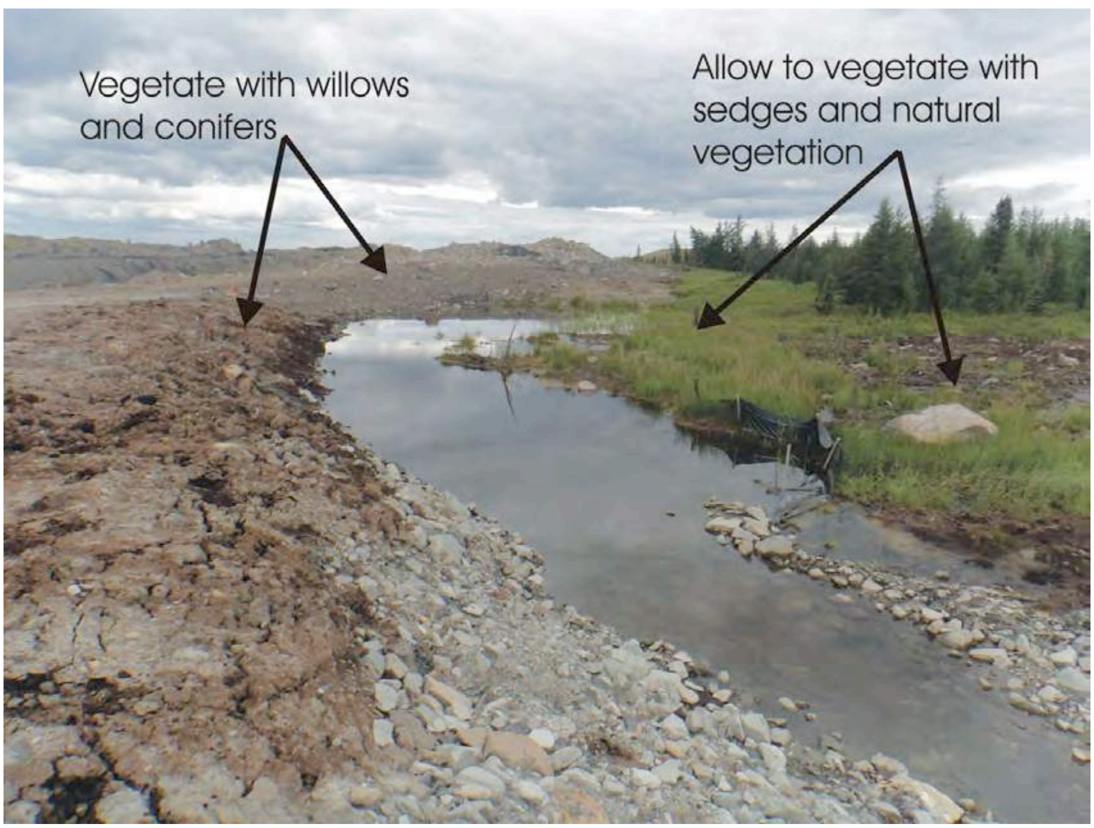


Figure 10.

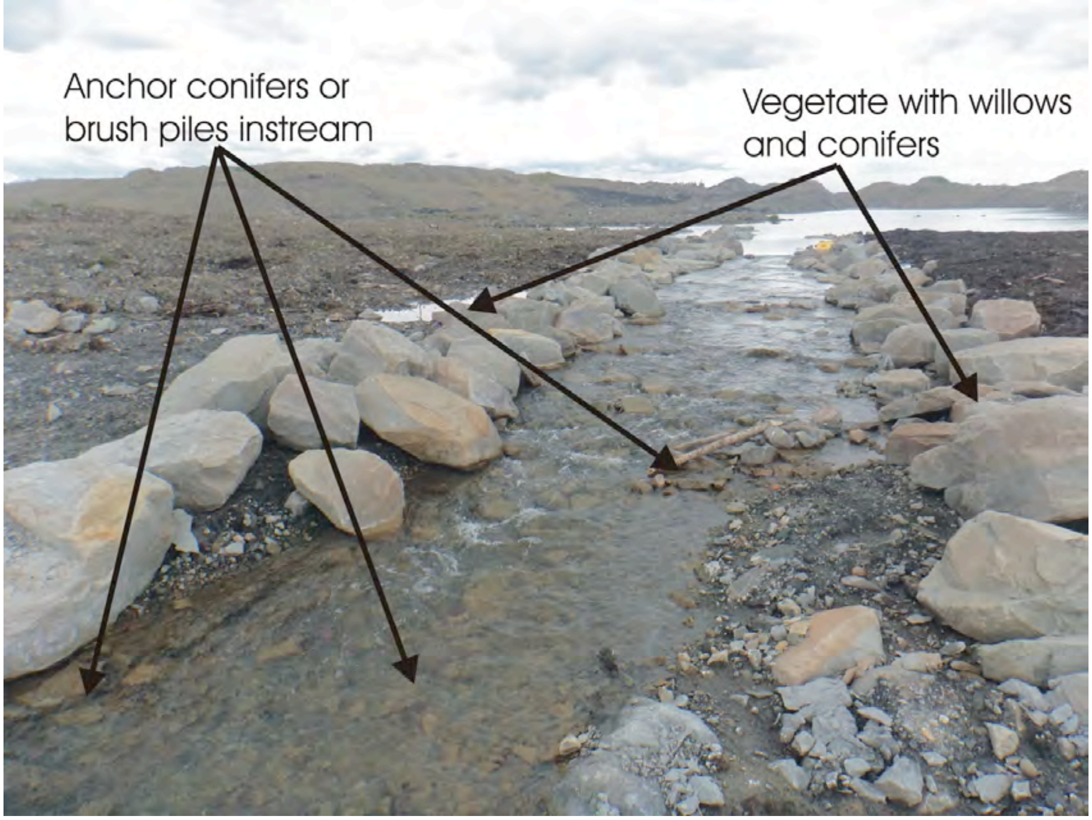


Figure 11.

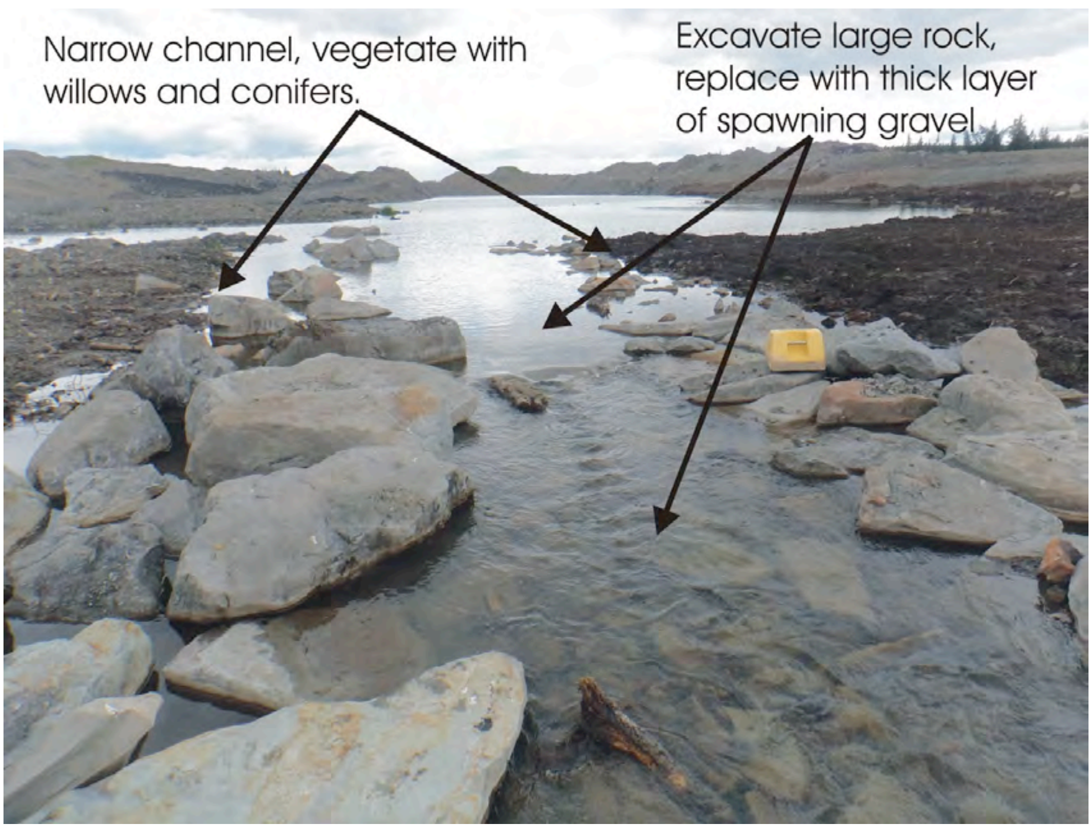


Figure 12.

Report #7

CVRI Robb Trend Project
Summary of Fish Habitat Impacts, Mitigation and Habitat Compensation Strategies

Prepared for: Coal Valley Resources Inc. Edson, AB
August 2013

PISCES ENVIRONMENTAL CONSULTING SERVICES LTD.

CVRI Robb Trend Project

Summary of Fish Habitat Impacts and Mitigation and Habitat Compensation Strategies

Prepared for:
Coal Valley Resources Inc.
Edson, Alberta

Submitted to:
Fisheries and Oceans Canada (DFO)

Prepared by:
Pisces Environmental Consulting Services Ltd.
Red Deer, Alberta

August 2013

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDICES

1.0 INTRODUCTION

Coal Valley Resources Inc. (CVRI) is proposing an extension of the existing Coal Valley Mine (CVM) operation approximately 100 kilometres southwest of Edson, Alberta. Termed the Robb Trend Project (Project), the mine expansion includes development of areas to the northeast of existing operations. The Project mine permit area is approximately two kilometres wide and almost 50 kilometres long, extending in a northwest direction from the Pembina River past the Hamlet of Robb. A Project Application for the proposed expansion entitled *Robb Trend Coal Mine Expansion Project* was submitted to government regulators in April 2012 (CVRI 2012).

This document is intended to address key information requests that have been communicated by Fisheries and Oceans Canada (DFO) to CVRI. Specifically, this document provides:

- A description of updated mine plans and reclamation strategies that have been developed since the Project Application was submitted.
- A summary of direct habitat impacts resulting from the Project based on review of the updated mine plans.
- A discussion of other potential indirect impacts to fish habitat (if it was determined that the updated mine plans had changed the impact assessment scenario presented in the Project Application).
- A discussion of updated mitigation initiatives proposed by CVRI.
- A description of the proposed habitat compensation framework for the Project. It is expected that this conceptual plan will form the basis of agreement from which CVRI and DFO will work in consultation to satisfy the requirements of the federal *Fisheries Act*.
- A discussion of monitoring initiatives proposed by CVRI.

Much of the information provided in this document is summarized from, and makes reference to, sections of the Project Application as well as the responses to Supplemental Information Requests (SIRs) that were submitted as part of the review process. The analysis and conclusions presented in these documents remain applicable and should be referred to if additional details to the points raised in this document are required.

2.0 UPDATED MINE PLANS

To facilitate mine planning, the Project was divided into four areas referred to as Robb West, Robb Main, Robb Centre, and Robb East (Figure 1). The estimated Project lifespan is expected to be approximately 25 years with mine activities expected to progress as indicated below:

- Mining in the Robb West Area: 2032 to 2034
- Mining in the Robb Main Area: 2017 to 2031
- Mining in the Robb Centre Area: 2023 to 2026
- Mining in the Robb East Area: 2027 to 2039

After consultation with stakeholders, CVRI initiated a review of the original mine plan to identify solutions for concerns raised by regulators. Through this process CVRI has produced an updated mine plan that will result in reduced impacts to fish habitat and fewer on-stream/flow-through end pit lakes post reclamation.

The Project will consist of 13 main watercourse diversions; a description of each of the diversions is provided below. The anticipated schedule for development along with the predicted impacts to fish habitat are illustrated in Figure 2.

Erith River Diversion

Diversion of the Erith River involves several phases as illustrated on Figure 5.

Short sections of stream channel to route the Erith River out of the proposed McPherson Pit area will be constructed. These sections would be short, cutting off small meanders of the river and forcing the river toward the south. Once construction is completed the flow would be moved into the new channels. This diversion would last approximately three years while the McPherson Pit is mined and a new channel built in the floor of the McPherson Pit. The river would then be moved to the new McPherson Pit channel, which would be constructed to provide habitat for fish. This diversion would be in place for approximately five years while the Mynheer Pit was mined and reclaimed with a new channel in the base of the Mynheer Pit. Once the Mynheer Pit is complete, the Erith River would be moved into the new channel routed through the Mynheer Pit. This channel replaces Lake 4 (previously proposed in the Project Application). Mining of the Val d'Or Pit will also require movement of the Erith River channel to accommodate mining beneath the river. This will be accomplished by moving the river to the east into a constructed channel so that mining can be conducted on the west side of the river. Once mining is completed, a land bridge will be backfilled to the west and a new channel constructed on the land bridge as the final reclaimed river channel. All channels will be constructed to provide fish habitat. The 'switch' will take approximately four years to accomplish. Lake 5 (West and East) will outlet into the new channel.

ERT1 Diversion

Plans involving ERT1 have been revised to reduce direct impacts to fish habitat (Figure 5).

A short portion (~500 m) of the Mynheer Pit is being excluded from development in order to maintain spawning habitat in ERT1. Flows in ERT1 will be maintained to flow into the Erith River. A short diversion channel on the north side of the Mynheer Pit (highwall side) will be used to direct flows below sensitive habitat (spawning sites) that was identified during baseline investigations. This diversion will be in place approximately two years before it is discontinued as it is replaced by a new channel in the pit floor of Mynheer Pit. All channels will be constructed to provide fish habitat.

Bacon Creek Diversion

Plans involving Bacon Creek have been revised to reduce direct impacts to fish habitat (Figures 5 and 6).

A short section of the Mynheer Pit will be excluded from development in order to maintain certain sections of the existing Bacon Creek channel. However mining of the Val d'Or Pit will require that portions of Bacon Creek be moved to accommodate mining beneath the creek. This will be accomplished moving the creek to the east into a constructed channel so that mining can be conducted on the west side of the river. Once mining is completed a land bridge will be backfilled to the west and a new channel constructed on the land bridge as the final reclaimed river channel. All channels will be constructed to provide fish habitat. The 'switch' will take approximately four years to accomplish. The new channel will be located between Lake 5 and 6. Lakes will outlet into the creek.

Halpenny Creek Diversion

Plans involving Halpenny Creek have been revised to reduce direct impacts to fish impact. (Figure 6).

Two short sections of the Mynheer Pit will be excluded from development in order to ensure continued flow in the Halpenny Creek basin. Mining which directly impacted HLT1 will no longer be completed and HLT1 will continue to flow into Halpenny Creek (Main). Mining which interrupted HLT2 will no longer be completed and HLT2 will continue to flow into Halpenny Creek (Main). Mining which interrupted Halpenny Creek (Main) in the Mynheer Pit area will no longer be completed. Mining of the Val d'Or Pit will require movement of Halpenny Creek to accommodate mining beneath the creek. This will be accomplished by moving the creek to the east into a constructed channel so that mining can be conducted on the west side of the river. Once mining is completed a land bridge will be backfilled to the west and a new channel constructed on the land bridge as the final reclaimed creek channel. All channels will be constructed to provide fish habitat. The 'switch' will take approximately four years to accomplish. Lake 6 will not outlet into Halpenny Creek as it will flow westward into Bacon Creek.

Lendrum Creek Diversions

Plans involving Lendrum Creek have been revised to reduce direct impact to fish habitat (Figures 7 and 8).

Flow in LET1 will be ditched or pumped to LET3 during mining of the Mynheer Pit. This transfer is expected to be in place for approximately one year. Afterwards, the flow can be accommodated in the pit floor.

Flow in LET3 will be handled with a diversion ditch or pumping during mining of the Mynheer Pit. This transfer is expected to be in place for approximately one year. Afterward a constructed channel will be put in place as part of reclamation to handle LET1 and LET3. Flow in LET3 will be handled with a diversion ditch or channel during mining of the Val d'Or Pit. This transfer is expected to be in place for approximately two years. Further mining to the east can be isolated from LET3. Final flow of LET3 will be through Lake 7. This diversion is expected to be in place for approximately three years.

Upper Lendrum Creek will be handled by ditching during the mining of the Mynheer Pit. This transfer is expected to be in place for approximately three years until the Mynheer Pit is reclaimed. Flow would then be moved into a new channel established in the pit floor and connected to LET3. The ditching is expected to be in place for approximately three years.

Hay Creek Diversion

Mining in the Mynheer Pit will intercept drainage of the upper portion of this creek. Water caught by the mining area will be collected, treated and returned to Hay Creek. This transfer is expected to be in place for approximately four years. Lake 3 will outlet to Hay Creek (Figure 4).

Lund Creek Diversions

LDT1 will be intercepted by mining in both Mynheer and Val d'Or Pits. Land bridges provided in both pits will provide uninterrupted flow during mining. Lakes 8 and 9 will be developed as part of the reclaimed profile (Figures 8 and 9). LDT1 will flow through both Lakes 8 and 9 with a short channel between the two lakes. These relocations are expected to last approximately four years and may be completed concurrently.

LDT3 will be intercepted by mining in both Mynheer and Val d'Or Pits. Flows in both pits will be handled by pumping. Alternatives for ditching flows either to the east or west could also be considered. Lakes 10 and 11 will be developed as part of the reclaimed profile. LDT3 will flow through both Lake 10 and 11 with a short channel between the two lakes. Lake 12 will outlet into Lake 10. This interruption is expected to extend over approximately two years.

Bryan Creek Diversion

Plans involving Bryan Creek have been revised to provide restored channel on the final reclamation landscape rather than a flow-through end pit lake (Figure 3).

Short sections of stream channel to route Bryan Creek out of the proposed Mynheer Pit area will be constructed. These sections would be short, cutting off small meanders of the creek and forcing the creek toward the north. Channels would be constructed to provide fish habitat. Once construction is completed the flow will be directed into the new channels. This diversion would last approximately three years while the Mynheer Pit was completed and reclaimed with a stream channel in the base of the pit. Flow will be routed through the Mynheer Pit channel. This will be the final, reclaimed channel for the creek and would be constructed to provide fish habitat. Lake 2 will outlet into Bryan Creek below the new channel.

PET1 Diversion

Plans involving PET1 have been revised to provide restored channel on the final reclamation landscape rather than a flow-through end pit lake (Figure 9).

The easternmost end of the Val d’Or Pit nearest the Pembina River is being excluded from development. This provides an increased buffer between development and the Pembina floodplain. This revision allows for diversion of PET1 around the eastern end of the proposed Val d’Or Pit. This diversion can be accomplished prior to mining. The channel will be constructed to provide fish habitat.

3.0 SUMMARY OF EXISTING CONDITIONS

Baseline fish and fish habitat conditions within the Project area were described in detail in the Project Application (CVRI 2012). A brief summary of the information gathered during the baseline investigations is provided below.

3.1 FISH POPULATIONS

During baseline field investigations fish presence was confirmed at 53 of the 84 sites sampled (electrofishing and angling sites) in 42 waterbodies in and adjacent to the Project. Overall, 15 fish species were captured and identified (Table 1).

Rainbow Trout were the most common and widespread species within the Local Study Area (LSA) and Regional Study Area (RSA), captured in 38 of the 42 waterbodies sampled. Bull Trout, Burbot, Lake Chub, Longnose Sucker, and Spoonhead Sculpin were encountered much less frequently than Rainbow Trout but were still found at a number of different locations. Other species, including Arctic Grayling, Brook Stickleback, Brook Trout, Longnose Dace, Mountain Whitefish, Northern Pike, Pearl Dace, Trout-perch, and White Sucker were rare and found in one or two waterbodies. Rainbow Trout densities and catch-per-unit-effort (CPUE) for all sport fish captured in streams sampled during baseline investigations are presented in Figures 10 and 11 respectively.

3.2 FISH HABITAT

Habitat inventories were conducted on all streams within the LSA that exhibited habitat potential (i.e. exhibited a defined channel, did not have an excessive gradient (>12%)). Information obtained from the habitat inventories and fish sampling (local field data) was used to provide a conservative ranking of study streams in terms of their overall habitat potential/ability to support various life cycle phases of fish. The rating system was designed to provide a general understanding of habitat potential of subject watercourses based on local field data but should not be considered as a habitat suitability (HSI) ranking system. Photos depicting typical habitat conditions within Low, Moderate, and High habitat potential ranked watercourses are provided in Figure 12.

Preliminary scoping identified a total of 42 potential study streams in or immediately adjacent to the Project. A list of watercourses and general habitat characteristics is provided in Table 2.

A summary of habitat potential/utilization information and a habitat potential/utility ranking for watercourses that exhibited fish habitat potential are provided in Table 3 and Figure 13.

Table 1. Fish species distribution in watercourses in and adjacent to the Robb Trend Project.

Mine Area	Water Body	Reach	Arctic Grayling	Brook Stickleback	Brook Trout	Bull Trout	Burbot	Lake Chub	Longnose Dace	Longnose Sucker	Mountain Whitefish	Northern Pike	Pearl Dace	Rainbow Trout	Spoonhead Sculpin	Trout-perch	White Sucker
Robb West	Bryan Creek (BR-1 to BR-3)													✔✖			
	BRT2													✔✖			
	Embarras River (EM-1 & EM-2)		✔✖		✔✖	✖	✖	✔		✔	✔✖			✔✖	✔✖	✔✖	
	EMT1											✔					
	Jackson Creek				✔									✖			
Robb Main	Hay Creek (HA-1 to HA-4)	1 2 3					✔							✔✖ ✔ ✔			
	Erith River (ER-3, ER-4, & ER-5)	1 2 3	✖ ✖			✔✖	 ✖	✔ ✔	✔	✔ ✔✖	 ✔✖			✔ ✔✖ ✔	✔ ✔✖	✔	✔ ✖
	Erith River (ER-7)					✔								✔			
	ERT1					✔								✔✖	✔		
	ERT2													✔✖	✔		
	ERT3													✔			
	ERT4													✔			
	ERT5									✔✖				✔✖			
	ERT6					✖								✔✖			
	ERT7													✔✖			
	ERT10					✖								✔✖			
	ERT12													✔✖			
	Bacon Creek (BA-2)					✖								✔✖			
Robb Centre	Halpenny Creek (HL-2 & HL-3)	1 2				✖				✖	✖		✔	✔✖ ✔	✖		
	Halpenny Creek (HL-5)													✔			
	Halpenny Creek (HL-6)													✔			
	HLT1													✔✖			
	HLT2			✔													
	HLT5													✔			
	Lendrum Creek (LE-2 & LE-3)						✔							✔			
	LET1						✔							✔✖			
	LET1B													✔			
	LET3													✔			
Robb East	Lund Creek (LD-5 & LD-7)													✔			
	LDT1					✖								✔✖			
	LDT3													✔			
	PET1				✔		✔										

✔ Pisces baseline investigations (2005-2013)
✖ Historical Reference (FWMIS)

Table 2. Summary of watercourses identified in the Project area.

Mine Area	Watercourse	Code	Scoping Results	Stream Class[1]
Robb West	Bryan Creek	BR	• Defined channel (3.6 m wide), perennial flow	P
	Bryan tributary #1	BRT1	• Poorly defined channel, limited discharge	E
	Bryan tributary #2	BRT2	• Defined channel (1.2 m wide), perennial flow likely	P
	Embarras tributary #1	EMT1	• Poorly defined channel that transitions to quantifiable habitat downstream near mine permit boundaries, limited discharge	I
	Jackson Creek	JA	• Defined channel (0.8 m wide), perennial flow	P
Robb Main	Bacon Creek	BA	• Defined channel (2.0 m wide), perennial flow	P
	Erith River	ER	• Defined channel (6.2 m wide), perennial flow	P
	Erith tributary #1	ERT1	• Defined channel (2.6 m wide), perennial flow likely	P
	Erith tributary #2	ERT2	• Defined channel (1.4 m wide), limited discharge, Class 3 (<0.5 m deep) habitat only	I
	Erith tributary #3	ERT3	• Defined channel (1.0 m wide), limited flows	I
	Erith tributary #4	ERT4	• Defined channel (0.7 m wide), high gradient, natural impediments to fish movement	I
	Erith tributary #5	ERT5	• Defined channel (1.4 m wide), perennial flow likely	P
	Erith tributary #6	ERT6	• Defined channel (1.8 m wide), perennial flow likely	P
	Erith tributary #7	ERT7	• Defined channel (1.7 m wide), perennial flow likely	P
	Erith tributary #8	ERT8	• Defined channel (1.3 m wide), perennial flow likely	P
	Erith tributary #10	ERT10	• Defined channel (2.2 m wide), perennial flow likely	P
	Erith tributary #12	ERT12	• Defined channel (1.3 m wide), perennial flow likely	P
	Hay Creek	HA	• Defined channel (2.5 m wide), perennial flow	P
	Hay tributary #1	HAT1	• Poorly defined channel, limited discharge, Class 3 habitat only, natural impediments to fish movement	I
	Mitchell tributary #1	MIT1	• Small channel to poorly defined channel, limited discharge, high gradient, natural impediments to fish movement	E
	Mitchell tributary #2	MIT2	• Small channel to poorly defined channel, limited discharge, high gradient, natural impediments to fish movement	E
Robb Centre	Halpenny Creek	HL	• Defined channel (4.0 m wide), perennial flow	P
	Halpenny tributary #1	HLT1	• Defined channel (1.8 m wide), perennial flow likely	P
	Halpenny tributary #2	HLT2	• Defined channel (0.9 m wide), limited discharge, natural barrier to fish movement	I
	Halpenny tributary #3	HLT3	• No defined channel	E
	Halpenny tributary #4	HLT4	• Defined channel (1.1 m wide), limited discharge, Class 3 habitat only, natural impediments to fish movement	I
	Halpenny tributary #5	HLT5	• Defined channel (0.8 m wide), limited discharge, Class 3 habitat only	I
	Halpenny tributary #8	HLT8	• Poorly defined to undefined channel	E
	Halpenny tributary #9	HLT9	• Defined channel (1.3 m wide), perennial flow likely	P
	Lendrum Creek	LE	• Defined channel (3.3 m wide), perennial flow	P
	Lendrum tributary #1	LET1	• Defined channel (2.0 m wide), perennial flow likely	P
	Lendrum tributary #2	LET2	• Poorly defined, limited discharge	E
	Lendrum tributary #3	LET3	• Defined channel (3.2 m wide), perennial flow likely	P
Robb East	Lund Creek	LD	• Defined channel (2.5 m wide), perennial flow	P
	Lund tributary #1	LDT1	• Defined channel (2.4 m wide), perennial flow likely	P
	Lund tributary #2	LDT2	• Defined channel (1.0 m wide), limited discharge, Class 3 habitat only	I
	Lund tributary #3	LDT3	• Defined channel (2.1 m wide), perennial flow likely	P
	Lund tributary #4	LDT4	• Defined channel (0.8 m wide), limited discharge, Class 3 habitat only	I
	Lund tributary #5	LDT5	• Defined channel (0.9 m wide), limited discharge, Class 3 habitat only	I
	Lund tributary #6	LDT6	• Poorly defined to undefined channel	E
	Lund tributary#7	LDT7	• Defined channel (1.3 m wide), limited discharge, Class 3 habitat only	I
	Pembina tributary #1	PET1	• Defined channel (2.5 m wide), perennial flow likely	P

[1] Stream Classification:
E = Ephemeral, not fish habitat, no defined channel or discontinuous channel over length of survey reach
I = Intermittent, marginal fish habitat, defined channel over length of survey reach, flow present only seasonally
P = Permanent, fish habitat, flowing most or all of the year

Table 3. Habitat potential/utilization, limiting factors, and overall ranking for watercourses in the Project area.

Waterbody	Habitat Potential/Utilization					Limiting Factors	Overall Rank
	Spawning		Rearing	Overwintering	Feeding		
Robb West							
Bryan Creek Reach 1	High	RNTR	High	Moderate	High	- limited cover, presence of beaver dams, absence of Class 1 (>1m deep) habitat	High
Bryan Creek Reach 2	None		Low	Moderate	Moderate	- limited cover, presence of beaver dams, lack of gravel/cobble, low pool frequency	Low
Bryan Creek Reach 3	High	RNTR	High	Low	Moderate	- limited cover, beaver dams, limited Class 1 habitat, low pool frequency	High
Bryan Creek Reach 4	None		Low	Moderate	Moderate	- beaver dams, lack of gravel/cobble, absence of pool habitat	Low
BRT2	Low	RNTR	Low	None	Low	- limited flows, absence of Class 1 habitat, absence of pool habitat	Low
Embarras River	Moderate	ARGR BKTR MNWH RNTR	Moderate	High	High	- low pool frequency, limited cover	High
EMT1	Low	NRPK	Low	None	Moderate	- absence of Class 1 habitat, low pool frequency, lack of gravel/cobble, low winter dissolved oxygen	Low
Jackson Creek	None		Low	None	Low	- limited flows, absence of Class 1 habitat, low pool frequency	Low
Robb Main							
Hay Creek Reach 1	None		Moderate	None	Low	- absence of Class1 habitat, absence of pool habitat, no winter flow	Low
Hay Creek Reach 2	None		Low	None	Low	- limited Class 1 habitat, low pool frequency, beaver dams, no winter flow	Low
Hay Creek Reach 3	None		None	None	Low	- beaver dams, absence of pool habitat, lack of gravel/cobble, no winter flow	Low
Erith River Reach 1	Moderate	MNWH RNTR	High	Moderate	High	- limited cover, beaver dams, low pool frequency	High
Erith River Reach 2	Low	MNWH RNTR	Moderate	Moderate	High	- limited cover, beaver dams, low pool frequency, limited Class 1 habitat	High
Erith River Reach 3	Moderate	RNTR	High	Moderate	High	- limited cover, beaver dams, absence of pool habitat, limited Class 1 habitat	High
Erith River (ER-7)	Low	RNTR	Moderate	Low	Moderate	- limited Class 1 habitat, low pool frequency	Moderate
ERT1	High	RNTR	High	None	High	- absence of Class 1 habitat, limited flows	High
ERT2	Low	RNTR	Low	None	Low	- limited flows, absence of Class 1 habitat, low pool frequency, lack of gravel	Low
ERT3	None		None	Low	Low	- beaver dams, low winter dissolved O_2, lack of gravel/cobble, limited flows	Low
ERT4	Low	RNTR	Low	None	Low	- absence of Class 1 habitat, steep gradient	Low
ERT5	Low	RNTR	Moderate	None	Moderate	- absence of Class 1 habitat	Low
ERT6	Moderate	BLTR RNTR	Moderate	None	Moderate	- absence of Class 1 habitat	Moderate
ERT7	Moderate	RNTR	Low	None	Low	- limited flows, absence of Class 1 habitat	Low
ERT8	None		Low	None	Low	- limited flows, absence of Class 1 habitat, low pool frequency	Low
ERT10	None		Moderate	None	Moderate	- absence of Class 1 habitat, lack of gravel	Low
ERT12	Low	RNTR	Low	None	Moderate	- limited flows, absence of Class 1 habitat, absence of pool habitat	Low
Bacon Creek	High	RNTR	High	Low	Moderate	- absence of Class 1 habitat, limited pool frequency, limited cover	High
Robb Centre							
Halpenny Creek Reach 1	Moderate	RNTR	Moderate	Moderate	Moderate	- absence of Class 1 habitat, low pool frequency	High
Halpenny Creek Reach 2	None		Low	High	Low	- absence of gravel/cobble, lack of cover, beaver dams	Low
Halpenny Creek Reach 3	High	RNTR	High	Low	High	-absence of Class 1 habitat, low pool frequency, low winter flows	High
HLT1	High	RNTR	Moderate	None	Moderate	- fish passage issues, low pool frequency, absence of Class 1 habitat	Moderate
HLT2	None		Low	Moderate	Low	- limited flows, low pool frequency, lack of gravel/cobble	Low
HLT4	None		Low	None	Low	- limited flows, absence of Class 1 habitat, absence of pool habitat, lack of gravel/cobble	Low
HLT5	None		Low	None	Low	- limited flows, absence of Class 1 habitat, absence of pool habitat, lack of gravel	Low
HLT9	Low	RNTR	Low	None	Low	- limited flows, absence of Class 1 habitat, lack of cover	Low
Lendrum Creek Reach 1	Moderate	RNTR	High	High	Moderate	- low pool frequency, lack of gravel/cobble, limited cover, beaver dams, low winter dissolved O_2	High
Lendrum Creek Reach 2	Low	RNTR	Moderate	Low	Moderate	- absence of Class 1 habitat, low pool frequency, lack of gravel/cobble, limited cover, beaver dams	Moderate
LET1	Moderate	RNTR BURB	Moderate	Low	Moderate	- limited flows, absence of Class 1 habitat, low pool frequency, limited cover, beaver dams	Moderate
LET3	High	RNTR	High	Moderate	Moderate	- low pool frequency, limited cover, lack of gravel/cobble	High
Robb East							
Lund Creek	High	RNTR	Moderate	None	Moderate	- absence of Class 1 habitat, low pool frequency	Moderate
LDT1	Low	RNTR	Low	Low	Moderate	- limited flows, absence of Class 1 habitat, limited cover	Low
LDT1A	None		Low	None	Low	- limited flows, absence of Class 1 habitat, low pool frequency	Low
LDT1C	None		Low	None	Low	- limited flows, absence of Class 1 habitat, low pool frequency	Low
LDT1D	None		None	None	Low	- limited flows, absence of Class 1 habitat, low pool frequency, steep gradient, fish passage issues	Low
LDT2	None		None	None	Low	- limited flows, absence of Class 1 habitat, low pool frequency, lack of gravel	Low
LDT3	Low	RNTR	Low	None	Moderate	- limited flows, absence of Class 1 habitat	Low
LDT3A	None		None	None	Low	- limited flows, absence of Class 1 habitat, lack of gravel, steep gradient, limited cover	Low
LDT4	None		None	None	Low	- limited flows, absence of Class 1 habitat, lack of gravel, limited cover	Low
LDT5	None		None	None	Low	- limited flows, absence of Class 1 habitat, lack of gravel	Low
LDT7	None		None	None	Low	- limited flows, absence of Class 1 habitat, lack of gravel	Low
PET1	High	BKTR	Moderate	Moderate	Moderate	- limited cover, lack of gravel/cobble	High
PET1A	None		None	None	Low	- limited flows, discontinuous channel	Low
PET1B	None		None	None	Low	- limited flows, discontinuous channel	Low

4.0 IMPACTS TO FISH HABITAT

The potential impacts to fisheries resources as a result of the Project are addressed in the Project Application (CVRI 2012). For the assessment presented in this document, the most recent information regarding mine planning, surface water management, and reclamation was reviewed to determine if there are resultant changes to the impact assessment scenario in terms of direct and indirect impacts to fish habitat.

4.1 DIRECT HABITAT IMPACTS

Components of the Project with the potential to result in direct habitat loss/alteration are summarized in Table 4.

Table 4. Summary of project components potentially resulting in direct habitat loss/alteration in waterbodies within the Robb Trend Project area.

Mine Area	Project Phase	Waterbody	Project Component Potentially Impacting Habitat
Robb West	Construction	Bryan Creek	• Watercourse crossing construction
		BRT2	• Watercourse crossing construction
		Jackson Creek	• Watercourse crossing construction
	Operation	Bryan Creek	• Temporary diversion to maintain downstream flows during mining • Development of mine pit
	Reclamation	Bryan Creek	• Reclamation of watercourse crossing • Reclamation of aquatic ecosystem to include end pit lake and stream reconstruction
		BRT2	• Reclamation of watercourse crossings
		Jackson Creek	• Reclamation of watercourse crossing
Robb Main	Construction	Erith River	• Watercourse crossing construction
		ERT4,5,6,8,10	• Watercourse crossing construction
	Operation	Erith River	• Temporary diversion to maintain downstream flows during mining • Development of mine pits
		ERT1,2,3	• Temporary diversion to maintain downstream flows during mining • Development of mine pit
		Bacon Creek	• Temporary diversion to maintain downstream flows during mining • Development of mine pit
		Hay Creek	• Temporary diversion to maintain downstream flows during mining • Development of mine pit
	Reclamation	Erith River	• Reclamation of watercourse crossing • Permanent diversion • Reclamation of aquatic ecosystem to include end pit lake and stream reconstruction
		ERT4,5,6,8,10	• Reclamation of watercourse crossings
		ERT1,2,3	• Reclamation of aquatic ecosystem to include end pit lake and stream reconstruction
		Bacon Creek	• Reclamation of aquatic ecosystem to include stream reconstruction
		Hay Creek	• Reclamation of aquatic ecosystem to include end pit lake and stream reconstruction

Note: Table 4 continues on next page.

Table 4 continued.

Robb Centre	Construction	HLT1,9	• Watercourse crossing construction
	Operation	Halpenny Creek	• Temporary diversion to maintain downstream flows during mining • Development of mine pit
		Lendrum Creek	• Temporary diversion to maintain downstream flows during mining • Development of mine pit
		LET1,3	• Temporary diversion to maintain downstream flows during mining • Development of mine pit
	Reclamation	Halpenny Creek	• Reclamation of aquatic ecosystem to include end pit lake and stream reconstruction
		HLT1,9	• Reclamation of watercourse crossings • Reclamation of aquatic ecosystem to include end pit lake and stream reconstruction
		Lendrum Creek	• Reclamation of aquatic ecosystem to include end pit lake and stream reconstruction
		LET1,3	• Reclamation of aquatic ecosystem to include end pit lake and stream reconstruction
Robb East	Construction	None	• No haulroad watercourse crossing construction in this area
	Operation	Lund Creek	• Temporary diversion to maintain downstream flows during mining • Development of mine pit
		LDT1,3	• Temporary diversion to maintain downstream flows during mining • Development of mine pit
		PET1	• Diversion to maintain downstream flows during mining • Development of mine pit
	Reclamation	Lund Creek	• Reclamation of aquatic ecosystem to include end pit lake and stream reconstruction
		LDT1,3	• Reclamation of aquatic ecosystem to include end pit lake and stream reconstruction
		PET1	• Reclamation of aquatic ecosystem to include stream reconstruction

4.1.1 HAULROAD CROSSINGS

In total there will be 12 haulroad crossings located on watercourses that provide fish habitat (Table 5). All of the watercourse crossings will be designed to provide for fish passage and to maintain habitat connectivity. Clear span arch structures or large culverts that are sized to accommodate fish passage will be constructed on watercourses that are fish bearing. Numerous additional culverts (minimum 0.6 m diameter) will be required in ephemeral draws to maintain natural drainage patterns (Matrix 2012).

Table 5. Description of habitat and analysis of direct habitat impacts for the haulroad crossings.

Watercourse	Culvert Diameter (m)[1]	Fish Habitat Present (overall rank)	Habitat Impact[2]
Bryan Creek	3.0	• Low habitat potential/utilization in this section of Bryan Creek	• Low since culvert will be designed to accommodate fish passage and will likely be sized to exceed bankfull width
BRT2	2.4	• Low habitat potential/utilization	• Low since culvert will be designed to accommodate fish passage and will likely be sized to exceed bankfull width
Jackson Creek	2.0	• Low habitat potential/utilization	• Low since culvert will be designed to accommodate fish passage and will likely be sized to exceed bankfull width
Erith River	3.6	• High habitat potential/utilization	• Low since structure will be designed to accommodate fish passage and will likely be sized to exceed bankfull width
ERT4	2.2	• Low habitat potential/utilization	• Low since culvert will be designed to accommodate fish passage and will likely be sized to exceed bankfull width
ERT5	3.0	• Low habitat potential/utilization	• Low since culvert will be designed to accommodate fish passage and will likely be sized to exceed bankfull width
ERT6	1.4	• Moderate habitat potential/utilization	• Low since culvert will be designed to accommodate fish passage and will likely be sized to exceed bankfull width
ERT8	2.2	• Low habitat potential/utilization	• Low since culvert will be designed to accommodate fish passage and will likely be sized to exceed bankfull width
ERT10	2.6	• Low habitat potential/utilization	• Low since culvert will be designed to accommodate fish passage and will likely be sized to exceed bankfull width
HLT1	3.0	• Moderate habitat potential/utilization	• Low since culvert will be designed to accommodate fish passage and will likely be sized to exceed bankfull width
HLT9	2.2	• Low habitat potential/utilization	• Low since culvert will be designed to accommodate fish passage and will likely be sized to exceed bankfull width
HLT9A	2.2	• Low habitat potential/utilization	• Low since culvert will be designed to accommodate fish passage and will likely be sized to exceed bankfull width

[1] Subject to change based on final design
[2] A detailed assessment of the direct impacts to habitat will be completed once final design plans have been determined

4.1.2 Watercourse Diversions and Pit Development

As previously described there will be a total of 13 main watercourse diversions required for the Project. A comparison of habitat impacts resulting from watercourse diversions for the original Project Application and the proposed updated mine plan is provided in Table 6.

Table 6. Planned diversions and the associated potential habitat impacts in the Robb Trend Project area.

Mine Area	Watercourse	Diversion #/ Pit Development	Fish Habitat Impacted				
			Application		Revision		
			Length (m)	Area (m²)	Length (m)	Area (m²)	Habitat Present (overall rank)
Robb West	Bryan Creek	13 Pit Dev.	4,244 TBD	14,208 TBD	4,244 1,382	14,208 1,480	• High habitat potential/utilization in Reach's 1 and 3 and low habitat potential/utilization in Reach 2 • Low habitat potential/utilization in upper Bryan Creek
Robb Main	Erith River	1	10,500	67,485	10,500	67,485	• High habitat potential/utilization • Most of Reach 1, all of Reach 2 and the lower part of Reach 3 will be impacted
	ERT1 ERT1A	2 Pit Dev.	2,315 157	5,834 102	400 0	1,000 0	• High habitat potential/utilization in ERT1 • Low habitat potential/utilization in ERT1A, no disturbances planned
	ERT2	Pit Dev.	264	406	264	406	• Low habitat potential/utilization
	ERT3	Pit Dev.	507	7,751	507	7,751	• Low habitat potential/utilization, habitat considered sub-marginal further upstream
	Bacon Creek	3	1,424	2,777 TBD	1,424	2,777	• High habitat potential/utilization • Originally was being diverted into Lake 4/5 but now flows will be maintained
	Hay Creek	10	1,368	1,804 TBD	1,368	2,325	• Low habitat potential/utilization
Robb Centre	Halpenny Creek	5	1,563	7,601	295	4,129	• Low habitat potential/utilization in Reach 2 • Mynheer Pit diversion no longer occurring
	HLT1	4	1,237	2,239	0	0	• Moderate habitat potential/utilization • No diversion planned
	HLT2	6	246	219	0	0	• Low habitat potential/utilization • No diversion planned
	Lendrum Creek	9/Pit Dev.	4,335	17,468	4,335	17,468	• Moderate habitat potential/utilization in Reach 2
	LET1	7	1,534	1,923	1,534	3,282	• Moderate habitat potential/utilization
	LET3	8	1,167	22,161	1,167	7,959	• High habitat potential/utilization
Robb East	Lund Creek	14 Pit Dev.	2,762	11,026	2,762	7,319	• Moderate habitat potential/utilization
	LDT1 LDT1A	11 Pit Dev.	909 785	2,991 1,091	909 785	2,991 1,091	• Low habitat potential/utilization
	LDT2	Pit Dev.	TBD	TBD	200	209	• Low habitat potential/utilization
	LDT3	12	1,194	2,507	1,194	3,831	• Low habitat potential/utilization
	LDT4	Pit Dev.	TBD	TBD	686	542	• Low habitat potential/utilization
	LDT5	Pit Dev.	198	154	198	154	• Low habitat potential/utilization, habitat considered sub-marginal further upstream
	PET1	15	1,587	5,236	200	660	• High habitat potential/utilization in PET1
Total			38,296	174,983	34,354	147,067	

4.2 Changes in Flow Regime

The Project Application included a description of Project components that have potential to affect surface flows and provided discussion of the potential for these surface flow impacts to affect fish habitat availability. Table 7 provides an updated description of the anticipated changes in flow regime and the corresponding impacts to fish habitat.

Table 7. Summary of surface flow impacts and corresponding effects on fish habitat in major watercourses.

Mine Area	Watercourse	Potential Change to Flow Regime		Potential Impacts to Fish Habitat
		Application	Revision [1]	
Robb West	Bryan Creek	• Moderation of peak flows • Increase in low flows • Mean annual runoff may temporarily increase by as much as 20% during pit, groundwater dewatering	• Revised mine plan will allow for natural flow regime through the Project area	• Negligible, no significant impact to fish habitat expected • Impacted habitat has high and low potential/utilization ranking
Robb Main	Bacon Creek	• Approximately 70% of lower basin lost due to diversion • 2.4 km long channel remaining with ~30% of flow	• Revised mine plan will allow for natural flow regime through the Project area	• Negligible, no significant impact to fish habitat expected • Impacted habitat has high potential/utilization ranking
	Embarras River	• Small footprint upstream of Robb, impacts during mining expected to be negligible • Maximum estimated impacts downstream of Robb equate to: 3% decrease in high flows, 10% increase in low flows, and negligible change in mean annual flows	• No change to original impact scenario expected	• Negligible, no significant impact to fish habitat expected • Impacted habitat has high potential/utilization ranking
	Erith River	• Flow regulation due to settling ponds • 10% reduction in peak flows • Maintenance or slight increase in low flows • Overall modest change in annual runoff	• Revised mine plan will allow for natural flow regime through the Project area	• Negligible, no significant impact to fish habitat expected • Impacted habitat has high potential/utilization ranking
	Hay Creek	• Up to 50% reduction in peak flows • Up to 200% increase in low flows • Mean annual runoff may temporarily increase by as much as 25% during pit, groundwater dewatering	• Temporary reduction in flows during end pit lake filling • No change to original impact scenario expected once the end pit lake has been filled	• Reduced habitat availability for 2.25 kms downstream of pit during end pit lake filling (4,038 m^2) • Impacted habitat has low potential/utilization ranking
Robb Centre	Halpenny Creek	• Approximately 20% of flows altered depending on various diversions. • Impacts expected to be short term (temporary diversions) • Flow regulation due to settling ponds • Increased total annual runoff due to road runoff	• Revised mine plan will allow for natural flow regime through the Project area	• Negligible, no significant impact to fish habitat expected • Impacted habitat has high potential/utilization ranking
	Lendrum Creek	• Moderation of peak flows • Increase in low flows • Mean annual runoff may temporarily increase by as much as 20% during pit, groundwater dewatering	• No change to original impact scenario expected	• Negligible, no significant impact to fish habitat expected • Impacted habitat has moderate potential/utilization ranking
Robb East	Lund Creek	• Moderation of peak flows • Increase in low flows • Mean annual runoff may temporarily increase by as much as 25% during pit, groundwater dewatering • Reduced flows and habitat availability downstream of pit (potential loss of upper portion of creek if flows are diverted through lakes permanently)	• No change to original impact scenario expected	• Reduced habitat availability for 2.66 kms (8,714 m^2) due to flows being diverted through lakes • Impacted habitat has moderate potential/utilization ranking
	PET1	• Small portion of watershed may be re-directed into Lund Creek	• Revised mine plan will allow for natural flow regime through the Project area	• Negligible, no significant impact to fish habitat expected • Impacted habitat has high potential/utilization ranking
	Pembina River	• Minor influence, <2% decrease in flows in Pembina River due to permanent diversion of PET1	• With revised mine plan there is no expectation for measurable changes in flows in the Pembina River	• Negligible, no significant impact to fish habitat expected

[1] Conclusions subject to review by Matrix as mine plans progress

4.3 SUMMARY OF HABITAT IMPACTS

With the updated mine plan, the Project is expected to impact almost 160,000 square metres of fish habitat (Table 8). This represents a decrease from the overall instream footprint presented in the Project Application, largely due to substantial reductions (31 %) in impacts to habitat with high potential/utilization (Table 8).

Table 8. Summary of fish habitat impacts in the Robb Trend Project area.

	Application (2012)	**Revision (2013)**
Impacts to habitat with low potential/utilization (m^2)	33,643	33,655
Impacts to habitat with moderate potential/utilization (m^2)	42,656	36,783
Impacts to habitat with high potential/utilization (m^2)	128,684	89,381
Total Habitat Impacts (m^2)	**204,983**	**159,819**

5.0 MITIGATION FOR HABITAT IMPACTS

Mitigation measures that will be implemented during the life of the Project were described in the Project Application (2012) and remain applicable. Some additional discussion regarding mitigation of potential impacts to fish habitat is provided below.

5.1 MINE PLANNING

As planning progresses, CVRI will continue to review options and scenarios to further minimize impacts to fisheries resources.

5.2 SURFACE WATER MANAGEMENT & EROSION CONTROL

Water management is a priority consideration throughout mine planning and development. Minimizing surface disturbance and completing timely reclamation are essential considerations that can affect water management. CVRI will implement a surface water management plan throughout the life of the Project to eliminate or minimize the potential adverse effects on the aquatic ecosystem associated with changes in water quality. The plan will include and/or incorporate the following:

- Mine planning to minimize the need for drainage diversions and runoff interception and to maximize vegetation buffers near waterbodies;
- Education/training of personnel to minimize disturbances while maintaining drainage and sediment controls;
- Design and construction details for settling ponds or retention and clean-out areas that will collect surface runoff and allow for settling treatment prior to release into receiving waterbodies;
- Design and construction details for watercourse diversions to ensure minimize changes of sediment loading to receiving waterbodies;

- General measures that will be implemented to contain road runoff including berms and haulroad sump/retention areas such that run-off will be intercepted and treated prior to release into the aquatic ecosystem; and
- Monitoring and maintenance of surface water management facilities.

It is assumed that the surface water management plan will provide effective mitigation of impacts to aquatic resources related to potential sediment introduction due to Project activities. TSS concentrations in the waterbodies in the LSA are not predicted to increase to be above baseline or guideline levels (Hatfield 2012). In addition, Matrix (2012) predicts that the Project will have insignificant effect on sediment loads compared to natural conditions. As such, potential increases in TSS are not expected to adversely affect aquatic resources.

Potential adverse effects associated with activities that are outside of normal operations are addressed by CVM's emergency response plan. The emergency response plan includes methods for spill containment in streams and site clean-up. Such incidents are considered highly unlikely to occur and designated emergency response personnel are on-site 24-hours/day in connection with current CVM activities. Emergency response procedures will be expanded to the Project. In order to mitigate the long term potential for sedimentation due to surface runoff it is assumed that exposed ground and riparian areas will be revegetated during reclamation.

5.3 WATERCOURSE CROSSING CONSTRUCTION

All defined watercourse crossings will be designed, and constructed to meet the regulatory requirements for approval under the provincial *Water Act* and federal *Fisheries Act*. It is the goal of CVM to adhere to the "No Net Loss Guiding Principle" (NNL principle) and minimize the instream footprint of all haulroad crossings to ensure that the productive capacity of streams is maintained. Depending on construction plans (to be developed at a later date), habitat compensation measures will be identified and implemented at specific sites as needed, in consultation with DFO, ESRD, and stakeholders, in order to ensure NNL of habitat productivity.

Watercourse crossing structures will consist of clear span arch structures or culverts that are sized to accommodate fish passage. Smaller culverts will be used to convey water in ephemeral non-fish bearing streams (Matrix 2012).

Standard practices that are proven to be effective measures to mitigate potential adverse effects during instream construction, associated with watercourse crossings, will be implemented and include the following:

- Consideration of sensitive periods during construction planning by either planning construction to avoid these periods or implementation of additional site specific mitigation;
- Design structures located on fish-bearing waters to provide fish passage;
- Isolation of instream work site if flowing water is present at time of construction;
- Completion of a fish rescue and release from isolated areas;

- Implementation of sediment and erosion controls prior to work and maintenance during the work phase until the site has been stabilized;
- Implementation of measures to minimize introduction of deleterious substances during construction including cleaning, servicing, and fuelling of equipment well away from water bodies;
- Revegetation of disturbed areas around crossing sites;
- Upon reclamation of crossings, streambed and stream banks will be reclaimed to similar pre-disturbance conditions; and
- Implementation of TSS/turbidity monitoring during instream work if deemed necessary due to site conditions or timing of works.

5.4 STREAM DIVERSION PLANS

Construction plans for planned diversions will be refined as Project plans are developed and will include detailed plans to mitigate adverse effects to aquatic resources. General mitigation measures that will be employed during the construction and operation of diversion channels will include:

- Maintenance of downstream flow and monitoring to ensure instream flow needs are met;
- Appropriate sizing of diversion channels and/or pump systems based on the design life of the diversion and considering ramifications of greater than design runoff;
- Armouring and/or lining of channels or use of flumes where appropriate;
- Installation of silt fences and/or other erosion control measures on areas adjacent to open channel diversions;
- Placement and stockpiling of excavated materials in a location that is well away from the channel route;
- Gradual diversion of flow into constructed channels to minimize potential erosion and mobilization of sediment;
- Fish rescue and release (fish salvage) of sections or channel that will be abandoned due to diversion;
- Implementation of TSS/turbidity monitoring during instream work if deemed necessary due to site conditions or timing of works;
- Consideration of sensitive periods during construction planning by either planning construction to avoid these periods or implementation of site specific mitigation; and
- Construction of open channel diversions that allow for the movements of fish. If diversions are deemed to be impassable and are impeding important spawning migration then a fish relocation programs will be implemented whereby fish will be trapped and relocated to appropriate habitat upstream of the impediment.

6.0 HABITAT COMPENSATION FRAMEWORK

Final reclamation will consist of reconstructed channels and end pit lakes (Figures 3 to 9).

6.1 PRIMARY HABITAT COMPENSATION CONCEPTS

CVRI is committed to developing and implementing habitat compensation to ensure 'no net loss' (NNL) to the productive capacity of fish and fish habitat. Key habitat compensation strategies include construction of enhanced stream channel habitat and creation of several end pit lakes. Overall, the updated closure landscape is expected to result in a 5,504,934 m^2 increase in available habitat (Table 13).

6.1.1 RECONSTRUCTED STREAM CHANNEL HABITAT

Key to the compensation strategy proposed by CVRI is the reconstruction of disturbed stream reaches to provide viable fish habitat. The updated mine plan was developed to maximize the amount of lotic habitat that will be reconstructed. Almost 100 % of habitat considered to have high potential/utilization will be reclaimed to channel (Table 9). In total, 77 % of all lotic habitat will be reclaimed to channel under the new plan (Table 9).

Table 9. Fish habitat reclaimed to channel.

	Application (2012)	Revision (2013)
Low habitat potential/utilization reclaimed to channel (m^2)	1,553 (7 % of total impacts to low potential/utilization streams)	13,163 (39 % of total impacts to low potential/utilization streams)
Moderate habitat potential/utilization reclaimed to channel (m^2)	982 (2 % of total impacts to moderate potential/utilization streams)	21,573 (59 % of total impacts to moderate potential/utilization streams)
High habitat potential/utilization reclaimed to channel (m^2)	12,021 (9 % of total impacts to high potential/utilization streams)	88,017 (98 % of total impacts to high potential/utilization streams)
Total Habitat Reclaimed to Channel (m^2)	**14,556 (7 % of total impacts)**	**122,753 (77 % of total impacts)**

Sections of disturbed stream habitat will be reconstructed with habitat enhancement added in order to compensate for habitat losses associated with creek diversions. Stream reconstruction will include:

- Reclamation of diversion channels to have a similar grade and channel dimensions as the pre-disturbance channel.
- Reclamation of diversion channels will be lined in this order: clay, sand/gravel, and cobble.
- Design and construction of diversion channels so that physical habitat characteristics in the new channel are similar to the pre-disturbance channel in terms of size, habitat composition, substrate and cover.
- Reclamation of riparian areas to be similar to pre-disturbance condition and revegetation of the areas with rapid establishing species and native species.

- Additional habitat enhancement (i.e. pools) on diversion channels to meet the NNL principle.

In order to meet the ‘no net loss’ of productivity requirement, CVRI proposes to evaluate productivity losses due to stream channel diversions versus productivity gains due to habitat restorations based on a Habitat Evaluation Procedures (HEP) type approach (USFWS 1980). This system estimates habitat productivity based on a combination of habitat area and habitat suitability.

In the HEP-type analysis, Habitat Units (HUs) are calculated by multiplying habitat quantity with habitat quality. Habitat quantity is represented by surface area measured in m^2 and habitat quality is an estimate of the suitability of the habitats for use by fish as defined by Habitat Suitability Index (HSI) models. HUs are dimensionless numbers representing the overall value of the habitat for fish species that are present and these HU values are used as a representation of habitat productivity. Comparison of the HUs altered as a result of stream diversions with the HUs gained through stream channel restoration will allow an assessment of the degree to which the compensation measures employed can achieve the principle of no net loss of fish habitat. The quantity of habitat lost due to stream channel diversions is known, and is presented above. Habitat quality will be estimated using the HSI value to rank the importance of available habitat for specific species and life stages of fish. HSI models are species-specific models that evaluate the suitability of the habitat in question based on specific habitat conditions, represented by model variables, that are each considered crucial to the development of a self-sustaining population. Under HEP-type analysis procedures, an HSI value ranging between 0 and 1 is determined for each waterbody or watercourse segment for each species present. This is sometimes further assessed by each life stage, for example, embryo, fry, juvenile and adult.

At this time, CVRI intends to focus quality rating on the habitat requirements of Rainbow Trout since they are the most ubiquitous fish within the Project area. However, there will be opportunity to assess habitat requirements for other species (i.e. Arctic Grayling or Bull Trout) if necessary depending on local reclamation strategies of CVRI and ESRD fisheries management objectives for the area.

6.1.2 END PIT LAKES

CVRI also proposed to construct end pit lakes to off-set habitat losses associated with the Project. There were 12 proposed end pit lakes in the Project Application; 11 end pit lakes will be constructed as part of the reclamation landscape for the revised Project (Lake 4 will no longer exist). Six of the lakes will be “flow-through” lakes (7, 8, 9, 10, 11, and 12) that are constructed on streams and will have an inlet and an outlet. Five of the lakes will be constructed “off-channel” (1, 2, 3, 5, and 6) and will have no inlet but will have an outlet to adjacent streams.

Robb West End Pit Lakes

Two end pit lakes are planned for Robb West. Figure 3 shows the location of the lakes and the drainage patterns post reclamation. Current reclamation plans indicate that Lake 1 will be connected with Lake 2 via a 700 metre constructed channel. Lake 2 will ultimately outlets into Bryan Creek.

Robb Main End Pit Lakes

Two end pit lakes will be constructed in Robb Main. Figures 4 and 5 show the location of the lakes and drainage patterns post reclamation. Current reclamation plans indicate that Lake 3 will be situated in the upper portion of the Hay Creek drainage and will flow into Hay Creek, and eventually the Embarras River. Lake 5 (West, Middle, and East) will be connected by short constructed channels and subsequently will outlet to the Erith River.

Robb Centre End Pit Lakes

Two end pit lakes are planned to be developed in Robb Centre. Figures 6 and 7 show the location of the lakes and general drainage patterns post reclamation. Current reclamation plans indicate that Halpenny Creek will flow around Lake 6. Lake 6 will outflow to Bacon Creek and Lake 7 will accept flows from LET3 and will outlet to Lendrum Creek.

Robb East End Pit Lakes

Five end pit lakes are planned to be developed in Robb East. Figures 8 and 9 show the location of the lakes and general drainage patterns post reclamation. Current reclamation plans indicate that two lakes (Lakes 8 and 9) will be situated on LDT1. The lakes will be connected by a 100 metre constructed channel. A similar configuration will exist on LDT3, with water flowing through two lakes (Lakes 10 and 11) before returning to the natural channel. The lakes will be connected by a 600 metre constructed channel. Lastly, Lake 12 will collect water from upper Lund Creek and will outlet to a 1,500 metre constructed channel that ultimately flows into Lake 10.

End Pit Lake Final Design

The flow-through lakes will be designed to maximize habitat and biological diversity and use by native fish populations. Final design will incorporate guiding principles that are described in the draft guidelines for end pit lake development at coal mine operations (EPLWG 2004) and/or procedures provided in similar guideline documents that may be available in the future. Some of the lakes may be constructed to preclude fish access but conceptually, the lakes will be designed to maximize habitat and biological diversity and use by native fish populations.

The off-channel lakes may be designed to be fishless, stocked fisheries, or possibly self-reproducing populations (depending on local conditions). The lakes may be designed to allow or preclude natural recruitment to the lake. Final design will incorporate the primary objective for the lake and will consider the guiding principles that are described in the draft guidelines for end pit lake development at coal mine operations (EPLWG 2004) and/or procedures provided in similar guideline documents that may be available in the future.

Key design features that will be considered in the planning and creation of the end pit lakes are presented in Table 10.

Table 10. Key design parameters for a self-sustaining native salmonid end pit lake.

Design Factor	Parameter Ranges and Probability of Success (from EPLWG 2003)		
	High	Medium	Low
Sustainability (water balance)	Mean annual inflow > mean annual losses	Mean annual inflows = mean annual losses	Mean annual inflows< mean annual losses
Lake dynamics/function	Very stable water level (<1m annual variation)	Stable water level (1-2m annual variation)	Unstable water level (>2m annual variation)
Filling method/schedule	1-5yrs	5-10yrs	>10yrs
Lake geometry	<25m max depth	25-75m max depth	>75m max depth
Shoreline stability	>90% stable	60-90% stable	<60% stable
Stratification/mixing	<10m mean depth <20m max depth	10-15m mean depth 20-23m max depth	>15 m mean depth >23 m max depth
Water Quality	Close to median water quality values of natural water bodies in the region	Within the range of values for natural water bodies in the region	At the extreme, or outside of the range of natural water bodies in the region
Potential toxic substances	Meets water quality guidelines	Slightly exceeds guidelines	Significantly exceeds guidelines
Littoral zone	20-40%, <3m max littoral depth	10-20%	<10%, >40%, 3-6m max littoral depth
Substrate in littoral zone (high importance in truck/shovel lakes)	High density of boulders and fines in littoral zone		Low density of boulders and fines in littoral zone
Connectivity of lake to stream	Stable surface inlet and outlet	Ephemeral outlet only	No inlet/outlet
Riparian	High diversity of well-established plants	Medium diversity of well-established plants	Poor establishment of vegetation

6.2 RATIONALE

CVRI has successfully constructed stream channels and end pit lakes in the past and is therefore confident that they will be able to construct/implement the proposed compensation concepts to ensure that the productive capacity of fish habitat is maintained.

6.2.1 RECONSTRUCTED STREAM CHANNEL HABITAT

Over the last two decades, CVRI has reconstructed and/or enhanced a number of stream channels in the CVM area. A summary of these projects including photo documentation of current conditions and a discussion of monitoring results (and associated response plans) are provided in Appendix A.

6.2.2 END PIT LAKES

End pit lakes can exhibit various attributes and their potential to serve as fish habitat is often linked to the attributes and characteristics that they possess. The morphometric, geologic, hydrogeologic, geochemical and biological attributes of these lakes, directly influences the potential uses of these water bodies (Gammons et al. 2009). CVRI has accumulated considerable information regarding existing end pit lakes in the region. The following is a brief synopsis of how this existing information supports the idea that end pit lakes can provide good quality native fish species in the region.

Water quality is often the limiting factor in determining whether or not a pit lake has the potential to become fisheries habitat (Gammons et al. 2009). The local geology and the product being mined can have a profound effect on the water quality found in an end pit lake. Acidification and the introduction of heavy metals into ground and surface waters are often difficult to mitigate and can negatively impact biological environments due to contamination of ground and surface waters (Lemly 2007, Rudolf et al. 2008, Stekoll and Smoker 2009).

Silkstone, Lovett and Pit 24 (Stirling) Lakes are the oldest fish bearing end pit lakes located on the CVM lease; having been developed in the late 1980’s and early 1990’s. Water chemistry concerns with these end pit lakes have generally been negligible and the water quality in these pit lakes is very similar to Fairfax Lake, a naturally occurring lake in the area (Hatfield 2011). The CVM Lease is located in an area where acidification of ground and surface waters is rare due to the calcareous nature of the parent material. The thermal coal mined at the CVM Lease is also significantly different than the metallurgical coal found at the nearby Cheviot and Cardinal River Mine Leases and previously on the Gregg River Mine lease. Selenium enrichment of ground and surface waters is generally of lesser concern on the CVM lease.

One of the challenges with reclamation on the CVM is that there is often an insufficient amount of overburden material available to refill the end-pits. Left as is, these end-pits would naturally fill with surface and ground waters to form a body of water. Without prescribed reclamation procedures and guidelines, these lakes would have lesser ecological value. Guidelines for the development of end pit lakes are provided by Alberta Environment (EPLWG 2002) and include various design factors including hydrological, physical, chemical and biological design factors. Additional recommendations for developing end pit lakes in this area have also been identified in various pit lake studies (Hatfield 2011, Sonnenberg 2011). In addition, CVM is currently conducting research on existing end pit lakes on the mine to increase their understanding of these systems and to identify key design factors to maximize habitat productivity for target species.

End pit lakes have provided habitat and angling opportunities for Rainbow Trout (*Oncorhynchus mykiss*), Bull Trout (*Salvelinus confluentus*) and Brook Trout (*Salvelinus fontinalis*) on or near the CVM lease. Lakes such as Silkstone, Lovett, Pit 24 (Stirling), Pit 35, Pit 44 and Pit 45 are regularly stocked with Rainbow Trout and provide recreational angling opportunities (ESRD 2013). In addition to these “put and take” fisheries, fish have moved into end pit lakes on the CVM through channels that connect the lakes to natural drainages (Pisces 2013). Fisheries and Oceans Canada (Authorization No. ED 03-3080) have approved reclamation plans on the CVM which include a series of pit lakes on the Upper Embarras River for the purpose of establishing a self-sustaining population of Athabasca Rainbow Trout. Preliminary results indicate that the barrier downstream of the lake system is working to preclude fish species downstream from moving upstream. Rainbow trout in the Embarras Lake system have also successfully spawned in the connecting channels (Pisces 2013).

Populations of Athabasca Rainbow Trout and Bull Trout have been documented in several end-pit lakes in the area including Lac des Roches, Sphinx Lake and Pit-lake CD (Schwartz 2002, Pisces 2008, Pisces 2009, Sonnenberg 2011). Spawning at the outlets and in the streams downstream of Sphinx Lake and Pit-lake CD is well documented and the Rainbow Trout populations are self-sustaining. Productivity downstream of Sphinx Lake and Pit-lake CD has increased from pre-mining conditions, likely due to the buffering and warming effect of the lake (Sonnenberg 2011).

In addition to Athabasca Rainbow Trout, Bull Trout, and Brook Trout, end pit lakes may have the potential to bolster the dwindling Arctic Grayling (*Thymallus arcticus*) population in the CVM area. Arctic Grayling are native to portions of the McLeod watershed (SRD 2005). Arctic Grayling populations are found in several lakes in Alberta and natural recruitment has been documented in several of these water bodies (SRD 2005). End-pit lakes with outlet channels may provide suitable habitat for Arctic Grayling if reclamation plans include barriers that preclude the movement of other fish species from downstream. The planned and calculated development of end pit lakes is an important part of reclamation practices on the CVM.

6.3 QUANTIFICATION OF PREDICTED EFFECTS AND HABITAT GAINS

Table 12 provides a summary of predicted impacts for each watercourse and identifies the type of habitat (lotic or lentic) that will be available after final reclamation.

Table 12. Summary of predicted impacts to fish habitat by watercourse.

Mine Area	Watercourse	Impacted Habitat Area (m^2)	Reclaimed Habitat	
			Reconstructed Channel (m^2)	Lake
Robb West	Bryan Creek	15,688	15,688	
Robb Main	Bacon Creek	2,777	2,777	
	Erith River	67,485	67,485	
	ERT1	1,000	1,000	
	ERT2	406	406	
	ERT3	7,751		Lake 5
	Hay Creek	6,363		Lake 3
Robb Centre	Halpenny Creek	4,129	4,129	
	Lendrum Creek	17,468	17,468	
	LET1	3,282	1,600	Lake 7
	LET3	7,959	6,595	Lake 7
Robb East	Lund Creek	16,033	2,505	Lake 12
	LDT1	2,991	640	Lake 8 & 9
	LDT1A	1,091		Lake 8 & 9
	LDT2	209		Lake 10
	LDT3	3,831	1,800	Lake 10 & 11
	LDT4	542		Lake 10
	LDT5	154		Lake 12
	PET1	660	660	
Total		**159,819**	**122,753**	***5,542,000 m^2** (total lake habitat available upon final reclamation)

* Lake dimensions presented are consistent with Project Application but are likely subject to change as mine plans progress

Table 13 compares the predicted effects and habitat gains from the original application to the updated mine plan. In total, the predicted amount of fish habitat impacted is estimated at 159,819 m^2, which is a 22 % decrease from the original application. Final reclamation of aquatic resources will consist of reconstructed channel and 11 end pit lakes, for a total habitat gain of 5,504,934 m^2. With the updated mine plan, the amount of reconstructed channel will increase from 14,556 m^2 in the original application to 122,753 m^2 (approximately 77 % of impacted habitat will be reclaimed to channel).

Table 13. Summary of predicted effects and habitat gains in the Project area.

	Habitat Loss (m^2)		Habitat Gain (m^2)		
	Application (2012)	**Revision (2013)**	**Type of Reclamation**	**Application (2012)**	**Revision (2013)**
Natural Channel	204,983	159,819	Reconstructed Channel	14,556	122,753
			*End Pit Lake	*6,253,000	*5,542,000
Total Habitat Loss	**204,983**	**159,819**	**Total Habitat Gain**	**6,267,556**	**5,664,753**
Net Change (m^2)				**+6,062,573**	**+5,504,934**

* Lake dimensions presented are consistent with Project Application but are likely subject to minor change as mine plans progress

6.4 ADDITIONAL COMPENSATION OPTIONS

As a precautionary measure CVRI has identified several other habitat compensation initiatives that could be initiated if it is determined that the primary habitat compensation concepts are not sufficient to ensure no net loss of the productive capacity of fish habitat. These include:

- Habitat Defragmentation – CVRI has partnered with the Foothills Research Institute to complete a watercourse crossing inventory in the vicinity of the CVM to document fish presence and identify potential problem sites where fish passage or sediment deposition are issues. The compensation initiative would involve the repair and/or remediation of identified problem sites.
- Habitat Enhancement in RSA – CVRI is currently investigating other instream enhancement opportunities in the Erith River outside of the Project area. The compensation initiative would involve the completion of instream enhancement work to improve habitat suitability or address potential limiting factors.
- Rainbow Trout Research Initiative – CVRI is aware that an Athabasca Rainbow Trout Recovery Plan is likely to be released in the near future. The compensation initiative would involve participation or coordination of specific projects to address identified knowledge gaps, or contribute to research, or recovery techniques identified in the Recovery Plan.

7.0 MONITORING

7.1 CONSTRUCTION PHASE

All instream construction sites will be monitored to ensure best management practices are implemented and for compliance with the conditions and requirements of any and all regulatory permits applicable to construction. The most significant aspect of instream construction monitoring will be implementation of a sediment monitoring program. Sediment monitoring protocols will be designed site-specifically, but will be based on industry standards.

7.2 OPERATION PHASE

7.2.1 SURFACE WATER MONITORING

Surface water monitoring plans were originally discussed in the Project Application, (CVRI, 2012). Monitoring will be similar to existing CVM mine areas.

Surface water quality monitoring for the Project will include:

- A water quality monitoring program designed to meet the requirements of the Project approval will be implemented for the life of the Project (Hatfield 2012; CR#11);
- Flows and TSS will be monitored at all settling ponds (Matrix 2012; CR#6);
- Regular inspections of all drainage works will be conducted (Matrix 2012; CR#6); and
- Long term monitoring of flow in each main creek will be conducted to document critical low flow conditions during pit filling periods and to define the need for any bypass pumping to maintain in-stream flows (Matrix 2012; CR#6).

7.2.2 BIOLOGICAL MONITORING

The existing CVM aquatics monitoring program will be expanded to include additional benthic macroinvertebrate sample sites. Results of the monitoring will be used to assess the effectiveness of the surface water management plan and modifications will be made, if necessary.

Fish population monitoring programs to assess fish distribution, relative abundance and population structure will be developed as the Project progresses

7.3 FOLLOW-UP MONITORING

CVRI recognizes that periodic monitoring will be required to evaluate fisheries habitat components and populations in re-established aquatic environments (reconstructed channels). Monitoring protocols will be developed in conjunction with the details of the currently proposed compensation strategies. The general monitoring approach will be to monitor habitat created or enhanced by evaluation of the physical and biological characteristics of the habitats as well as fish utilization of the habitats. Habitat improvements would be implemented, as part of an adaptive management approach, if new or enhanced habitat were not providing the required habitat components for the target fish species (i.e. Rainbow Trout).

A detailed end pit lake monitoring program will be developed two to five years prior to construction of each lake allowing for CVRI to take advantage of information regarding end pit lake development that may become available in the future and to design the lake to meet future end-use objectives and regional management strategies. In general CVRI anticipates implementing a monitoring program that will include but is not necessarily limited to the following:

- Post-construction monitoring to assess physical stability of end pit lakes and connecting channels.
- Assessment of fish community and habitat within the end pit lakes and associated channel systems.
- Assessment of various biological and chemical parameters in end pit lakes including:
  - Fish, benthic invertebrates, zooplankton, phytoplankton, macrophytes.
  - Measurement of temperature, dissolved oxygen, conductivity profiles, as well as select water quality variables.

Monitoring results will be used, if necessary, to adjust mitigation and habitat compensation measures and make design improvements as required. Habitat monitoring will be key to confirming the no net loss objective can be achieved. Should, for some reason, the proposed habitat compensation not be sufficient to achieve no net loss of the productive capacity of fish habitat, additional habitat compensation would then be developed in consultation with the appropriate regulators.

8.0 SUMMARY

This document is intended to provide an updated outline of the impacts to fish habitat and proposed strategies to mitigate and compensate for the impacts that may occur as a result of the Project. Detailed habitat compensation plans will be developed for specific phases as the project progresses. Given that this project will be developed over the next 25 years there will be opportunity to adjust and adapt mitigation and compensation strategies to ensure that the project will not result in the loss of productive capacity of fish and fish habitat.

9.0 REFERENCES

Alberta Environment (AENV). 2006. Code of Practice for Watercourse Crossings (made under the Water Act and the Water (Ministerial) Regulation). Queen's Printer for Alberta.

Alberta Environment and Sustainable Resource Development (ESRD). 2013. Fisheries Management Information System: Stocking Report for 2013.

Alberta Sustainable Resource Development (SRD). 2005. Status of the Arctic grayling (*Thymallus arcticus*) in Alberta. Alberta Sustainable Resource Development, Fish and Wildlife Division, and Alberta Conservation Association, Wildlife Status Report No. 57, Edmonton, Alberta. 41 pp.

Alberta Transportation. 2009. Fish Habitat Manual: Guidelines and procedures for watercourse crossings in Alberta. 11-4 pp. + Appendices.

Coal Valley Resources Inc. 2012. Robb Trend Project Environmental Impact Assessment and Mine Permit Application. Submitted April 2012.

Department of Fisheries and Oceans Canada (DFO). 1986. Policy for the Management of Fish Habitat. Department of Fisheries and Oceans. Ottawa, Ontario.

Department of Fisheries and Oceans. 2006. Practitioners Guide to Habitat Compensation. Department of Fisheries and Oceans. Ottawa, Ontario.

End-Pit Lake Working Group. 2004. Guidelines for Lake Development at Coal Mine Operations in Mountain Foothills of the Northern East Slopes, Report # ESD/LM/00-1, Alberta Environment, Environmental Science.

Gammons, C. H., Harris, L.N., Castro J.M., Cott, P.A., and Hanna, B.W. 2009. Creating lakes from open pit mines: processes and considerations - with emphasis on northern environments. Can. Tech. Rep. Fish. Aquat. Sci. 2826: ix + 106 p.

Hatfield Consultants. 2008. Coal Valley Mine: An evaluation of existing end-pit lakes. Vancouver, British Columbia, Canada. Prepared by Hatfield Consultants for Coal Valley Resources Inc.

Hatfield Consultants. 2011. An evaluation of water quality in existing end-pit lakes in the Coal Valley Mine area – Final Report. Vancouver, British Columbia, Canada. Prepared by Hatfield Consultants for Coal Valley Resources Inc.

Hatfield Consultants. 2012. Robb Trend Coal Mine Project: Surface Water Quality Report. Prepared for Coal Valley Resources Incorporated.

Lemly, A. D. 2007. "A procedure for NEPA assessment of selenium hazards associated with mining." Environmental Monitoring and Assessment 125(1-3): 361-375.

Matrix Solutions Inc. 2012. Robb Trend Mine Project Environmental Impact Assessment – Surface Hydrology. Prepared for Coal Valley Resources Inc.

Pisces. 2008. Assessment of fish populations, growth and spawning in Sphinx Lake in 2007. Red Deer, Alberta, Canada, Prepared by Pisces Environmental Consulting Services Ltd. for Cardinal River Operations.

Pisces. 2009. Sphinx Lake monitoring in 2008. Red Deer, Alberta, Canada, Prepared by Pisces Environmental Consulting Services Ltd. for Cardinal River Operations.

Pisces. 2013. Aquatic monitoring program for end pit lakes in the headwaters of the Embarras River. Red Deer, Alberta, Canada, Prepared by Pisces Environmental Consulting Services Ltd. for Coal Valley Resources Inc.

Rudolph, B. L., I. Andreller, et al. (2008). "Reproductive success, early life stage development, and survival of Westslope Cutthroat Trout (*Oncorhynchus clarki lewisi*) exposed to elevated selenium in an area of active coal mining." Environmental Science & Technology 42(8): 3109-3114.

Schwartz, T. 2002. Fish populations, biomass and growth in Lac Des Roches, Alberta. Red Deer, Alberta, Canada, Prepared by Pisces Environmental Consulting Services Ltd. for Cardinal River Coals Ltd.

Sonnenberg, R. 2011. Development of Aquatic Communities in High-altitude Mine Pit Lake Systems of West-central Alberta. Prepared for School of Graduate Studies of the University of Lethbridge in partial fulfillment of the requirements for the degree, Master of Science. Lethbridge, AB. 175pp + App.

Stekoll, M. S., W. W. Smoker, et al. (2009). "Response of the early developmental stages of hatchery reared salmonids to major ions in a simulated mine effluent." Aquaculture 298(1-2): 172-181.

Figures

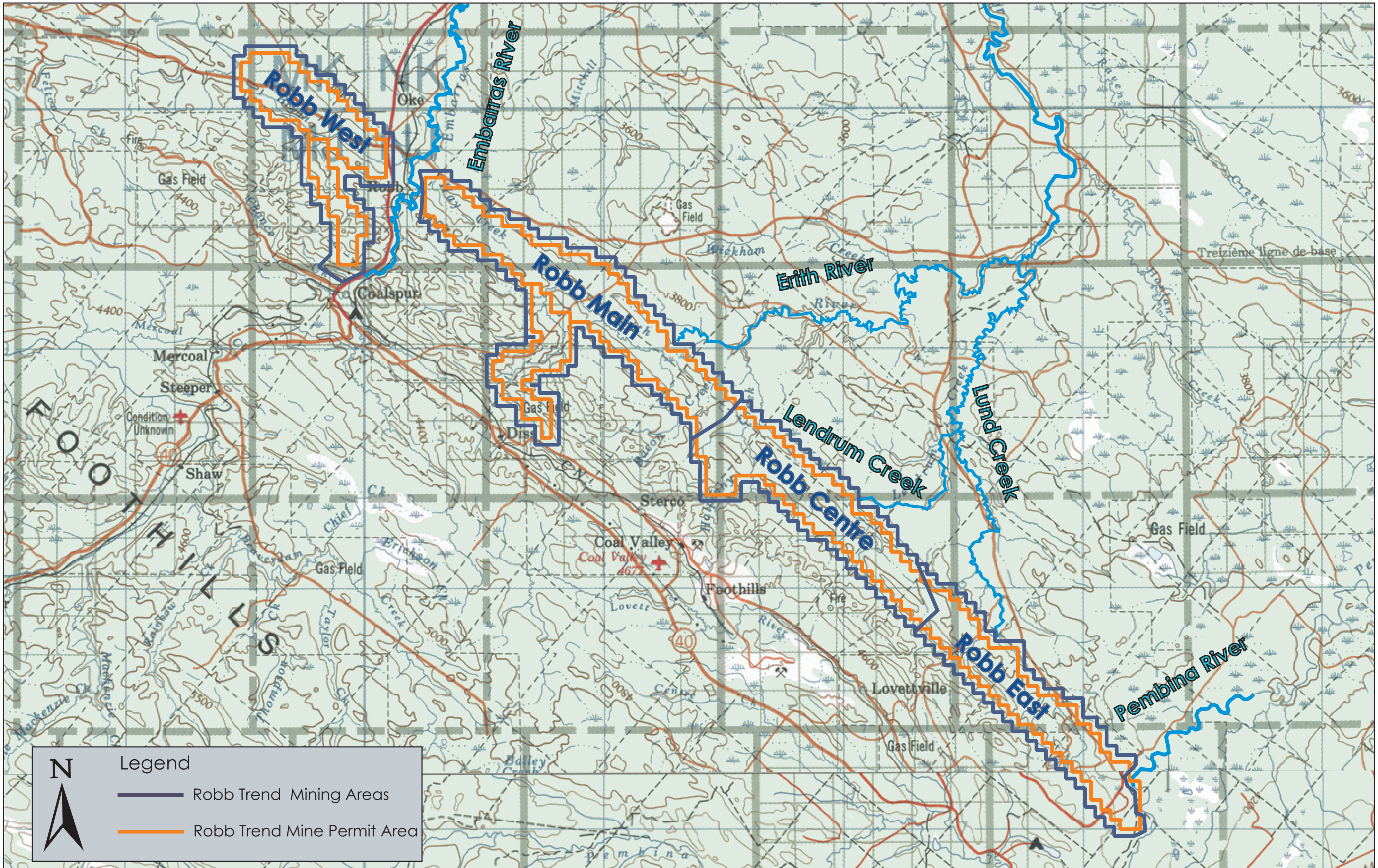


Figure 1. Robb Trend Project Area (adapted from Project Application)	Drawn by: JM / Checked by: ES
	August 2013
Pisces Environmental Consulting Services Ltd.	CVRI Coal Valley Mine
	Scale 1:250,000

ORIGINAL SCENARIO

Watercourse	Watercourse Code	Diversion #	Fish Habitat Impacted (m²)
Erith River	ER	1	67,485
Erith River Trib #1	ERT1	2	5,834
Bacon Creek	BA	3	2,777
Halpenny Creek Trib#1	HLT1	4	2,239
Halpenny Creek	HL	5	7,601
Halpenny Creek Trib#2	HLT2	6	219
Lendrum Creek Trib#1	LET1	7	1,923
Lendrum Creek Trib#3	LET3	8	22,161
Lendrum Creek	LE	9	17,468
Hay Creek	HA	10	1,804
Lund Creek Trib#1	LDT1	11	2,991
Lund Creek Trib#3	LDT3	12	2,507
Bryan Creek	BR	13	14,208
Lund Creek	LD	14	11,026
Pembina River Trib#1	PET1	15	5,236

REVISED SCENARIO

Watercourse	Watercourse Code	Diversion #	Fish Habitat Impacted (m²)
Erith River	ER	1	67,485
Erith River Trib #1	ERT1	2	1,000
Bacon Creek	BA	3	2,777
Halpenny Creek Trib#1	HLT1	4	0
Halpenny Creek	HL	5	4,129
Halpenny Creek Trib#2	HLT2	6	0
Lendrum Creek Trib#1	LET1	7	3,282
Lendrum Creek Trib#3	LET3	8	7,959
Lendrum Creek	LE	9	17,468
Hay Creek	HA	10	2,325
Lund Creek Trib#1	LDT1	11	2,991
Lund Creek Trib#3	LDT3	12	3,831
Bryan Creek	BR	13	14,208
Lund Creek	LD	14	7,319
Pembina River Trib#1	PET1	15	660

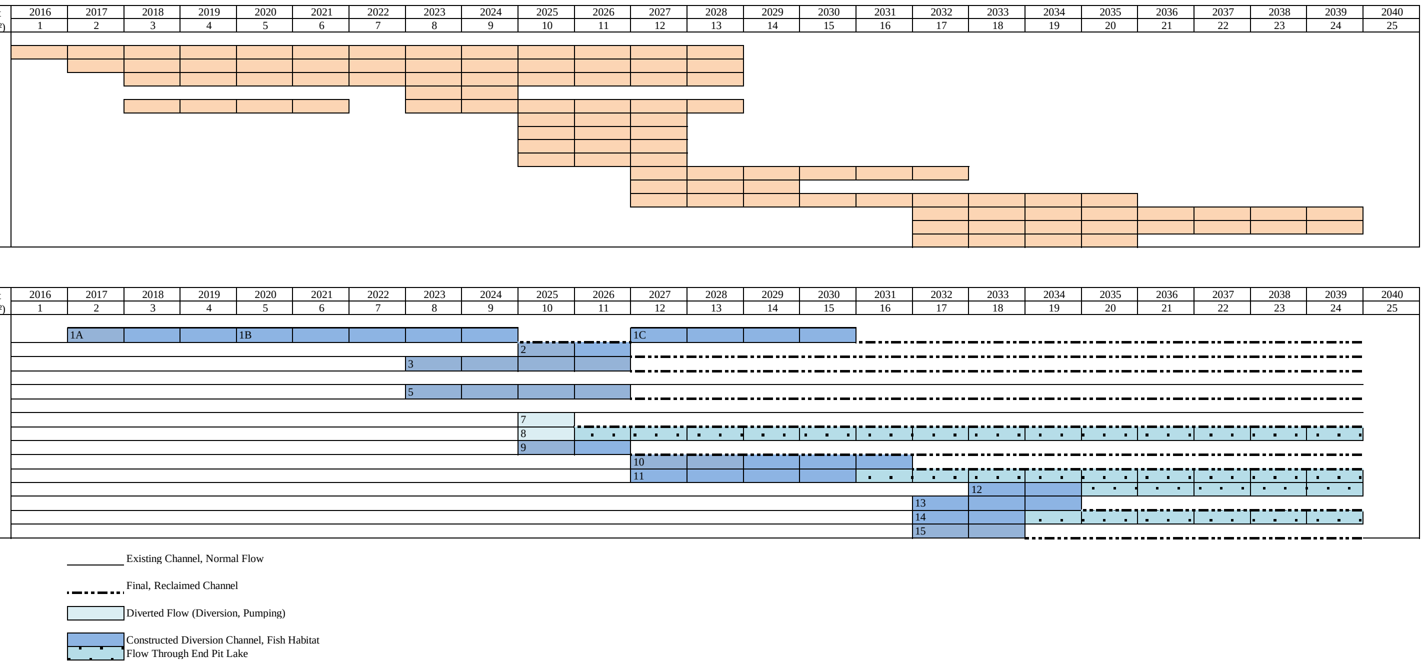
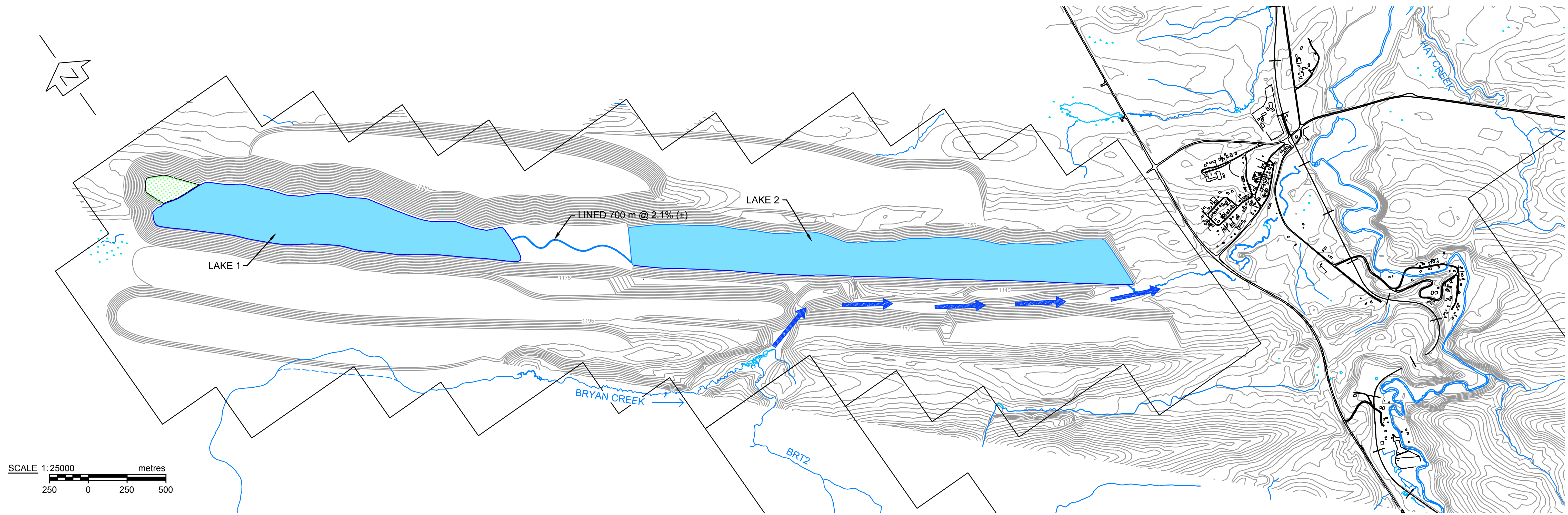


Figure 2. Anticipated schedule for mine development along with the predicted impacts to fish habitat

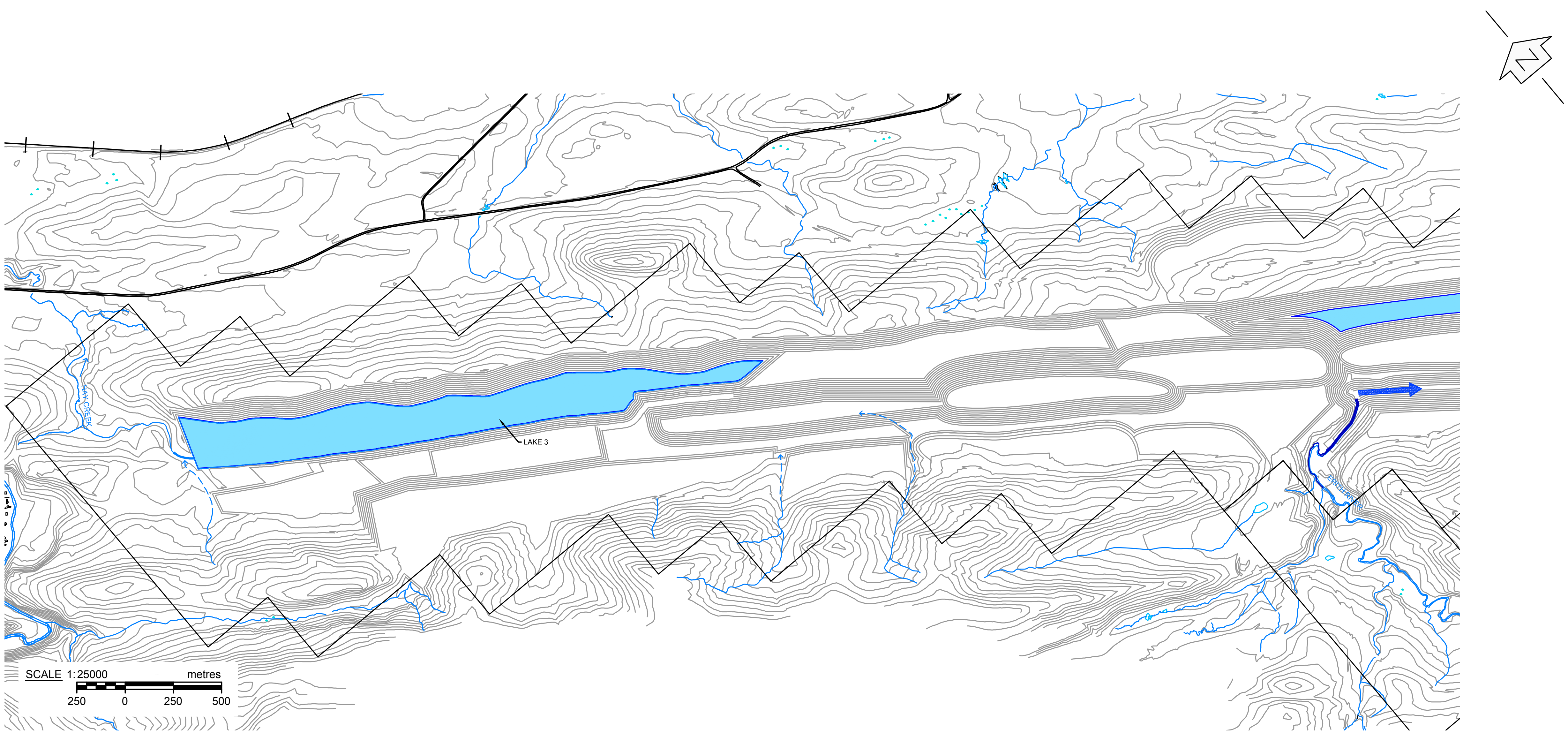


LEGEND

- Lake
- Wetland
- Constructed Steams

REF: Matrix Solutions Inc., December 2011.

PROJECT: **Coal Valley Mine** **Robb Trend SIR - DFO Compensation Plan**	cvri
TITLE: **Figure 3. Lakes 1 and 2 Reclamation Plan**	FILE: Final Docs\08-041b\DFO\Fig_Various.dwg DRAWN: JG CHECKED: KP DATE: Aug 1/13 PROJECT: 08-041b FIGURE:



LEGEND

Lake

Wetland

REF: Matrix Solutions Inc., December 2011.

PROJECT:

Coal Valley Mine
Robb Trend SIR - DFO Compensation Plan

TITLE:

Figure 4. Lake 3 Reclamation Plan

FILE: Final Docs\08-041b\DFO\Fig_Various.dwg

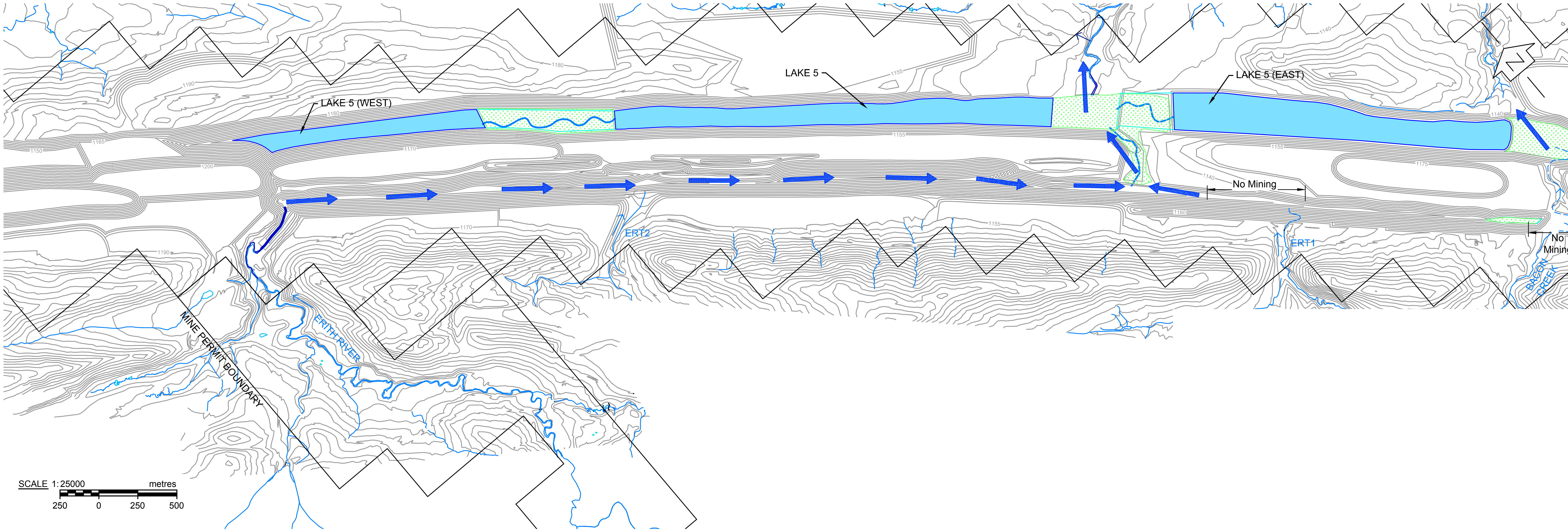
DRAWN: JG

CHECKED: KP

DATE: Aug 1/13

PROJECT: 08-041b

FIGURE:



LEGEND

- Lake
- Wetland
- Constructed Streams

REF: Matrix Solutions Inc., December 2011.

PROJECT:

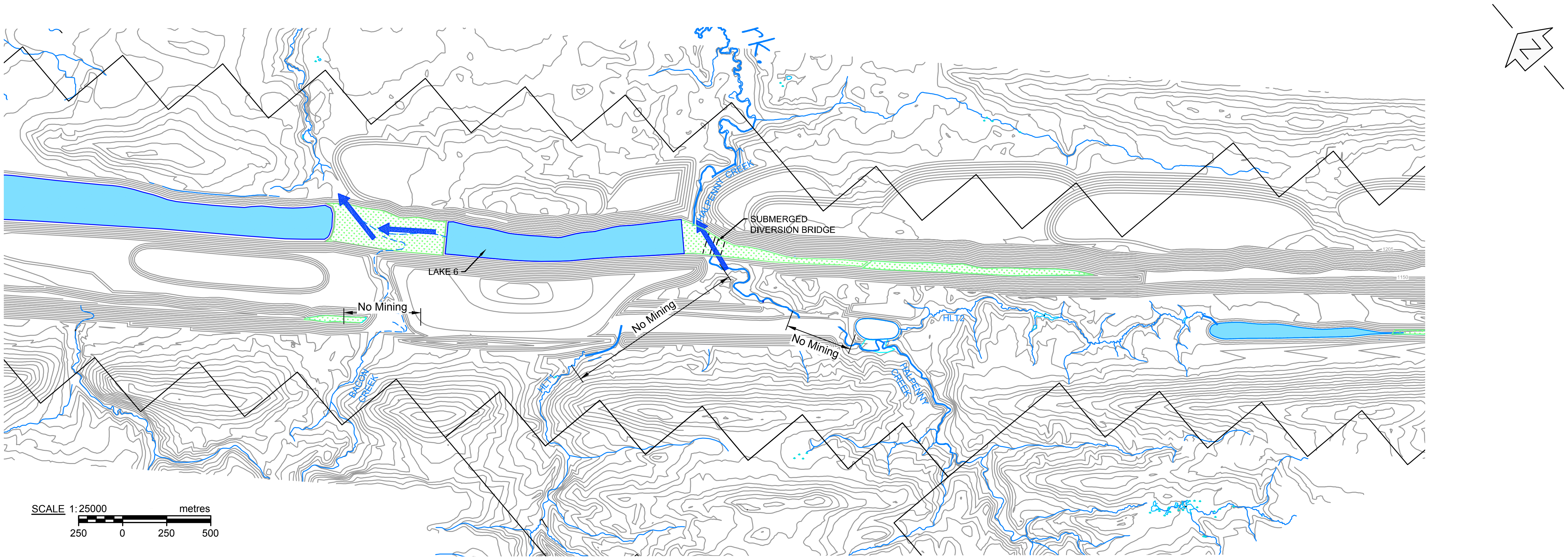
Coal Valley Mine
Robb Trend SIR - DFO Compensation Plan

cvri

TITLE:

Figure 5. Lake 5 Reclamation Plan

FILE: Final Docs\08-041b\DFO\Fig_Various.dwg	
DRAWN: JG	FIGURE:
CHECKED: KP	
DATE: Aug 2/13	
PROJECT: 08-041b	



LEGEND

- Lake
- Wetland
- Constructed Streams

REF: Matrix Solutions Inc., December 2011.

PROJECT:

Coal Valley Mine
Robb Trend SIR - DFO Compensation Plan

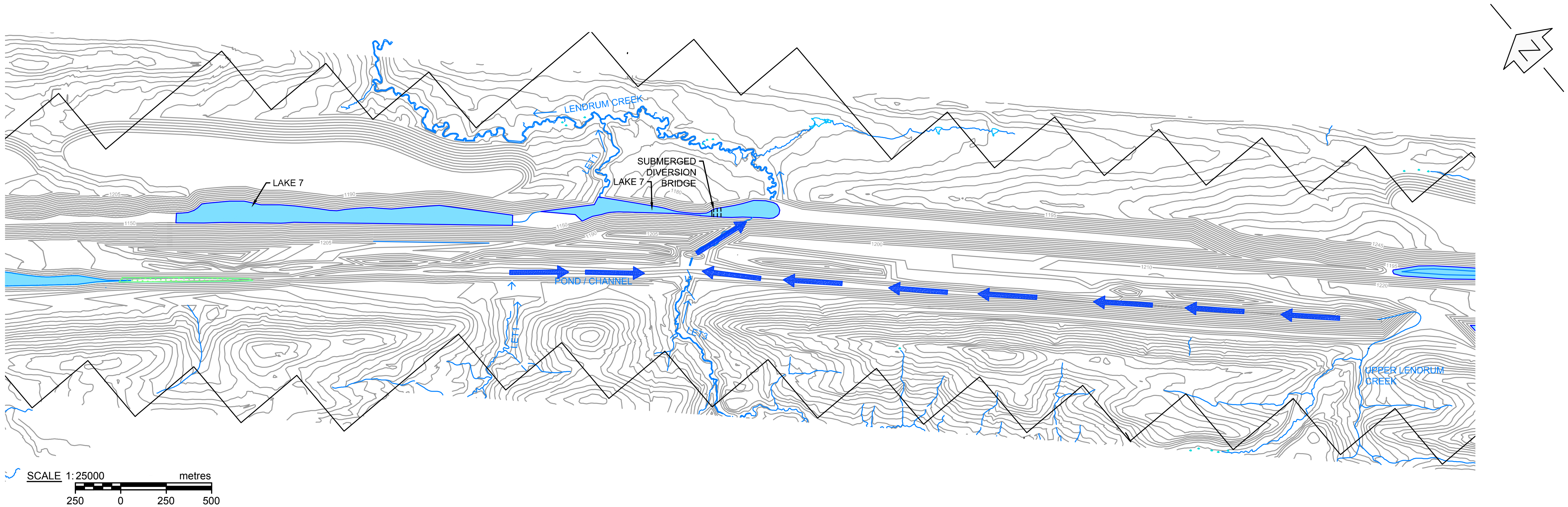
TITLE:

Figure 6. Lake 6 Reclamation Plan

cvri

FILE: Final Docs\08-041b\DFO\Fig_Various.dwg

DRAWN:	JG
CHECKED:	KP
DATE:	Aug 2/13
PROJECT:	08-041b
FIGURE:	



LEGEND

- Lake
- Wetland
- Constructed Streams

REF: Matrix Solutions Inc., December 2011.

PROJECT:

Coal Valley Mine
Robb Trend SIR - DFO Compensation Plan

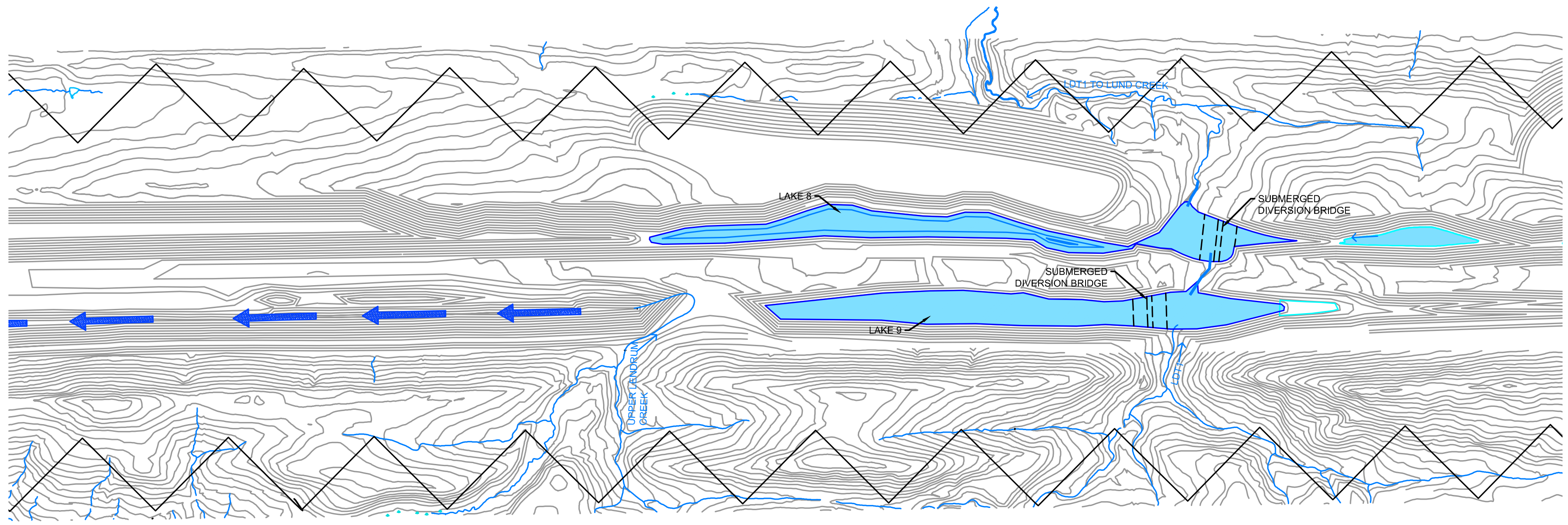
TITLE:

Figure 7. Lake 7 Reclamation Plan

cvri

FILE: Final Docs\08-041b\DFO\Fig_Various.dwg

DRAWN: JG	FIGURE:
CHECKED: KP	
DATE: Aug 2/13	
PROJECT: 08-041b	



SCALE 1:25000 metres
250 0 250 500

LEGEND
- Lake
- Wetland
- Constructed Streams

REF: Matrix Solutions Inc., December 2011.

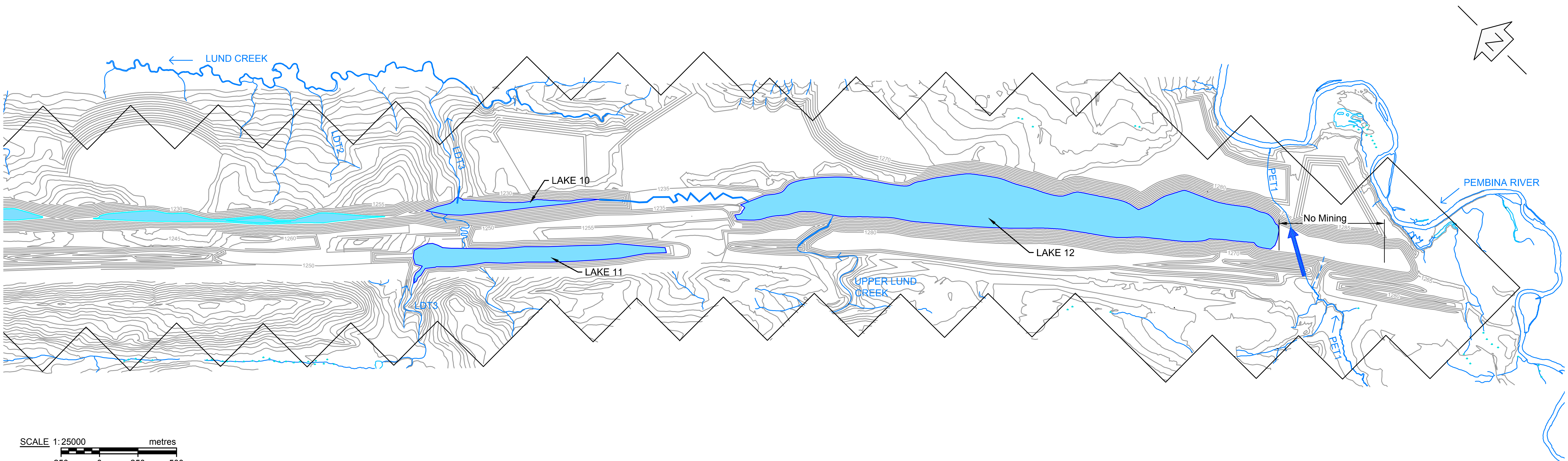
PROJECT:
Coal Valley Mine
Robb Trend SIR - DFO Compensation Plan

TITLE:
Figure 8. Lakes 8 and 9 Reclamation Plan

cvri

FILE: Final Docs\08-041b\DFO\Fig_Various.dwg

DRAWN: JG	FIGURE:
CHECKED: KP	
DATE: Aug 2/13	
PROJECT: 08-041b	



SCALE 1: 25000 metres

250 0 250 500

LEGEND

- Lake
- Wetland
- Constructed Streams

REF: Matrix Solutions Inc., December 2011.

PROJECT:

Coal Valley Mine
Robb Trend SIR - DFO Compensation Plan

cvri

TITLE:

Figure 9. Lakes 10 - 12 Reclamation Plan

FILE: Final Docs\08-041b\DFO\Fig_Various.dwg

DRAWN: JG	FIGURE:
CHECKED: KP	17-7
DATE: Aug 22/13	
PROJECT: 08-041b	

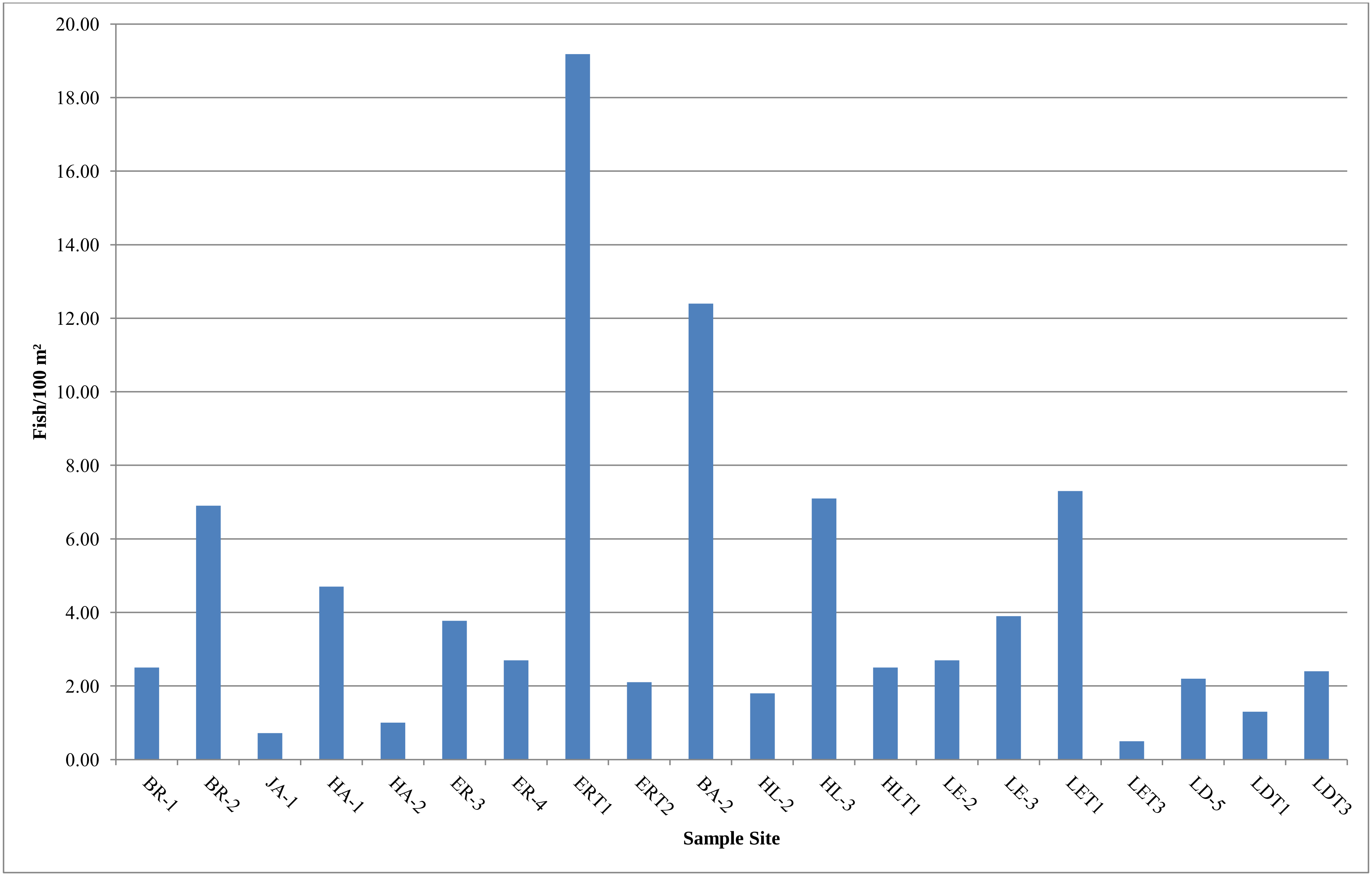


Figure 10. Rainbow Trout densities (fish/100 m^2) for population estimates performed in the Robb Trend Mine Area.	CVRI Robb Trend Project
	August 2013
	Pisces Environmental Consulting Services Ltd.

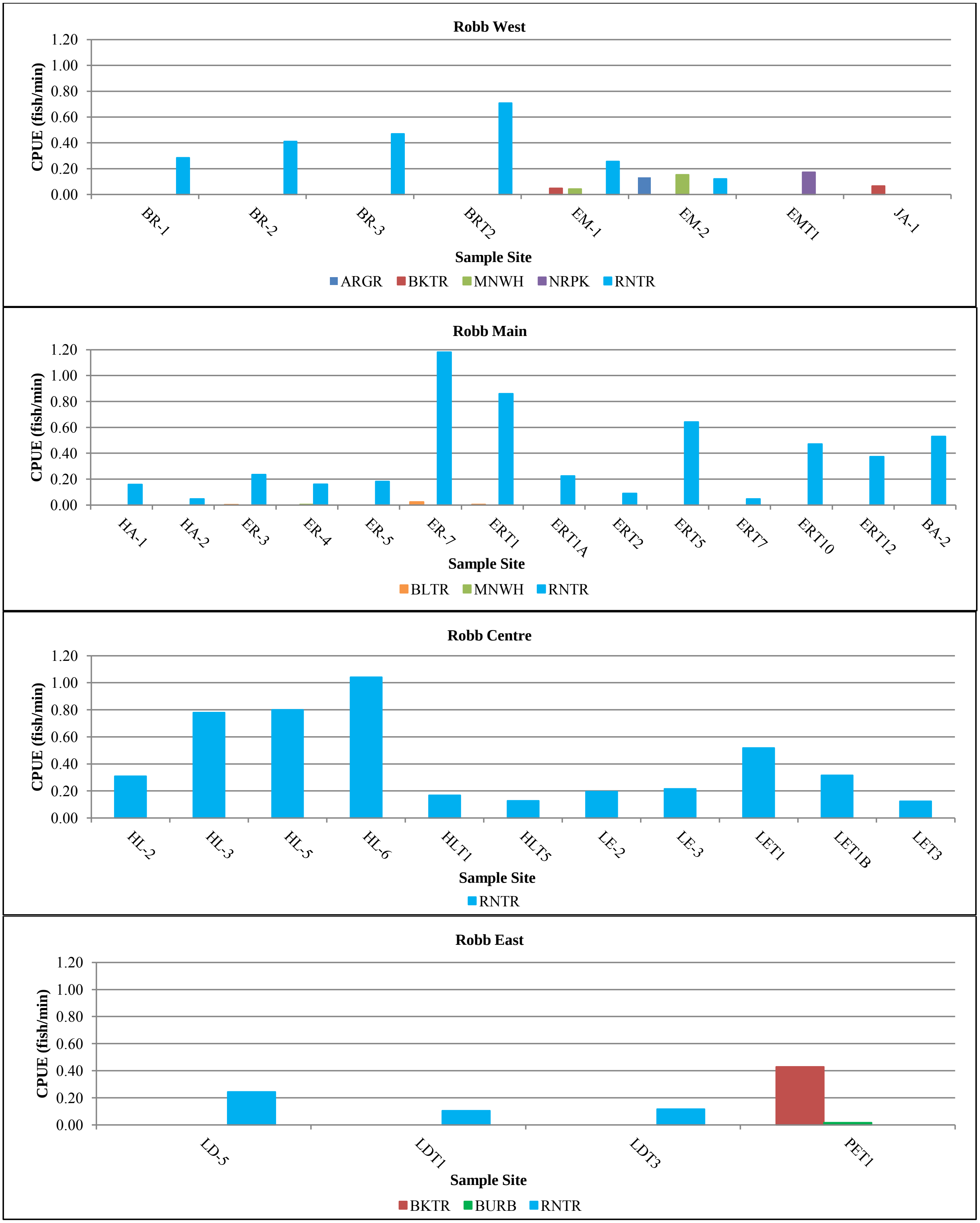


Figure 11. First-pass catch per unit effort (CPUE) for sport fish captured at Robb Trend sample sites.	CVRI Robb Trend Project
	August 2013
	Pisces Environmental Consulting Services Ltd.

<table>
<tr><th>Low</th><th>Moderate</th><th>High</th></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>Photo 1. Upper Hay Creek.</td><td>Photo 3. Unnamed tributary to Halpenny Creek #1 (HLT1).</td><td>Photo 5. Unnamed tributary to the Erith River #1 (ERT1).</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>Photo 2. Unnamed tributary to the Erith River #2 (ERT2).</td><td>Photo 4. Lendrum Creek.</td><td>Photo 6. Erith River.</td></tr>
<tr><td colspan="2" rowspan="3">Figure 12. Photos of typical habitat conditions found within Low, Moderate, and High habitat potential rankings.</td><td>CVRI Robb Trend Project</td></tr>
<tr><td>August 2013</td></tr>
<tr><td>Pisces Environmental Consulting Services Ltd.</td></tr>
</table>

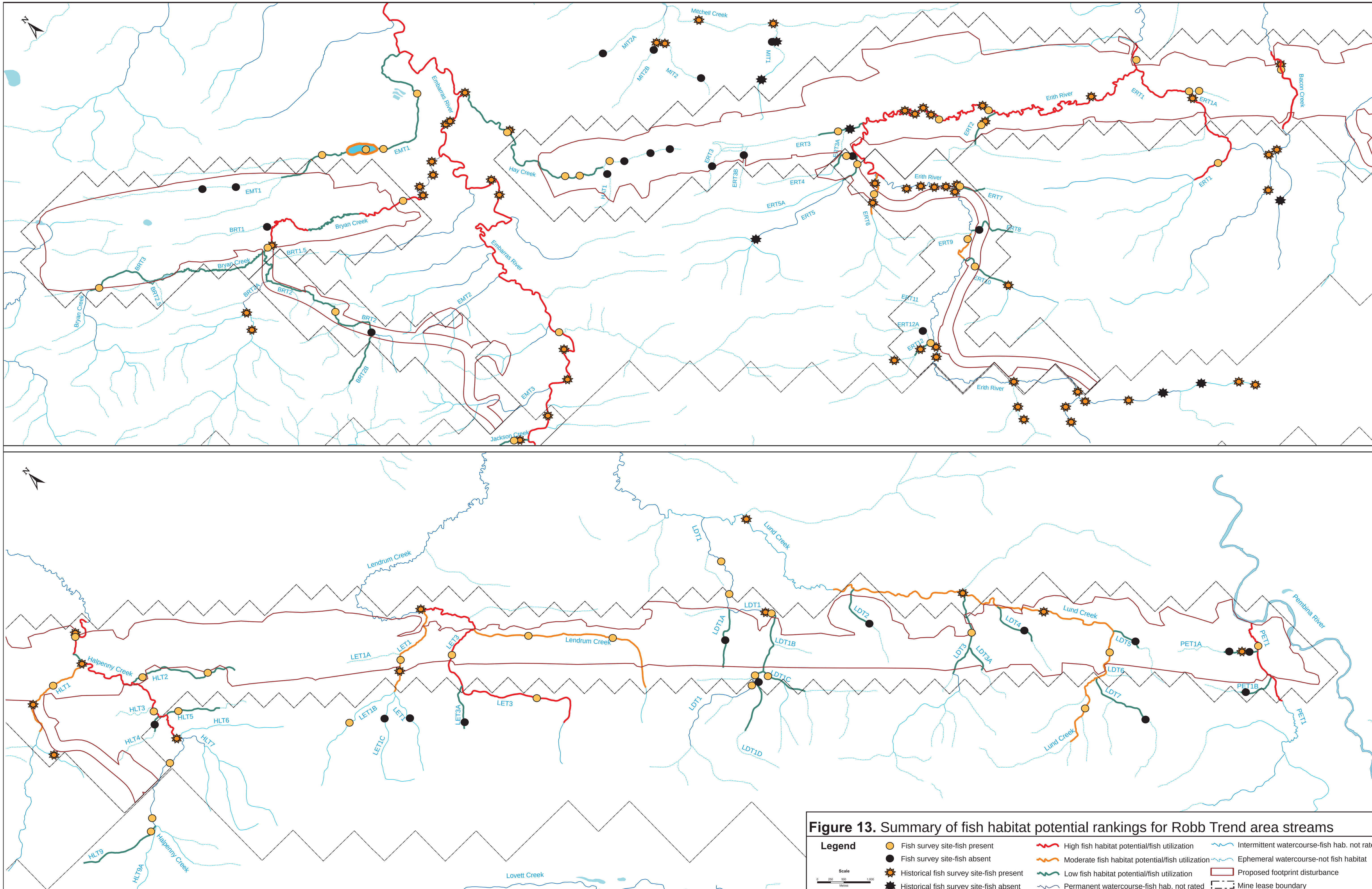


Figure 13. Summary of fish habitat potential rankings for Robb Trend area streams

Appendix A

CVRI has reconstructed several stream channels as part of past reclamation efforts. The following summarizes past work and discusses challenges and improvements in channel construction proposed for the future.

Centre Creek Tributary (1989)

In the winter of 1989, a 2.3 kilometer stretch of an unnamed tributary to Centre Creek was diverted to facilitate mining (Pisces 1989). Habitat assessments completed following the reconstruction showed the reconstructed channel exhibited good diversity, increased the amount of deep water habitat, and increased the overall habitat area of the unnamed tributary (Pisces 1989). During sampling conducted in 1996 this channel was found to have the highest Brook Trout density of all sites sampled with 56 fish/100m^2 being captured (Carson and Allan 1999). Carson and Allan (1999) also classified the habitat within the tributary as high quality habitat. Brook trout were observed spawning within the reconstructed channel during the fall of 1999 (Allan 1999).

The diverted channel as it currently exists (fall 2012) is portrayed in Figure 1.

Figure 1. Centre Creek Tributary Diversion fall 2012 (Dean Woods Photograph).

Pit 45 Lake Outflow (2000)

The Pit 45 Lake outflow channel drains Pit 45 Lake, which is managed as a quality stocked lake by AESRD. The channel has well established vegetation and exhibits no slumping or instability. No fisheries enhancements were completed within the channel and minimal discharge was noted in spring 2013.

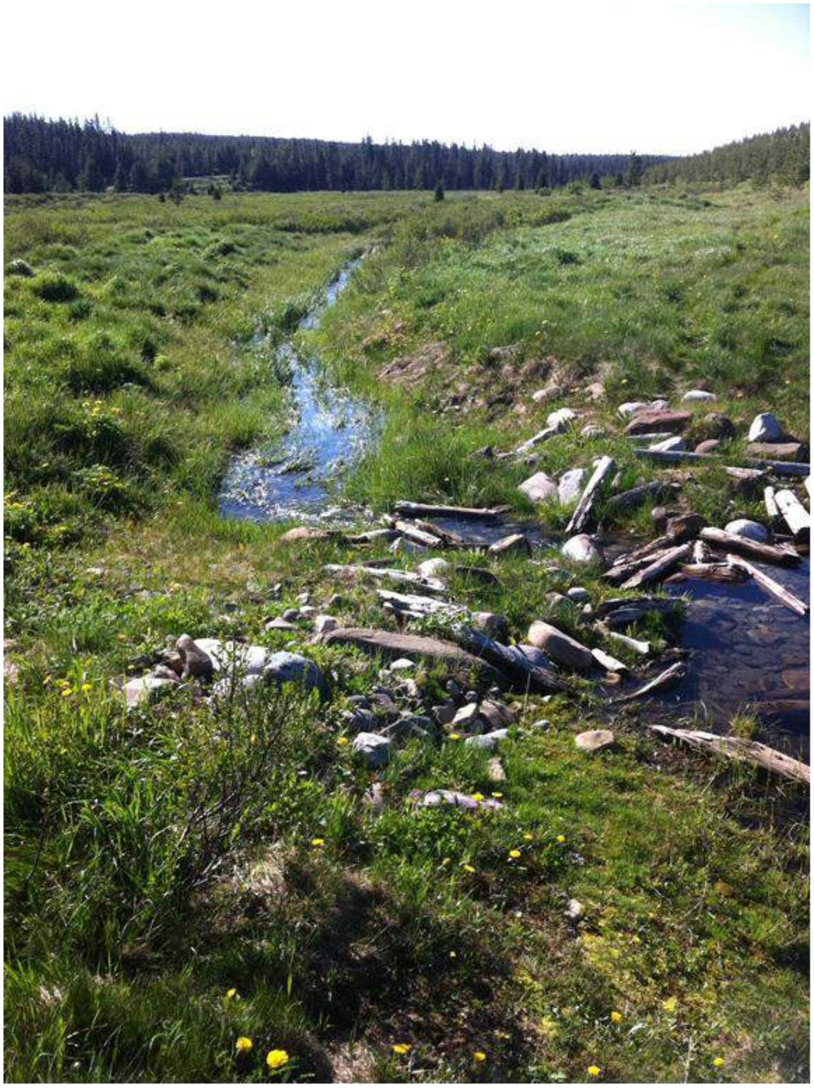


Figure 2. Pit 45 Lake Outflow Summer 2011 (Dean Woods photo)

Pit 43 W Outflow (2004)

The Pit 43W Outflow drains a small end pit lake and connects to the Lovett River (Figure 3 and 4). Fish were observed in the bottom 50 metres of channel but no sampling has been completed. Monitoring was initiated in spring 2013 and is ongoing.

Figure 3. Pit 43W outflow channel spring 2013.

Figure 4. Pit 43 W outflow channel downstream section.

Pit 34 Lake Outflow (2004)

The Pit 34 Lake outflow was constructed in 2004 but final reclamation and enhancement is ongoing in the area. Preliminary investigations conducted in spring 2013 indicate Brook Trout are occupying the constructed habitat. The channel is stable and vegetation is slowly becoming established (Figure 5). Monitoring was initiated in spring 2013 and is ongoing.

Figure 5. Pit 34 Lake Outflow spring 2013.

25E Creek Channels (2010)

CVRI has more recently completed construction of several lake outlet channels as part of the reclamation process. Monitoring of many of these outlets is ongoing but early indicators show the reclaimed landscape is providing habitat for colonizing fish species. 25E creek was heavily influenced during mining and has been reconstructed (Figure 6 and 7). Fish were observed in 25E Creek in the constructed inlet and outlet channels of Pit 25E Lake in spring 2013. Additional fisheries surveys are scheduled for summer 2013. Brook Trout were documented in 25E Lake during the winter of 2010.

Figure 6. 25E Creek immediately upstream of 25E Lake spring 2013.

Figure 7. 25E Creek at outlet of 25E Lake (looking downstream) spring 2013

Fish presence has not been documented in the headwaters of 25E Creek but monitoring of the constructed 25E Creek channel was initiated in the spring of 2013. The constructed channel exhibited significant discharge in spring 2013 and preliminary measurements indicate it is capable of providing fish habitat (Figure 8 and 9). Monitoring was initiated in spring 2013 and is ongoing.

Figure 8. 25E Creek immediately downstream of 25S Lake spring 2013


Figure 9. 25E Creek approximately 100 metres downstream of 25S Lake.

Upper Mercoal Creek Diversion (2009)

A portion of the headwaters of Mercoal Creek was diverted into an enhanced channel in the summer of 2009. The reconstructed channel appears to provide an increased amount of fish habitat compared to baseline conditions (Figure 10) and vegetation is becoming established (Figure 11). No fish have been captured in the vicinity of the diversion during fish salvage operations in 2009 or during subsequent monitoring (2010, 2012). However, large beaver dams located a substantial distance downstream of the diversion are suspected of impeding fish movements into this constructed habitat.

Figure 10. Baseline conditions of upper Mercoal Creek during fish salvage operations in 2009.

Figure 11. Upper Mercoal Creek diversion channel in summer 2012.

Embarras Lakes (2011)

The Embarras Lakes system was constructed to connect three end-pit lakes located in the headwaters of the Embarras River. Prior to mining, low densities of fish were present a short distance downstream of the mining area (Figure 12). Though the system is early in its developmental stages and some final reclamation work still needs to be completed, the constructed channels have been found to provide habitat for native Athabasca Rainbow Trout (Pisces 2013).

Although vegetation and instream habitat enhancements still need to be constructed (Figure 13 and 14) preliminary investigations show increased fish densities in the upper Embarras drainage compared to baseline conditions. Prior to mining, very few fish were present in the vicinity of the existing Embarras Lakes (single Rainbow Trout captured) while low densities of Rainbow Trout (2.6/100m^2), Brook Trout (0.34/100m^2), and a single Bull Trout were captured downstream of where the existing fish exclusion barrier is located (Boorman 2003). In August 2012, 85 Rainbow Trout were captured from within constructed channels upstream of the exclusion barrier during single pass surveys. Population estimate data collected downstream of the fish exclusion indicates Rainbow and Brook Trout densities have increased orders of magnitude over baseline conditions.

Figure 12. Upper Embarras Baseline condition (2004) downstream of existing fish exclusion barrier.

Figure 13. Reconstructed channel downstream of Lower Embarras Lake spring 2012.

Figure 14. Outlet channel of Upper Embarras Lake spring 2012.

Challenges and Future Work

Monitoring of existing diversions and reconstructed channels continues in 2013 as CVRI prepares for future reclamation projects. A significant amount of the Chance Creek channel will be constructed in the Yellowhead Tower area following mining.

CVRI has acknowledged limited fisheries work/enhancement has been carried out in several of the diversion channels. Monitoring is ongoing and preliminary results will be relied to make recommendations for enhancements. A lack of woody vegetation and fish cover components in several of the existing channels will be addressed as final replanting and reclamation occurs. Gravel and instream habitat placements are proposed in systems where self-sustaining fish populations are desired.

Reference

Allan. 1999. Fall fisheries investigations at the Coal Valley Mine in 1999. Prepared by Pisces Environmental Consulting Services Ltd. For Luscar Ltd. Coal Valley Mine. 9pp+app

Boorman. 2003. Baseline fisheries resource assessment of waterbodies on and adjacent to the proposed Mercoal east mine extension. Prepared by Pisces Environmental Consulting Services ltd. For Luscar Ltd. Coal Valley Mine, Edson, AB. 35pp+app

Carson and Allan. 1999. Fisheries studies on and adjacent to the Luscar Ltd. Coal Valley Mine Lease, 1996-1998. Prepared by Pisces Environmental Consulting Services for Luscar Ltd. Coal Valley Mine, Edson, AB. 51pp +app

Pisces. 1989. Habitat assessment of a diversion channel on an unnamed tributary to Centre Creek. Prepared by Pisces Environmental Consulting Services for Luscar Sterco Ltd. 9pp

Pisces. 2011. Aquatic Monitoring Program for End Pit Lakes in the Headwaters of the Embarras River, 2011-12. Prepared by Pisces Environmental Consulting Services Ltd. for Coal Valley Resources Inc. Edson, AB

Report #8

2012 Revised Benthic Invertebrate Biomonitoring Program for the Coal Valley Mine: The Pembina River and McLeod River Drainage Basins

Prepared for: Coal Valley Resources Inc.

April, 2013

PISCES ENVIRONMENTAL CONSULTING SERVICES LTD.

--this page left blank for printing purposes--

2012 Revised Benthic Invertebrate Biomonitoring Program for the Coal Valley Mine: The Pembina River and McLeod River Drainage Basins

Submitted to:

Coal Valley Resources Inc.
April, 2013

Prepared by:

Pisces Environmental Consulting Services Ltd.
Unit 118, 239 Spruce Street
Red Deer County, Alberta
T4E 1B4

--this page left blank for printing purposes--

Table of Contents

APPENDICES

Appendix A- Benthic Invertebrate Sample Processing Methods

Appendix B- Raw Benthic Invertebrate Identification Data

Appendix C- Site Summary Tables of Benthic Invertebrate Data

Appendix D- Statistical Analysis- Results of Multi-dimensional Scaling

List of Tables

List of Figures

--this page left blank for printing purposes--

1.0 INTRODUCTION

Coal Valley Resources Inc. (CVRI) operates the Coal Valley Mine (CVM) in the foothills of the Rocky Mountains southwest of Edson, Alberta. The CVM has been in operation since 1978 and recently received Environmental Protection and Enhancement Act (EPEA) Approval (11066-02-00) for ongoing operations extending to November 2020. One of the requirements of the EPEA Approval was submission of a Revised Benthic Invertebrate Biomonitoring Program (RBIBP). Initial test sampling under the new BIBP was conducted in September 2012 for the purpose of monitoring the efficacy of mine effluent mitigation and controls surrounding mining activity in the Pembina River drainage basin and the McLeod River drainage basin.

2.0 OBJECTIVES

The RBIBP is designed to meet the terms and conditions of the EPEA Approval which state that:

> *The Benthic Invertebrate Biomonitoring Program shall include, at a minimum, all of the following requirements:*
>
> a) *Monitoring of all major receiving water bodies as identified in the receiving water monitoring program and their proposed sampling frequency;*
> b) *Shall determine significant changes in the benthic invertebrate community which are attributable to the effects of the mine effluent and the length of impact along the creek;*
> c) *Shall quantify variables that include epilithic algae (i.e. chlorophyll a), substrate conditions, flow velocities, water levels, and effluent plume distribution;*
> d) *Follow the protocol set out in: Guidelines for Monitoring Benthos in Freshwater Environments, Environment Canada, January 1993 and;*
> e) *Be submitted to the Director by May 1st of the year following sampling.*

Specific objectives of the RBIBP are to:

- Establish the range of natural variability (based on select measurement endpoints) of the benthic invertebrate communities in watercourses in the vicinity of the CVM.
- Compare data from test reaches (potentially impacted) with reaches designated as reference (un-impacted) to determine how the communities compare to natural variability.
- Determine whether there is a detrimental effect on the benthic invertebrate community downstream of mining activity.

3.0 STUDY AREA

Field sampling was conducted from September 20th to the 26th of 2012. The sampling included the establishment of additional *reference sites* (not expected to be affected by mining activity) and of *test sites* (potentially influenced by mining activity) within the Pembina River and McLeod River drainage basins. *Reference* and *test sites* are delineated on Figure 1. For the 2012 biomonitoring, *Test sites* were established on the Pembina River, the Lovett River, Centre Creek, Mercoal Creek (and one tributary), and the McLeod River (Table 3.1). A list of the reference sites sampled in 2012 and a list of the historical reference sites included in the Coal Valley Mine Biomonitoring Project are provided in Tables 3.2 and 3.3 respectively.

Table 3.1. Biomonitoring test sites sampled in 2012

Site Code	Waterbody	Date sampled	UTM Coordinates NAD 83 Zn 11U
CC9	Centre Creek	Sep .21/ 2012	516522E 5875148N
CC10	Centre Creek	Sep. 21/ 2012	516464E 5875400N
CC11	Centre Creek	Sep. 25/2012	521542E 5870567N
LR1	Lovett River	Sep. 24/2012	508047E 5880645N
LR2	Lovett River	Sep. 24/2012	516443E 5879371N
LR3	Lovett River	Sep. 25/2012	521267E 5875182N
LR4	Lovett River	Sep. 24/2012	523595E 5872182N
ME2	Mercoal Creek	Sep. 24/2012	494253E 5890110N
ME4	Mercoal Creek	Sep. 22/2012	488156E 5891047N
MET2	Tributary to Mercoal Creek	Sep. 21/2012	490879E 5891474N
PR2	Pembina River	Sep. 25/2012	523415E 5870450N
PR3	Pembina River	Sep. 25/2012	524700E 5869695N
PR4	Pembina River	Sep. 26/2012	528911E 5864966N
MC5	McLeod River	Sep. 22/2012	487512E 5890577N
MC6	McLeod River	Sep. 23/2012	481365E 5901481N

Table 3.2. Biomonitoring reference sites sampled in 2012

Site Code	Waterbody	Date sampled	UTM Coordinates NAD 83 Zn 11U
BD1.2012	Beaverdam Creek	Sep. 23/2012	493170E 5881794N
BD2.2012	Beaverdam Creek	Sep. 23/2012	493513E 5881966N
FE1.2012	Felton Creek	Sep. 23/2012	486393E 5902256N
FET1.2012	Tributary to Felton Creek	Sep. 23/2012	487799E 5897092N
ER3.2012	Erith River	Sep. 21/2012	512351E 5890167N
LD2.5.2012	Lund Creek	Sep. 20/2012	526510E 5879652N
LD3.5.2012	Lund Creek	Sep. 20/2012	528531E 5875984N
LD4.2012	Lund Creek	Sep. 20/2012	529420E 5874550N
PET1.2012	Tributary to the Pembina River	Sep. 20/2012	531835E 5871593N

Table 3.3. Historical sampling-benthic invertebrate reference sites sampled prior to 2012

Site Code	Waterbody	Date sampled	UTM Coordinates NAD 83 Zn 11U
AP7.2010	Plante Creek	Sep. 21/2010	482484E 5945383N
BA2.2006	Bacon Creek	Sep. 20/2006	514387E 5888340N
BA3.2006	Bacon Creek	Sep. 21/2006	513556E 5887389N
BR1.2010	Bryan Creek	Oct. 02/2010	500791E 5897904N
BR2.2010	Bryan Creek	Oct. 02/2010	498580E 5899357N
CH1.2006	Chance Creek	Sep. 19/2006	494805E 5895409N
CH2.2006	Chance Creek	Sep. 19/2006	498453E 5892578N
EM1.2005	The Embarras River	Sep. 16/2005	501103E 5895562N
EM2.2005	The Embarras River	Sep. 18/2005	502843E 5898831N
ER3.2005	The Erith River	Sep. 16/2005	512333E 5889910N
HL2.2006	Halpenny Creek	Sep. 20/2006	515986E 5887021N
HL4.2006	Halpenny Creek	Sep. 21/2006	516053E 5884248N
LD3.2007	Lund Creek	Sep. 12/2007	527093E 5877484N
LD4.2007	Lund Creek	Sep. 12/2007	529414E 5874575N
LDT1.2007	Tributary to Lund Creek	Sep. 11/2007	525352E 5878989N
LDT3.2007	Tributary to Lund Creek	Sep. 12/2007	527458E 5875031N
LE1.2006	Lendrum Creek	Sep. 21/2006	520985E 5882791N
LE2.2006	Lendrum Creek	Oct. 06/2006	521911E 5881256N
LET1.2006	Tributary to Lendrum Creek	Oct. 05/2006	519625E 5882133N
LET3.2006	Tributary to Lendrum Creek	Oct. 05/2006	520851E 5881867N
ME2.2004	Mercoal Creek	Oct. 13/2004	491682E 5890330N
MA1.2004	McCardell Creek	Oct. 15/2004	480119E 5896691N
MA2.2004	McCardell Creek	Oct. 15/2004	478736E 5897973N
MC1.2004	The McLeod River	Oct. 21/2004	492909E 5887604N
MC6.2004	The McLeod River	Oct. 20/2004	481446E 5901298N
MCT1.2004	Tributary to the McLeod River	Oct. 23/2004	480758E 5892032N
MET2.2004	Tributary to Mercoal Creek	Oct. 14/2004	490918E 5891478N
PET1.2007	Tributary to the Pembina River	Sep. 12/2007	531835E 5871593N
PR1.2007	The Pembina River	Sep. 19/2007	521560E 5870478N
WH1.2010	White Creek	Oct. 01/2010	489524E 5909949N
WH3.2010	White Creek	Oct. 02/2010	490695E 5906869N

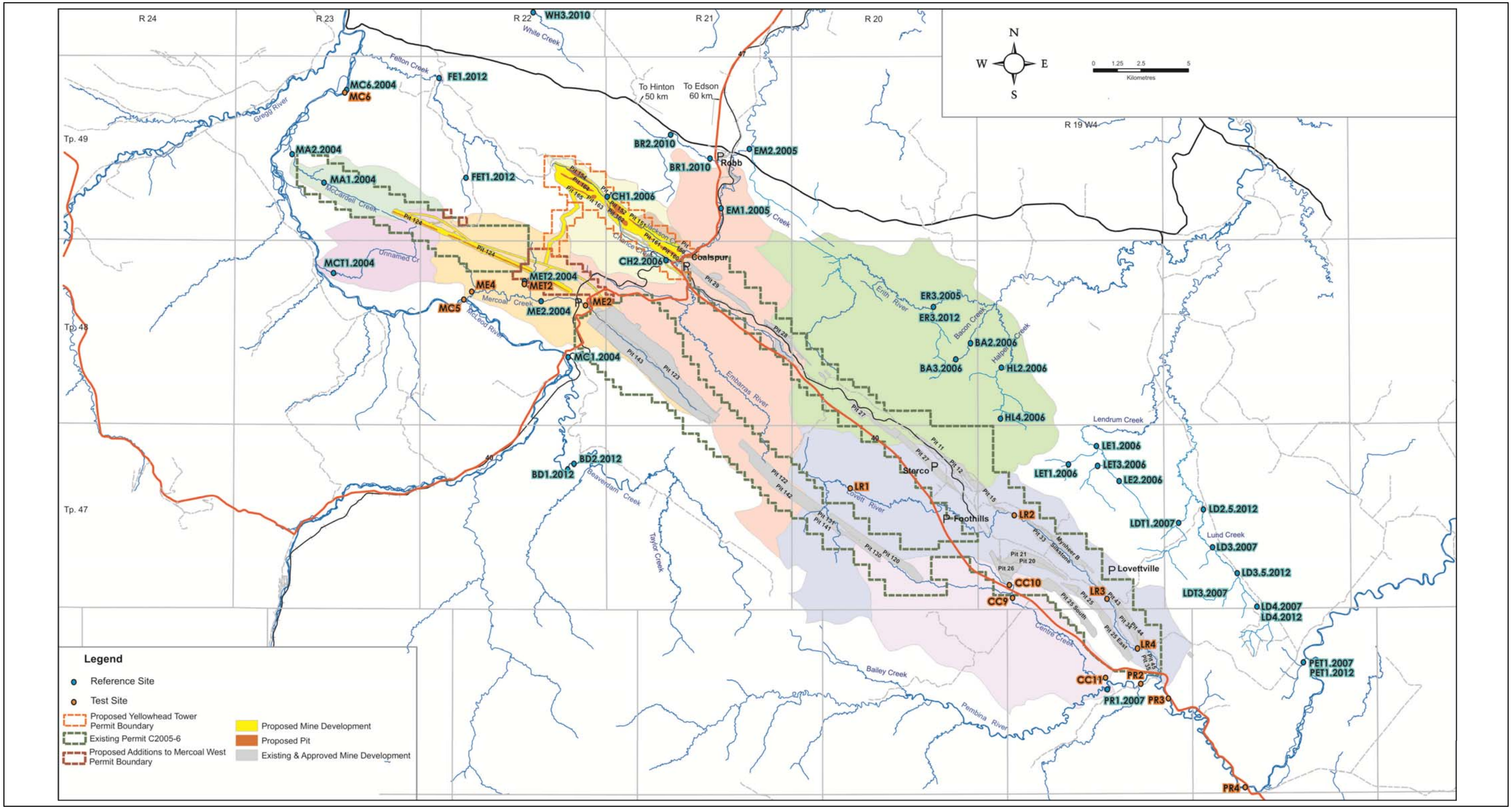


Figure 1. Monitoring locations (2012 test sites) and the majority of the reference sites for the Coal Valley Mine Benthic Invertebrate Biomonitoring Program.

Reference sites WH-1.2010 and AP-7.2010 not located on map-Locations described in Table 3.3.

4.0 METHODS

4.1 GENERAL APPROACH

The proposed monitoring program will employ the Reference Condition Approach (RCA) whereby *test sites* which have the potential of being impacted are compared to an appropriate *group* of *reference sites* (that represent the normal condition) to determine if there is an impact. The degree of potential impairment is determined by how far the benthic communities at the *test sites* deviate from those at *reference sites.* Further analysis of test sites will incorporate common metrics that will use indicator groups to determine if the community structure is indicative of impairment. Key elements of the RCA approach include:

1. Selection of a pool of candidate *reference sites* that includes locations sampled during monitoring or baseline assessment work and new sites that could be sampled in the future.
2. Selection of *test sites* (based on mine plans) that will be established in the immediate vicinity of an effluent discharge point and additional *test sites* will be established at locations downstream (depending on the size of the water body) to determine the linear extent of an impact.
3. Use of existing regional benthic data that CVM has accumulated during previous monitoring and baseline investigation to:
    a. Develop a model that explains the natural variability of the benthic populations in the region.
    b. Determine (through statistical analysis described in Section 4.6, the number of reference sites (from the candidate pool) that need to be sampled in a given monitoring year.
    c. Identify data gaps in the model (e.g. additional reference site information may be required to ensure the model is accurate)
4. Implementation of the monitoring program whereby:
    a. *test sites* will be sampled.
    b. A subset of reference sites will be sampled and included in the model to account for effects of natural temporal variation.
5. Employment of statistical analysis to match *test sites* with the appropriate group of *reference sites* (*Reference Group*) for comparison and assessment of effects.
6. Analysis of the community structure of test sites identified to be divergent from their assigned reference group through the use of metrics. The metrics used will employ indicator benthic groups in the calculations to ascertain whether the benthic community exhibits characteristics of an impaired community.

7. Review of the RCA biomonitoring model for the CVM, post assessment, to identify data gaps. There is potential for additional reference information to be required as prescribed test sampling continues for the CVM biomonitoring program to account for a reference group(s) that requires a higher number of samples.

4.2 MONITORING CHRONOLOGY

Due to the size and scope of this program, a staged approach will be undertaken whereby a portion of the program is completed in a given year. The 10 year schedule is devised with the following guiding principles in mind:

- The five year monitoring frequency will be continued in the Pembina drainage where mining has ceased. Under this scenario monitoring will be conducted again in 2017.
- A three year monitoring frequency will take place within the Embarras River and the McLeod River drainage basins where active mining is ongoing in the Mercoal West and Yellowhead Tower areas.
- A sub set of reference sites will be selected from the pool of candidate sites and sampled in each monitoring year. New candidate sites may be chosen for the purpose of increasing the sample size in low sample reference groups.

4.3 FIELD SAMPLING

4.3.1 Benthic Invertebrates

Field sampling protocols for the Benthic Invertebrate Monitoring were based largely on methodology described by Alberta Environment (2006) which included the collection of random, replicate samples at each location using a Neil-Hess Cylinder with a 250 micron mesh. Sampling was conducted in the fall with all samples preserved with a minimum 80% ethanol prior to shipment. At each site, three replicate samples were taken within erosional streambed habitat.

4.3.2 Habitat and Water Quality

General habitat conditions, including substrate type and size, water depth and velocity, and bankfull and wetted width, were characterized at each site. In addition, at each site, basic water quality parameters including conductivity, water temperature, pH, dissolved oxygen and turbidity were measured and recorded in the field.

4.3.3 Epilithic Algae

Epilithic algae were sampled at each site by randomly scraping a 2 x 2 cm area on randomly selected rocks. Epilithic algae field sampling methods were completed as described by Alberta Environment (2006). A composite sample was sent to an independent laboratory (Bio-Aquatics Research and Consulting) for analysis of total chlorophyll ‘*a*’. Epilithic algae samples were taken at all the benthic invertebrate monitoring sites visited in September of 2012. Of the historical sites that met the criteria for use in the benthic invertebrate model, 26 of the 32 sites had chlorophyll ‘a’ data available.

4.4 BENTHIC INVERTEBRATE IDENTIFICATION

Samples were processed by an independent taxonomist following standard procedures (Appendix A). Taxonomic resolution is provided in Table 4.1.

Table 4.1. Taxonomic level of identification (minimum) for biological groups for the CVM Revised Benthic Invertebrate Biomonitoring Program

Biological Group	Level of identification	Biological Group	Level of identification
Ephemeroptera	Genus	Arachnida	Suborder
Plecoptera	Genus	Cnidaria	Genus
Trichoptera	Genus	Crustacea	Order
Chironomidae	Subfamily	Gastropoda	Genus
Diptera	Subfamily	Pelecypoda	Genus
Coleoptera	Family	Oligochaeta	Genus
Megaloptera	Genus	Nematoda	Phylum

4.5 EPILITHIC ALGAE-LABORATORY METHODS

Algae samples were analysed using the spectrophotometric method to quantify chlorophyll ‘a’. The methods used by Bio-Aquatics Research and Consulting are based upon methodology provided in Moss, B. 1967(a) and in Moss, B. 1967(b).

4.6 MONITORING STUDY DESIGN

4.6.1 Reference Sites

Selection of Reference Sites

Reference sites were selected on the requirements that they were within the same ecoregion as the test sites (Western Alberta Upland), that they would not be influenced by mine activity (ongoing or recently reclaimed), and that they exhibited erosional streambed habitat. All of the reference sites have influences to some degree from development by forestry and oil and gas activity (i.e. roads, cutlines, well pads, harvested cut blocks) due to the fairly widespread nature of these industries throughout this area of the province. The reference sites are not pristine but do exemplify the common baseline condition of the majority of watercourses within this ecoregion. Approximately 75% of the reference data used to build the RCA Model was obtained from baseline studies or monitoring studies conducted for CVRI between the years of 2004 and 2010.

Reference Groups

A group of reference sites is required by the RCA to determine the reference condition. As indicated in section 4.1, *test sites* will be compared with this *reference group* (group of *reference sites*) to determine effects. The number of *reference sites* required to complete the monitoring program will depend on the number of *reference groups* needed to accurately depict the natural stream environment (Bowman and Sommers 2005, Environment Canada 2010). To accomplish this, discriminant analysis (Environment Canada 2010) can be used in conjunction with hierarchical clustering to determine the number of necessary reference groups based on habitat attributes at sites and existing community composition data.

Reference Sites

A power analysis (as suggested by Environment Canada 2010) will be applied using the following formula to estimate the likelihood of detecting effects with the chosen number of *reference sites* per *reference group*.

$$N = 2(t_\alpha + t_\beta)^2(SD/ES)^2$$

> where, n is the number sites per *group*, t_α and t_β are the critical t values at significance levels for Type 1 and Type 2 error rates respectively, SD is the within reach standard deviation, and ES is the critical effect size (where ES is the mean reference condition ± 2 SDs assuming that effects exceeding ±2 SDs are of interest)

Power analysis calculated at a 5 % chance of type 1 error (t-alpha) and a 5 % chance of type 2 error (t-beta), with the assumption that critical effect size is >2 SD's, determined that >9 sites per group are required.

Similarly, Environment Canada (2010) suggests that there be a minimum of 10 *sites* within each *reference group* which would translate to 20 *sites* if there were two *reference groups* (as described above). It should be noted that this requirement represents the number of "data points" required to characterize the reference group and not necessarily the number of "reference sites required per monitoring year". As such, historical data from suitable sites will also be utilized to characterize the reference group when possible. To elaborate, information from the pool of historical *reference sites* (Table 3.3) was used to develop the model that describes the natural variability of benthic invertebrate populations in the region. The historical reference site data was sourced from information that the mine collected during previous baseline and monitoring work in the area.

4.6.2 Test Sites

The proposed program will consist of 22 *test sites* on 8 different water bodies. The location of the existing test sites on the Pembina River, Lovett River, Centre Creek, Embarras River, and Mercoal Creek (Figure 1) will essentially remain unchanged from previous monitoring. In addition to these sites, new *test sites* will be established on the Embarras River, McLeod River, Chance Creek and Mercoal Creek (Figure 1).

4.6.3 Number of Sub-Samples (Replicates) per Site

With the RCA approach, replication is at the sample site scale and since variation within a site is often much lower than among sites, a single sample can be taken at each site and variation among sites is used to describe the reference condition (Environment Canada 2010). However, additional sub-samples or *site replicates* may be required to accurately reflect organism abundance and species richness. If required, the following formula (Environment Canada 2010) will be applied to existing benthic invertebrate data (from the previous monitoring program) to determine the number of sub-samples needed to provide confidence that a representative number of organisms has been captured.

$N = s^2 / D^2 \bar{X}^2$

> where, $\bar{X}$ is equal to the sample mean, N is equal to the number of field sub-samples, s2 is equal to the sample variance and D is equal to the index of precision.

The 2012 data was collected using the minimum number of sub-samples (3) recommended by Environment Canada (2010). Power analysis found that the mean number of replicates required for the 2012 data sufficient to provide an estimate with 20 % precision, using sample variance calculated at 95 % confidence, was calculated to be 2.7.

4.7 RCA MODEL DEVELOPMENT

The Canadian Aquatic Biomonitoring Network (CABIN) program was developed in response to the need for a nationally standardized method to assess the ecological condition of Canada's freshwater. Procedures for designing a biomonitoring study, analyzing the data, and results interpretation provided in the training modules for the use in the program were consulted for the CVM monitoring study. The data analysis procedures used in Environment Canada's Benthic Assessment of Sediment (BEAST) analysis model used by the CABIN program were largely adhered to in regards to constructing and utilizing the RCA model.

4.7.1 Sample Data

The benthic invertebrate data collected from reference sites (historical and 2012) was statistically analyzed in its raw form in line with CABIN procedures (CABIN 2010) as defined groupings could be determined without transforming the data. The mean of the count data for each taxon was calculated for each site. Sampling completed prior to 2012 included 5 replicates for each site, whereas the 2012 sampling involved three replicates per site in line with the minimum required by Environment Canada (2010). The mean of the appropriate data from all replicates of one site was used for any data analysis and site summaries. The raw count data was organized into families or less specific (as per CABIN BEAST analysis procedures). Those taxonomic groups not identified to the family level were instead identified to the level commonly used for each group (as in Table 4.1). Rare families were included in the data as some rare families can be indicative of ecological stress (CABIN 2010). For the site summary and metric calculations, taxonomic resolution was identified to the level as described in Table 4.1.The raw benthic data is provided in Appendix B and the summarized benthic data in Appendix C.

4.7.2 Cluster analysis

Hierarchical cluster analysis was used to group the reference site benthic invertebrate count data. The cluster analysis was done using IBM SPSS 13.0 to create dendrograms using various linkage and distance measure combinations that best define groups of similar sites graphically. Sites found to have less distance between them (more similar benthic communities) are found closer together on the dendrogram, as sites found to have larger differences between their count data are located farther away. Numerous dendrograms were created and those that showed a large relative distance between one or more groups of sites were considered for further testing to determine if they would be found to have a high correlation with the habitat data collected for each site. The average within-groups linkage using a Phi-square distance measure was found to provide the clusters that were well correlated to the habitat data as further described in 4.7.3.

4.7.3 Discriminant Function Analysis

The habitat data was organized by site and by the reference site groups (determined through the cluster analysis and the creation of dendrograms), and then tested using discriminant function analysis (DFA). The DFA completed on the habitat data determined which habitat variables are the most discriminating between the assigned reference groups by comparing the raw habitat data using a distance measure. The Mahalanobis distance measure was used for the DFA using IBM SPSS 13.0 statistical software. The Mahalanobis distance reflects the similarity between a case and the mean of each reference group, and is commonly used for multivariate analysis of normal distributions.

The habitat parameters (variables) included in the DFA are provided in Table 4.2.

Table 4.2. The habitat variables included in the DFA of the assigned reference groups

Depth (m)	Velocity (m/s)	Water Temp (^{0}C)	pH	Conductivity (µS)
Dissolved oxygen (mg/L)	Turbidity (NTU's)	Wetted width (m)	Bank-full width (m)	Mean diameter of stones (mm)
Stone count* (# >50 mm)	Discharge (m^3/L)	Boulder (%)	Cobble (%)	Gravel (%)
FN (%)	Stream order (Strahler 1964)			

*The number of stones within the Hess sample area that were greater than 50 mm in diameter along their longest axis

The stepwise DFA builds discriminant functions (with the number depending on the possible number of reference group categories) from the reference group data through iterative tests, combining only the most highly correlated and discriminating variables to predict group membership. Stepwise DFA allows for the ability to choose the variables included in the classification process by allowing for the manipulation of the limit of the minimum significance at which variables are included in the creation of the discriminant functions. Limiting the inclusion of only the most discriminating variables helps to maximize the predictive power of the discriminant function(s) created. The final variables were chosen by noting which grouping of variables produced the highest accuracy of site prediction by the cross validation method, as well as which grouping best met Box's M test for homogeneity of variances. An error rate is determined through the cross-validated method (as it has less potential to overestimate the predictive power of the discriminant function) and is equal to the percentage of sites that are placed incorrectly into a reference group by the discriminant functions.

4.8 ASSESSMENT OF TEST SITES USING THE RCA MODEL

4.8.1 Classification of Test Sites

The test sites are assigned to the reference group that has the most similar habitat qualities. The test site habitat data membership is predicted using the same discriminant function(s) determined in the reference site DFA. Once the test sites are assigned a reference group, the test site count data are compared to the count data of its assigned reference group through multidimensional scaling, which is further described in 4.8.2.

4.8.2 Assessment of Test Sites

The reference site count data was reduced to three variables using multidimensional scaling (PROXSCAL algorithms) in IBM SPSS 13.0 due to there being a high number of independent variables and because a majority of the variables did not possess a normal distribution. Each combination of the three variables (dimensions or d-scores) created from the scaling process were plotted in 2 dimensional space in order to determine how similar the test sites coordinates compared to the reference group centroid (mean coordinate). This comparison was done through the graphing of density ellipses (also known as confidence ellipses) around the reference group of coordinates. The d-scores for each site are provided in Appendix D.

Density ellipses were created for each of the scatterplots (i.e. three combinations of the three variables) for the reference group at 90.0 %, 99.0 % and 99.9 % confidence using SAS Institute Inc. JMP IN Software. Test site values for the same variables were plotted against the reference sites density ellipses to determine how comparable the test sites were to the reference group.

The location of the test site plots relative to the reference group and their interpretation are provided in Table 4.3.

Table 4.3. Interpretation of test site scaling score in reference to density ellipses determined from the group of reference sites (as per CABIN 2010)

Within the 90 % range	Between 90% and 99.0%	Between 99.0% and 99.9%	Outside of the 99.9% range
• Similar to reference group • Not considered to be impaired	• Mildly divergent • 10% probability of type 1 error	• Divergent from reference group • 1% probability of type 1 error	• Severely divergent from reference group • 0.1% probability of type 1 error

4.8.3 Metric calculations

Metric calculations are complimentary to the RCA analysis in that they provide another way in which impaired communities can be detected and also serve to aid in the interpretation of the results of the RCA analysis. The metric calculations used were chosen from those suggested in CABIN (2010). The raw benthic invertebrate count data provided by the taxonomist was used to calculate five separate metrics for each reference site within the reference group and for all the test sites. The mean of the replicate counts for each site was used for all metrics except for the Shannon Diversity Index which was calculated for each replicate and then averaged. The metrics used were as follows:

- Total Abundance- Sum of all organisms
- Mean Taxa Richness- Mean number of taxa present at the selected taxonomic level (see 4.1.2 for taxonomic resolution)
- EPT abundance-Abundance of EPT individual organisms
- EPT/Chironomidae + EPT-Abundance of EPT individuals divided by the abundance of Chironomids and EPT individuals

- Shannon Diversity Index- Index to measure the relative abundance and the distribution amongst the taxa present (evenness). The Shannon Diversity Index is a measure of species diversity based on the number of species as well as the evenness of distribution of organisms (Shannon and Weaver 1949) and is used as a metric by CABIN (2010) as a descriptor of the benthic community. A high diversity value indicates a healthy population consisting of a number of individuals from a variety of taxa. Low species diversity suggests an uneven distribution of individuals between taxa indicating an unstable population. The Shannon Diversity Index was calculated for all sites as follows:

$$H' = -\sum_{i=1}^{s} p_i \ln p_i$$

where “s” = number of species

“p_i” = proportion of the total number of individuals consisting of the i^{th} species

“ln” = natural logarithm

The mean of each metric for each reference group will be calculated so that the test site value for each of the five metrics can be compared to this value. The comparison involves calculating the ratio of the test site value to the reference group mean value for each metric (i.e. the observed value divided by the expected value).

5.0 RESULTS

5.1 CLUSTER ANALYSIS

Cluster analysis was conducted on the raw data (at a resolution of family or less specific) for the 40 reference sites that met the reference site criteria. The hierarchical cluster analysis used the average within-groups linkage and a distance measure of Phi-square. The results of this analysis are depicted graphically in the dendrogram provided in Figure 2. The division between groups was chosen at approximately 96% dissimilarity which formed 2 separate groups. Group 1 contains 32 reference sites and group 2 contains 8 reference sites. Group 2 (Figure 2) has less than the 10 sites minimum required by the CABIN procedures; however, the size of the group does not affect the analysis for the 2012 test sites, as none of them had similar habitat characteristics to group 2. Some site names on the dendrogram (Figure 2) have the first two digits from the year missing so that the name would fit into the SPSS database.

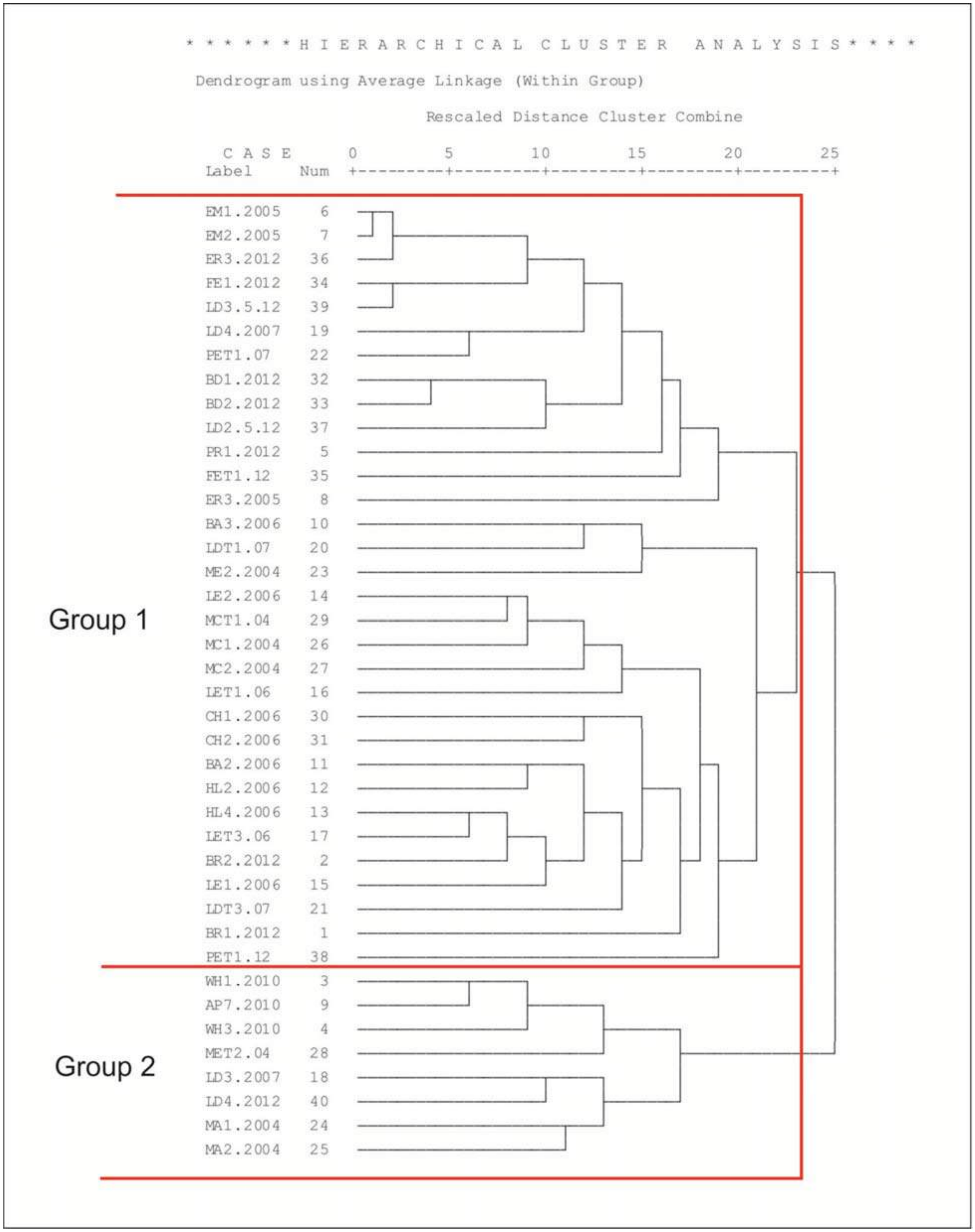


Figure 2. Dendrogram showing classification of reference site invertebrate count data using average within-groups linkage method and a distance measure of phi-square

5.2 DISCRIMINANT FUNCTION ANALYSIS

The stepwise DFA for the habitat data determined that four habitat variables best discriminate between the two assigned groups determined in the cluster analysis.

The variables were screened by a minimum partial F to enter of 2.6 and a maximum partial F to remove of 1.0. The four habitat variables determined to be the most discriminating between the two groups are provided below in Table 5.1.

Table 5.1. SPSS table of the variables included in the stepwise DFA for the reference habitat data

Variables Entered/Removed[a,b,c,d]

		Min. D Squared					
				Exact F			
Step	Entered	Statistic	Between Groups	Statistic	df1	df2	Sig.
1	Velocity	.414	1.00 and 2.00	2.647	1	38.000	.112
2	Rock Count	1.179	1.00 and 2.00	3.674	2	37.000	.035
3	Stream Order	1.788	1.00 and 2.00	3.615	3	36.000	.022
4	Bank	2.624	1.00 and 2.00	3.868	4	35.000	.011

At each step, the variable that maximizes the Mahalanobis distance between the two closest groups is entered.

a. Maximum number of steps is 28.

b. Minimum partial F to enter is 2.6.

c. Maximum partial F to remove is 1.0.

d. F level, tolerance, or VIN insufficient for further computation.

Canonical correlation for the functions is provided below in Table 5.2.

Table 5.2. Table of eigenvalues for the DFA on the reference site habitat data

Eigenvalues

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	.442(a)	100.0	100.0	.554

a First 1 canonical discriminant functions were used in the analysis.

The classification results show the number of sites predicted to be classified within each of the two reference groups and the percentage of sites that this prediction represents (Table 5.3). Also within the table the ‘cases not selected’ represent the test sites and their assignment to the most similar reference group. All of the 15 test sites sampled in 2012 were assigned to Reference Group 1, with no test sites assigned to Reference Group 2. Using the cross validation method, it was found that 85 % of the sites were correctly classified.

Table 5.3. Classification results of the DFA for the reference habitat data using assigned groups from the cluster analysis

Classification Results[b,c,d]

			BPhi2Group	Predicted Group Membership 1.00	2.00	Total
Cases Selected	Original	Count	1.00	31	1	32
			2.00	4	4	8
		%	1.00	96.9	3.1	100.0
			2.00	50.0	50.0	100.0
	Cross-validated[a]	Count	1.00	30	2	32
			2.00	4	4	8
		%	1.00	93.8	6.3	100.0
			2.00	50.0	50.0	100.0
Cases Not Selected	Original	Count	1.00	0	0	0
			2.00	0	0	0
			Ungrouped cases	15	0	15
		%	1.00	.0	.0	100.0
			2.00	.0	.0	100.0
			Ungrouped cases	100.0	.0	100.0

a. Cross validation is done only for those cases in the analysis. In cross validation, each case is classified by the functions derived from all cases other than that case.

b. 87.5% of selected original grouped cases correctly classified.

c. .0% of unselected original grouped cases correctly classified.

d. 85.0% of selected cross-validated grouped cases correctly classified.

5.3 Classification of Test Sites

As provided in Table 5.3, each of the test sites was assigned a reference group through the DFA of the habitat data. The assigned reference group has the most similar measurements of each of the four variables (velocity, rock count, stream order, and bank-full width) when compared to the test site. All test sites were assigned to Reference Group 1.

5.4 Assessment of the Test Sites using the RCA Model

The count data for reference group 1 and all the test sites were reduced using multidimensional scaling down to three variables. Test Sites were analyzed to determine if they fell within the 90 %, 99% or 99.9 % confidence ellipsoid of the three dimensions (variables) of Reference Group 1. Density ellipses were created in two dimensions in order to determine if any test sites were outside the 90 % confidence density ellipse. If any test site was found to be outside any of the three ellipses it was considered to be divergent from the reference group. Each of the three dimensions, using only reference site values, were found to have normal distributions as provided in table 5.4 using the Kolmogorov-Smirnov and Shapiro-Wilk tests. A significance result of 0.05 or less from either test would indicate a non-normal distribution.

Table 5.4. Results of the Kolmogorov-Smirnov and Shapiro-Wilk tests for normality on the combined D-scores

Tests of Normality

	Kolmogorov-Smirnov(a)			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Dim1	.098	32	.200(*)	.960	32	.276
Dim2	.131	32	.174	.976	32	.665
Dim3	.122	32	.200(*)	.957	32	.223

* This is a lower bound of the true significance.
a Lilliefors Significance Correction

For the RCA assessment of the test sites, any test site that is outside of the 90 % confidence interval of the reference group distribution is considered to be divergent from the reference group and is considered to be impaired (CABIN 2010).

Scatterplots of the dimensions produced from the multidimensional scaling are provided in Figures 3, 4 and 5. The innermost ellipse encloses the densest 90.0 % of the estimated distribution, with the nearest larger ellipse enclosing 99.0 %, and the largest ellipse enclosing 99.9 %.

The test site data plotted with the reference group density ellipses indicate that sites ME2 and CC10 were the most divergent from the Reference Group 1 centroid (Figures 3, 4 and 5). Test site ME2 is considered to be severely divergent as per interpretation through CABIN (2010), as it is outside of the 99.9 % reference group density ellipse. As per interpretation through CABIN (2010) test site CC10 would be considered mildly divergent as it is located between the 90.0 % and 99.0 % reference group density ellipses. Other points (sites) that can be seen to be located outside the 90.0 % density ellipse that are not labelled are reference sites and not test sites.

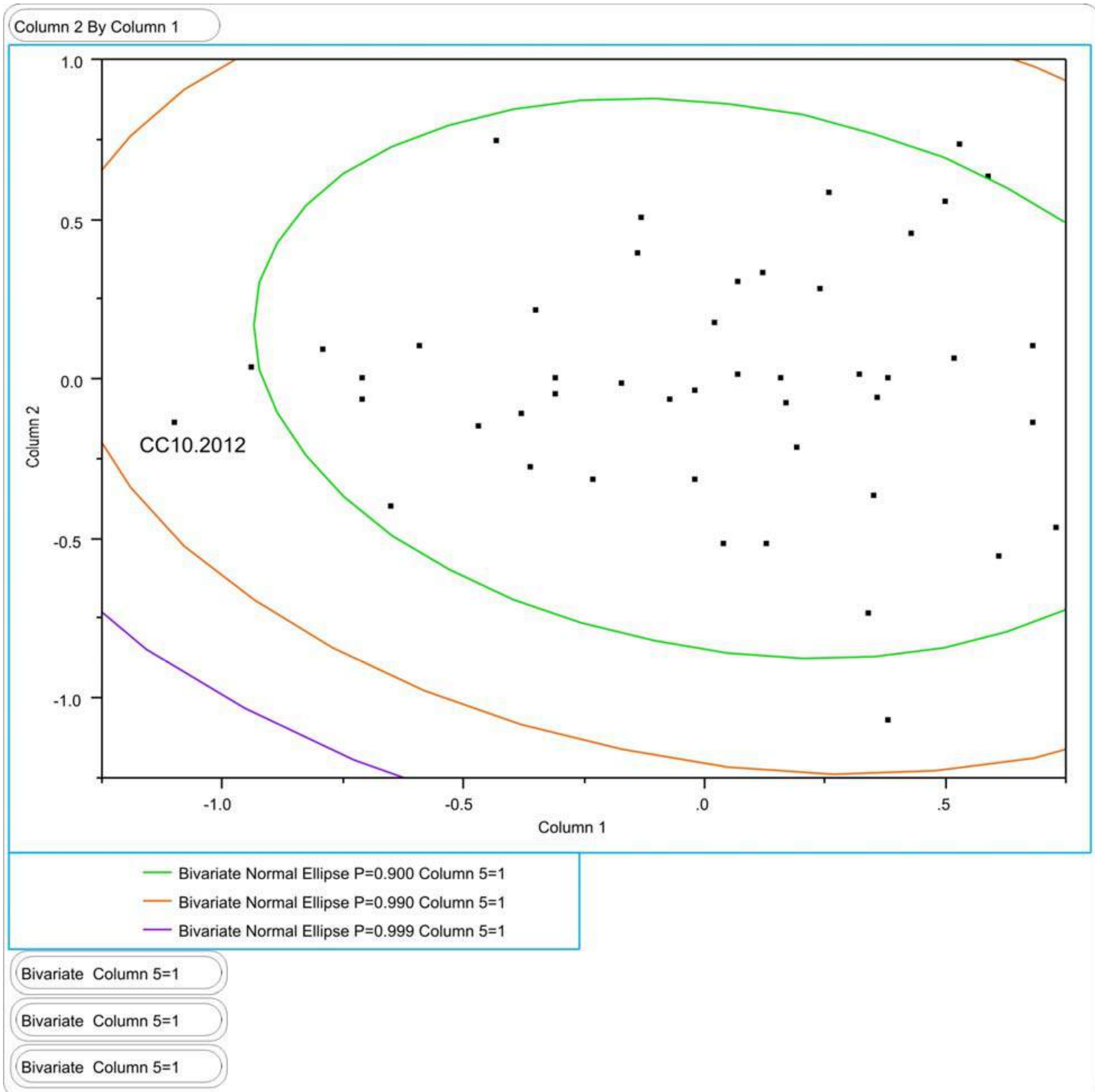


Figure 3. Scatterplot of dimension 1 vs. dimension 2 with Reference Group 1 density ellipses plotted at 90.0 %, 99.0 % and 99.9 %

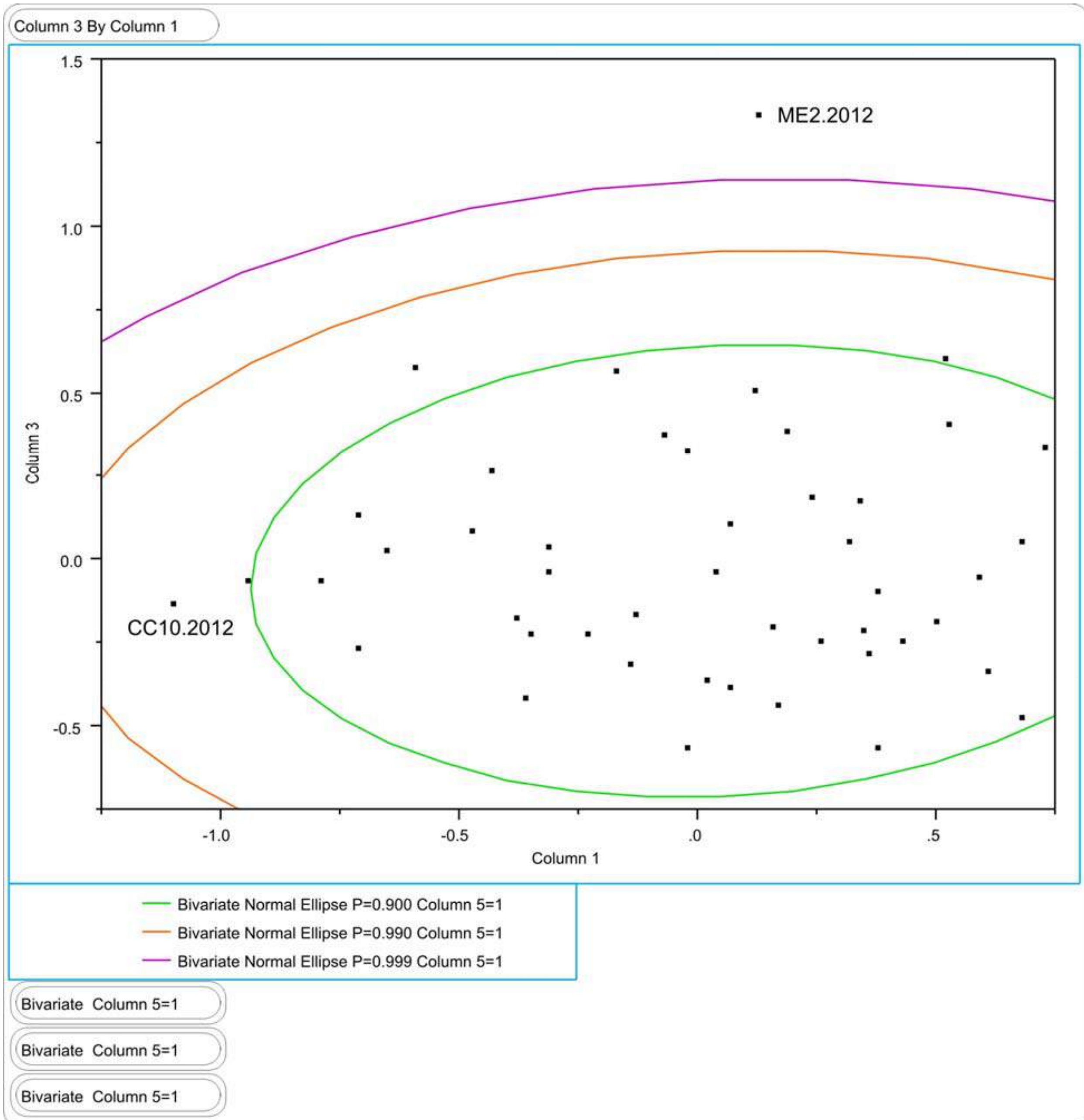


Figure 4. Scatterplot of dimension 1 vs. dimension 3 with Reference Group 1 density ellipses plotted at 90.0 %, 99.0 % and 99.9 %

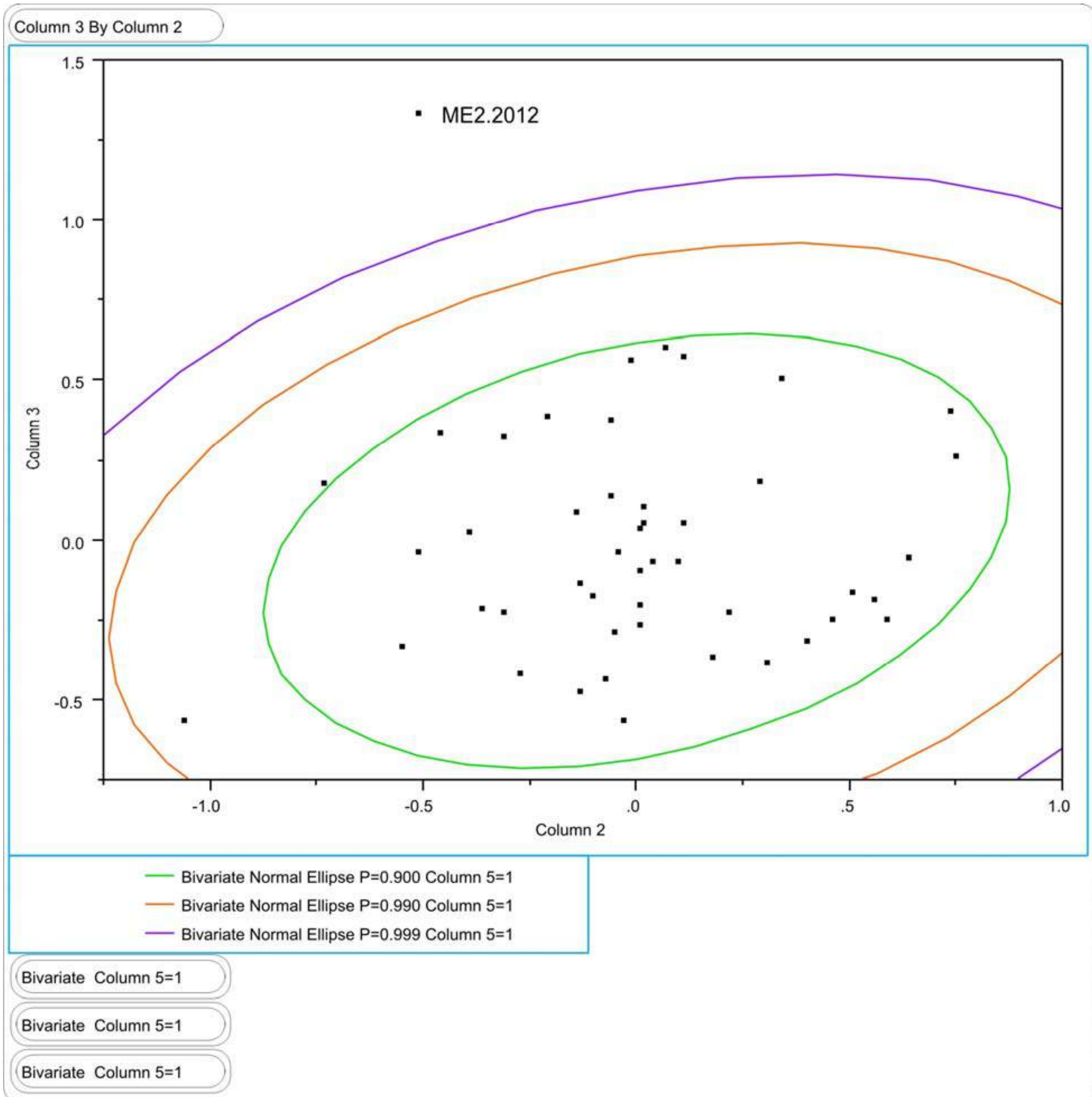


Figure 5. Scatterplot of dimension 2 vs. dimension 3 with Reference Group 1 density ellipses plotted at 90.0 %, 99.0 % and 99.9 %

5.5 METRIC CALCULATIONS

The results of the metric calculations for Reference Group 1 are provided in Table 5.5.

Table 5.5. Results of the five metric calculations for Reference Group 1

Reference Group 1	EPT/ Chir.* + EPT	Shannon Index	EPT abundance	Total abundance	Mean # of taxa
BA2.2006	0.95	-1.62	327.8	448.6	18.6
BA3.2006	0.92	-1.76	66.4	208.00	18.0
BD1.2012	0.98	-1.58	843.3	956.3	18.0
BD2.2012	0.99	-1.72	1163.7	1294.0	22.0
BR1.2010	0.94	-1.90	1094.4	1275.6	28.0
BR2.2010	0.95	-2.30	766.4	970.2	22.8
CH1.2006	0.93	-2.38	261.6	346.6	25.2
CH2.2006	0.92	-2.32	696.4	899.6	24.2
EM1.2005	1.00	-1.83	326.6	359.2	19.6
EM2.2005	1.00	-1.14	311.8	336.8	16.2
ER3.2005	0.95	-2.05	267.6	436.6	21.6
ER3.2012	1.00	-2.12	3249.3	3474.0	25.0
FE1.2012	0.91	-2.11	659.3	802.7	20.0
FET1.2012	0.86	-2.12	622.7	787.0	21.7
HL2.2006	0.97	-2.18	577.6	685.8	25.6
HL4.2006	0.97	-2.00	720.2	863.4	26.0
LD2.5.2012	0.97	-2.24	655.7	699.0	10.7
LD3.5.2012	0.97	-1.90	910.0	1043.0	16.7
LD4.2007	0.28	-2.17	225.0	964.4	29.0
LDT1.200	0.85	-2.40	294.6	543.6	29.8
LDT3.200	0.85	-2.74	441.6	628.2	32.6
LE1.2006	0.89	-2.25	267.6	339.4	21.4
LE2.2006	0.84	-2.37	476.2	630.0	30.8
LET1.2006	0.74	-2.28	558.4	836.0	24.2
LET3.2006	0.98	-1.83	765.8	848.8	19.8
MC1.2004	0.89	-2.27	822.2	957.2	30.6
MC6.2004	0.64	-2.27	464.2	751.6	25.0
MCT1.2004	0.82	-2.09	520.2	703.2	24.2
ME2.2004	0.89	-1.90	1008.6	1211.0	24.4
PET1.2007	0.98	-2.06	595.4	1015.6	28.4
PET1.2012	0.91	-2.30	404.3	638.7	17.0
PR1.2007	0.82	-2.24	494.4	771.0	20.0
Mean	0.89	-2.08	651.85	835.16	23.03

*Chir.= Chironomidae

The results of the metric comparisons between each test site and the mean of the reference group is provided in Table 5.6. The ratios of the observed value (test site metric) to the expected value (mean of the reference sites metric values from the assigned reference group) for each test site are provided in the coloured columns. Ratios that are less than 0.7 have been highlighted. The value of 0.7 was chosen arbitrarily as a threshold for presentation purposes that would indicate if a ratio was substantially lower than the mean.

Table 5.6. Comparison of Group 1 test site metrics with the mean of the reference sites' metrics

Group 1	Observed	Expected	Ratio	Obs.	Exp.	Ratio	Obs.	Exp.	Ratio	Obs.	Exp.	Ratio	Obs.	Exp.	Ratio
Site	EPT/ Chir + EPT	Ref. mean	O/E	Shannon Index	Ref. mean	O/E	EPT abundance	Ref. mean	O/E	Total abundance	Ref. mean	O/E	Mean # of taxa	Ref. mean	O/E
CC9.2012	0.93	0.89	1.04	-1.76	-2.08	0.85	1813.7	651.9	2.78	2130.7	835.2	2.55	20.3	23.0	0.82
CC10.2012	0.98	0.89	1.11	-1.01	-2.08	0.49	1340.3	651.9	2.06	1412.7	835.2	1.69	20.7	23.0	0.84
CC11.2012	0.95	0.89	1.07	-2.10	-2.08	1.01	1773.7	651.9	2.72	2097.3	835.2	2.51	28.7	23.0	1.16
LR1.2012	0.99	0.89	1.11	-2.12	-2.23	0.95	862.0	651.9	1.32	1011.3	835.2	1.21	21.7	23.0	0.88
LR2.2012	0.96	0.89	1.08	-2.24	-2.08	1.08	1047.3	651.9	1.61	1380.7	835.2	1.65	23.7	23.0	0.96
LR3.2012	0.68	0.89	0.76	-2.21	-2.08	1.06	553.0	651.9	0.85	1019.7	835.2	1.22	25.0	23.0	1.01
LR4.2012	0.89	0.89	1.00	-2.26	-2.08	1.09	770.7	651.9	1.18	1031.7	835.2	1.24	22.3	23.0	0.91
MC5.2012	0.99	0.89	1.11	-1.87	-2.08	0.90	477.3	651.9	0.73	512.0	835.2	0.61	15.0	23.0	0.61
MC6.2012	0.99	0.89	1.12	-1.79	-2.08	0.86	691.0	651.9	1.06	728.3	835.2	0.87	18.3	23.0	0.74
ME2.2012	0.36	0.89	0.41	-2.22	-2.23	1.00	261.0	651.9	0.40	1018	835.2	1.22	20.3	23.0	0.82
ME4.2012	0.90	0.89	1.02	-2.03	-2.08	0.98	815.0	651.9	1.25	1020.3	835.2	1.22	24.7	23.0	1.00
MET2.201	0.98	0.89	1.10	-1.61	-2.23	0.72	496.0	651.9	0.76	539.0	835.2	0.65	11.3	23.0	0.46
PR2.2012	0.76	0.89	0.86	-2.40	-2.08	1.15	596.3	651.9	0.91	870.7	835.2	1.04	23.0	23.0	0.93
PR3.2012	0.67	0.89	0.76	-2.32	-2.08	1.12	711.0	651.9	1.09	1140.7	835.2	1.37	22.7	23.0	0.92
PR4.2012	0.94	0.89	1.06	-2.09	-2.08	1.00	539.3	651.9	0.83	605.7	835.2	0.73	16.7	23.0	0.68

5.6 EPILILITHIC ALGAE

The results of the laboratory analysis of the epilithic algae samples collected are provided in Tables 5.7 and 5.8. Six reference sites have no chlorophyll ‘a’ data due to the failed preservation of samples.

Table 5.7. Results of chlorophyll ‘a’ determined through spectrophotometry of epilithic algae scrapings from the test sites

Site Code (Test Sites)	**Chlorophyll ‘a’ mg/m2**
CC9.2012	3.094
CC10.2012	2.286
CC11.2012	14.880
PR2.2012	14.417
PR3.2012	26.070
PR4.2012	6.525
LR1.2012	8.775
LR2.2012	18.275
LR3.2012	20.549
LR4.2012	16.381
MC5.2012	10.494
MC6.2012	6.234
ME2.2012	109.472
ME4.2012	3.664
MET2.2012	3.235

Table 5.8. Results of chlorophyll ‘a’ analysis through spectrophotometry of epilithic algae scrapings from the reference sites

Site Code (Reference Sites*)	**Chlorophyll ‘a’ mg/m2**	**Site Code (Reference Sites)**	**Chlorophyll ‘a’ mg/m2**	**Site Code (Reference Sites)**	**Chlorophyll ‘a’ mg/m2**
BD2.2012	8.600	LET1.2006	10.870	HL4.2006	3.59
BD1.2012	4.834	LET3.2006	16.650	LE1.2006	6.430
ER3.2012	3.736	LD3.2007	11.133	LE2.2006	39.79
FE1.2012	6.208	LD4.2007	35.380	EM1.2005	0.418
FET1.2012	11.160	LDT1.2007	5.157	EM2.2005	9.541
LD2.5.2012	4.443	LDT3.2007	18.547	MC1.2004	43.547
LD3.5.2012	6.659	PET1.2007	6.323	MC6.2004	1.760
LD4.2012	8.613	CH1.2006	21.060	ME2.2004	14.540
PET1.2012	6.156	CH2.2006	11.530	HL2.2006	5.77
ER3.2005	0.565	MA1.2004	15.837	MCT1.2004	47.660
BA3.2006	2.27	MA2.2004	19.220		
BA2.2006	11.36	MET2.2004	18.043		

*Six reference sites were not included because the samples did not preserve properly.

6.0 DISCUSSION

6.1 BENTHIC INVERTEBRATES

The RCA analysis found test sites CC10 and ME2 to be divergent from the reference group, with ME2 being severely divergent and CC10 being mildly divergent. These results indicate that there are significantly different benthic invertebrate communities at these sites as compared to Reference Group 1 at 90 % confidence. The metric comparisons for test site CC10 show that the Shannon Diversity Index (SDI) value is quite low relative to Reference Group 1. The low mean number of taxa measurement partially explains why the diversity score is low, but the data also shows that a number of the groups present are only represented by a low number of organisms (i.e. low evenness). Test site ME2 scored quite low in the EPT/ Chironomidae + EPT metric as well as the EPT abundance. Chironomidae counts were approximately double that of the EPT counts and much smaller than that of the mean reference group value. It is likely that this site has been impacted by sediment from upstream sources.

A few of the other test sites also showed low scores when compared to the reference group mean for each metric, although they were not considered to be divergent according to the RCA model analysis.

One of the test sites for which this is true is MC5. It had low values of total abundance but all other metric values were very similar to the mean reference group metric values. This site exhibited lower numbers of invertebrates but did not have a substantially lower SDI value, or lower proportions of sensitive to tolerant benthic groups as compared to the reference group.

Test site PR4 had similar metric values as MC5 in that the abundance values were down but the other metric values were similar to the reference group.

Site MET2 measured low on the SDI and quite low on the mean number of taxa; however, the proportion of sensitive benthic groups to the tolerant groups was high. It is possible that the benthic community at this site is stressed, although the same site was sampled in 2004, prior to upstream development, and was found to have a low SDI value (-1.84) as well as a low mean number of taxa (19.8) at that time; however, it was not as low as the mean number of taxa in 2012 (11.3).

Within the headwaters of Mercoal Creek, test site ME2, was identified as being impacted. In addressing the length of impact within Mercoal Creek it can be said that the impact ends before the next test site, ME4, as it was not considered divergent from the reference group in the RCA analysis and the metric values for this site were similar to the reference mean metric values. For test site CC10, the range of impact (though much less significant in magnitude than ME2) would end prior to test site CC11 as this test site was not identified as divergent from the reference group and did not have any metric value that was substantially different from the reference mean metric value.

6.2 EPILITHIC ALGAE

Results from the 2012 sampling show a large variability in algal biomass levels indicated through the chlorophyll ‘a’ lab analysis. The ME2 site was found to have much higher amounts of algal biomass from the samples taken as compared to reference sites and other test sites. This may indicate nutrient loading but could be caused by a number of different variables including low depth, low velocity and possibly a lack of cover from direct sunlight. Temperature at the time of sampling does not indicate that it was higher than average as compared to the other test sites. The water velocity is often the most influential factor of algal biomass due to removal of benthic algae from scouring by high velocity water or by ice. Other physical factors that are known to affect algal biomass are temperature, light penetration, sediment type, and turbidity. The manipulation of discharge rates or water velocities can greatly affect the epilithic algae of a watercourse. The timing of sampling and the techniques used can also influence results and preclude comparisons between historic data sets. As such, it is difficult to assess the source of the variability due to the multiple number of factors or groups of factors that can influence measurement results.

6.3 DATA GAPS AND FUTURE DESIGN

The mean variance calculated from the top 10 sites (including sites sampled 2012) with the highest variance in counts, requires approximately 5 replicates per site (determined through power analysis) in order to determine a representative count of the site with 95 % confidence. The increase from 3 to 5 replicates sampled per site should be considered for future sampling due to the high variance present in some of the benthic habitat sampled in 2012.

The construction of the RCA model resulted in two reference groups; Reference Group 1 was composed of 32 sites while Reference Group 2 was composed of 8 sites. It is possible that future test sites may be comparable to Reference Group 2; therefore, group 2 requires more sites to meet the minimum number of sites recommended. In the CABIN manual (2010) it recommends a minimum of 10 sites per group and the power analysis completed using data from the 2012 sampling found that the number of sites would need to be greater than 9. Reference Group 2 is characterized by slower velocities, higher rock counts, and narrower channel width than reference group 1. The addition of benthic data from reference sites that are similar to (i.e. have these habitat qualities) Reference Group 2 would improve the accuracy and precision of the RCA model.

7.0 REFERENCES

Alberta Environment 2006. Aquatic Ecosystems Field Sampling Protocols. Alberta Environmental Protection, Surface Water Assessment Branch.

Bowman, F. M. and K. M. Somers. 2005. Considerations when using the Reference Condition Approach for bioassessment of freshwater ecosystems. Water Quality Resources Journal of Canada. Vol 40, n3, 347-360.

CABIN. 2010. Canadian Aquatic Biomonitoring Network website. (http://www.ec.gc.ca/rcba-cabin/default.asp?lang=En&n=72AD8D96-1)

Environment Canada. 2010. Pulp and paper EEM guidance document. Environment Canada, National EEM Office, Gatineau, Quebec.

Environment Canada. 1993. Guidelines for Monitoring Benthos in Freshwater Environments. Prepared for Environment Canada by EVS Consultants.

Moss, B., 1967(a). A note on the estimation of chlorophyll a in freshwater algal communities.Limnol. Oceanogr. 12:340-342.

Moss, B., 1967(b). A spectrophotometric method for the estimation of percentage degradation of chlorophylls to pheo-pigments in extracts of algae. Limnol. Oceanogr. 12:335-340.

Strahler, A.N. 1964. Quantitative geomorphology of drainage basins and channel networks; section 4-2, in Handbook of Applied Hydrology, ed. Ven te Chow, McGraw-Hill, New York.

Appendix A

Benthic Invertebrate Sample Processing Methods

Method used for picking animals and taxonomy

The picking of animals was performed in accordance with the process developed by Wrona et al. (1982), with slight modifications. This procedure has been used for many years. It provides a good estimate of animal population in aquatic systems based on samples.

The Picking and Sub Sampling Process

The whole sample is washed through double stacked 2 mm and 106 μm meshes. All the animals that remain on the 2 mm mesh (coarse fraction) are picked. The fine fraction from the 106 μm mesh is put into an aeration apparatus and diluted with water until the total sample plus water volume is 1 litre. The sample is aerated, and when well mixed, five 50 mL sub samples are taken out of the aeration apparatus. The entire sub samples are picked using a compound microscope at 10 times magnification for the course fraction and 40 times magnification for the fine fraction. Once picking has been completed, the course and fine fraction are saved for quality assurance. The total of animals in each sub sample is determined for all taxa. After the samples are picked, quality assurance is performed to confirm that no visible animals are left in the sample.

All the animals are classified using the keys: '*Aquatic Invertebrates*' of Alberta by Hugh F. Clifford (1991), '*Ecology and Classification of North American Freshwater Invertebrates*' by James H. Thorp and Alan P. Covich (1991), and '*Fresh Water Invertebrates of the United States*' by Robert W. Pennak (1978).

The complete hierarchical classification through Phylum, Class, Order, Family, Genus, and Species is attempted for all taxa. However, in some cases when parts of the animals are missing, complete classification cannot be performed. In that case, classification was performed to the level recognizable to the taxonomer.

Reference:
Wrona, F.J., Culp, J.M. and Davies, R.W. 1982. *Macroinvertebrate subsampling: a simplified apparatus and approach*. Can. J. Fish. Aquat. Sci. 39:1051-1054

Appendix B

Raw Benthic Invertebrate Identification Data

Organism counts at Test Sites CC9, CC10, CC11 and LR1

Taxon	CC9-1	CC9-2	CC9-3	CC10-1	CC10-2	CC10-3	CC11-1	CC11-2	CC11-3	LR1-1	LR1-2	LR1-3
Ephemeroptera												
Baetidae												
Baetis sp.	1278	536	1431	936	1266	1180	2152	418	261	272	120	284
nymph							1					
Ephemerellidae												
Drunella sp.	26	35		5		8		1	1	9		2
Ephemerella sp.		4		2	2		3	4	6			
Serratella sp.	33	48	51		4		128	12	24	8	21	41
Heptageniidae												
Rhitrogena sp.	1			1		2	9		6			
Cinygmula sp.	95	124	64	44	24	94	297	401	329	271	247	212
Epeorus sp.		2				1				2		5
Caenidae										4		
Leptophlebiidae												
Paraleptophlebia sp.				16	25	55	12		4	4		
Siphlonuridae				8	8	3		12	12	3	4	4
Parameletus sp.												
Plecoptera												
Chloroperlidae	21	8	36	16	2	5	18	26	18	244	20	98
Leuctridae	13					8	8	4	12	4	12	8
Nemouridae												
Visoka sp.									4			
Zapada sp.	68	69	115	19	13	48	233	132	21	19	5	16
Perlidae												
Claassenia sp.												
Hesperoperla sp.					4	6	38	21	6	5	4	1
Perlodidae	593	242	341	23	12	16	285	54	48	208	120	156
Diura sp.			24									
Cultus sp.	4	5	21	4		9		1	16	24	40	16
Megarcys sp.	1	2										4
Isogenoides sp.							4		1			1
Isoperla sp.			5	16	12	44	16					
Pteronarcyidae												
Pteronarcella sp.												
Capniidae	8	8				4	12	20	16	12	16	4
Hemiptera												
Veliidae												
Mesoveliidae												
Mesovelia sp.												
adult												
Corixidae, adult												
Lepidoptera												
Noctuidae												
Trichoptera												
Brachycentridae												
Brachycentrus sp.							8		4			
Micrasema sp.				4	8		88	8	12			
Glossosomatidae												
Glossosoma sp.	32	4	8				4	4	12	3		4
Hydropsychidae												
Hydropsyche sp.												
Cheumatopsyche sp.							27	17	10			
Hydroptilidae												
Hydroptila sp.												
Rhyacophilidae												
Rhyacophila sp.	31	11	43	10	8	46	9	7	4	12	8	9

Organism counts at Test Sites CC9, CC10, CC11 and LR1 continued

Taxon cont.	CC9-1	CC9-2	CC9-3	CC10-1	CC10-2	CC10-3	CC11-1	CC11-2	CC11-3	LR1-1	LR1-2	LR1-3
Coleoptera												
Elmidae	14	6	18	6	3	2	18	8	10	6	16	3
Narpus sp.	99	70	140	11	10	19	120	42	110	99	100	23
adult	10	3	1	9	4		4		4	30	8	7
Hydrophilidae												
adult												
Chrysomelidae												
Hydrophilidae												
Diptera												
Ceratopogonidae												
Ceratopogoninae	4	5	4							4		4
Chironomidae												
Orthocladiinae	37	45	271	4	37	20	116	29	64	12	6	4
Tanypodinae								4				
Tanytarsini			1		4		8		4	4		
Chironomini	21	4	54		4	4	48	4	4	3		
Diamesinae												
Pupae							4					
adult												
Empididae	6		12		4	1	5	13	1			
Simuliidae	26		20	4			9			5		12
Pupae									1			
adult				1								
Tipulidae												
Tipulinae												
Tipula sp.											1	
Limoniinae												
Dicranota sp.	4		8				4		8			8
Antocha sp.							13	24	16			
Hexatoma sp.						1					4	
Pupae												
Psychodidae												
Pericoma /Telmatoscopus	8	4	4				8	8	8			4
Athericidae												
Atherix sp.												
Nematoda												
Oligochaeta												
Naididae												
Specaria sp.		4			5	4	8	4	4			
Lumbriculidae												
Lumbriculus sp.												
Pelecypoda												
Sphaeriidae												
Sphaerium												
Pisidium sp.												
Arachnida												
Acari												
Hydrachnidia	12		36	12	8	24	140	48	48	44	4	16
Stygothrombididae												
Hydrothrombium sp.												
Araneae												
Pisauridae												
Dolomedes triton												
Crustacea												
Ostracoda												
Cyprididae					3	4					9	8
Ilyocyprididae					5							

Organism counts at Test Sites CC9, CC10, CC11 and LR1 continued

Taxon cont.	CC9-1	CC9-2	CC9-3	CC10-1	CC10-2	CC10-3	CC11-1	CC11-2	CC11-3	LR1-1	LR1-2	LR1-3
Crustacea cont.												
Copepoda												
Cyclopoida										4		
Malacostraca												
Amphipoda												
Gammarus lacustrus												
Branchiopoda												
Cladocera												
Daphnidae												
Daphnia sp.												
Conchostraca												
Lynceidae												
Cnidaria												
Hydrozoa												
Hydra												
Hydra oligactis				4								

Organism counts at Test Sites LR2, LR3, LR4 and ME2

Taxon	LR2-1	LR2-2	LR2-3	LR3-1	LR3-2	LR3-3	LR4-1	LR4-2	LR4-3	ME2-1	ME2-2	ME2-3
Ephemeroptera												
Baetidae												
Baetis sp.	284	262	64	261	404	29	151	129	97	85	57	132
nymph				4	1							
Ephemerellidae												
Drunella sp.	1	1							1			
Ephemerella sp.				3	4		1	1				
Serratella sp.	34	28	5	9	9	5	30	22	64	37	189	62
Heptageniidae												
Rhitrogena sp.		89		4	2	2	13	13	12	5	8	
Cinygmula sp.	145	743	164	48	42	278	404	502	272	24	20	20
Epeorus sp.		4										
Caenidae												
Leptophlebiidae												
Paraleptophlebia sp.						4					24	8
Siphlonuridae					4	4						
Parameletus sp.												
Plecoptera												
Chloroperlidae	53	30	21	21	12	63	28	48	45		4	
Leuctridae	12		4	4	8	4	12		4	4	4	12
Nemouridae												
Visoka sp.												
Zapada sp.	76	91	8	33	4	5	42	44	48			3
Perlidae												
Claassenia sp.												
Hesperoperla sp.	10	30		3	1		5	10	28			
Perlodidae	425	256	29	80	29	16	56	44	28	13	8	12
Diura sp.												
Cultus sp.	28	33		16	4		8	12	4			
Megarcys sp.												
Isogenoides sp.	3	4	6	6	2	6	7		3	1		
Isoperla sp.	12	4	1	8	8		10	24	14		5	
Pteronarcyidae												
Pteronarcella sp.												
Capniidae	60	32	48	36	12	97	16	20	32			4
Hemiptera												
Veliidae			8	4	1							
Mesoveliidae												
Mesovelia sp.							9					
adult												
Corixidae, adult												
Lepidoptera												
Noctuidae												
Trichoptera												
Brachycentridae												
Brachycentrus sp.		4	4	16	16		8					
Micrasema sp.				4	8							
Glossosomatidae												
Glossosoma sp.	4	8			16					2	2	
Hydropsychidae												
Hydropsyche sp.												
Cheumatopsyche sp.	2	3										
Hydroptilidae												
Hydroptila sp.										1		
Rhyacophilidae												
Rhyacophila sp.	17				4					21	4	12

Organism counts at Test Sites LR2, LR3, LR4 and ME2 continued

Taxon cont.	LR2-1	LR2-2	LR2-3	LR3-1	LR3-2	LR3-3	LR4-1	LR4-2	LR4-3	ME2-1	ME2-2	ME2-3
Coleoptera												
Elmidae	5	1	7	8	12	4	4		8			
Narpus sp.	90	160	91	113	156	40	140	66	59	10	16	5
adult	22	61	28	15	2	5	4	23	25	14		
Hydrophilidae												
adult												
Chrysomelidae												
Hydrophilidae												
Diptera												
Ceratopogonidae												
Ceratopogoninae		4	5							1		
Chironomidae												
Orthocladiinae	55	47	3	123	277	21	81	91	59	153	179	332
Tanypodinae										4	5	4
Tanytarsini										208	193	32
Chironomini	3	8		24	192		8	16	8	17	8	214
Diamesinae												
Pupae	1	4		53	95		4	8	12	4		23
adult												
Empididae	1	9			8	1	8					
Simuliidae				1						18	8	117
Pupae					1					31		159
adult												
Tipulidae												
Tipulinae												
Tipula sp.	4	10	2	1		2	7	4	6			
Limoniinae												
Dicranota sp.	1	16			5	12	4	9	2	48	10	20
Antocha sp.	1			4	5	5	1			4		
Hexatoma sp.		4	4			1	4		5			
Pupae												
Psychodidae												
Pericoma/Telmatoscopus	8	8					8	4				
Athericidae												
Atherix sp.												
Nematoda				8								
Oligochaeta												
Naididae												
Specaria sp.	16	12	8	20	56	4		16	16	32	89	12
Lumbriculidae												
Lumbriculus sp.					1					1		
Pelecypoda												
Sphaeriidae												
Sphaerium								3				
Pisidium sp.				4								
Arachnida												
Acari												
Hydrachnidia	92	168	32	24	72	20	20	20	20	144	56	76
Stygothrombididae												
Hydrothrombium sp.												
Araneae												
Pisauridae												
Dolomedes triton		1										
Crustacea												
Ostracoda												
Cyprididae												
Ilyocyprididae												

Organism counts at Test Sites LR2, LR3, LR4 and ME2 continued

Taxon cont.	LR2-1	LR2-2	LR2-3	LR3-1	LR3-2	LR3-3	LR4-1	LR4-2	LR4-3	ME2-1	ME2-2	ME2-3
Crustacea cont.												
Copepoda												
Cyclopoida											12	
Malacostraca												
Amphipoda												
Gammarus lacustrus							1					
Branchiopoda												
Cladocera												
Daphnidae												
Daphnia sp.										8		
Conchostraca												
Lynceidae											4	
Cnidaria												
Hydrozoa												
Hydra												
Hydra oligactis												

Organism counts at Test Sites ME4, MET2, PR2 and PR3

Taxon	ME4-1	ME4-2	ME4-3	MET2-1	MET2-2	MET2-3	PR2-1	PR2-2	PR2-3	PR3-1	PR3-2	PR3-3
Ephemeroptera												
Baetidae												
Baetis sp.	226	665	632	290	80	480	175	416	106	412	295	146
nymph												
Ephemerellidae												
Drunella sp.	4	15	4				19	4	2	7		5
Ephemerella sp.		7	3	4		4			4			
Serratella sp.	4	8		31	39	110	12	24	24	4	5	
Heptageniidae							64	78	40	56		
Rhitrogena sp.		1					96	30	46	68	73	56
Cinygmula sp.	85	66	137	69	43	81	65	100	121	4	227	78
Epeorus sp.						1						
Caenidae												
Leptophlebiidae												
Paraleptophlebia sp.	4	12										
Siphlonuridae												
Parameletus sp.												
Plecoptera												
Chloroperlidae	2	24	4	1		11	16	35	20	21	26	4
Leuctridae	29	8	20				61	8	21	1	20	16
Nemouridae												
Visoka sp.		4										
Zapada sp.	17	78	12	49	1	93		14	20	62	58	21
Perlidae												
Claassenia sp.								2	1			
Hesperoperla sp.		19				12		3	5	5	14	12
Perlodidae	36	82	36	21		29	8	80	8	136	77	24
Diura sp.												
Cultus sp.	5	8	4				4	5	4		2	16
Megarcys sp.						1				1		1
Isogenoides sp.		1					2	2	2		7	2
Isoperla sp.		2							1			2
Pteronarcyidae												
Pteronarcella sp.												
Capniidae	24	32	40			10		16		44	42	
Hemiptera												
Veliidae												
Mesoveliidae												
Mesovelia sp.												
adult												
Corixidae, adult												
Lepidoptera												
Noctuidae												
Trichoptera												
Brachycentridae												
Brachycentrus sp.		5						4			32	28
Micrasema sp.												
Glossosomatidae												
Glossosoma sp.		12						9	12			
Hydropsychidae												
Hydropsyche sp.												
Cheumatopsyche sp.	2	12	1							7		2
Hydroptilidae												
Hydroptila sp.												
Rhyacophilidae												
Rhyacophila sp.	2	44	7	19	9						1	13

Organism counts at Test Sites ME4, MET2, PR2 and PR3 continued

Taxon cont.	ME4-1	ME4-2	ME4-3	MET2-1	MET2-2	MET2-3	PR2-1	PR2-2	PR2-3	PR3-1	PR3-2	PR3-3
Coleoptera												
Elmidae	2	5					9	35	62			
Narpus sp.	20	68	65								21	25
adult	1		4			21	4					4
Hydrophilidae												
adult												
Chrysomelidae												
Hydrophilidae												
Diptera												
Ceratopogonidae												
Ceratopogoninae	1											
Chironomidae												
Orthocladiinae	21	85	65		11	10	126	153	166	230	365	148
Tanypodinae		5	8									
Tanytarsini	8	8	7	11			4		4	20	8	
Chironomini	12	28	9				8	54	21	77	132	48
Diamesinae												
Pupae		8					12		4	17		
adult			3									
Empididae		4						8	8	4		
Simuliidae		4								30	5	
Pupae	10						16	6		10	2	15
adult												
Tipulidae												
Tipulinae												
Tipula sp.										1		
Limoniinae												
Dicranota sp.	5	20	5					9	10	2	12	8
Antocha sp.	12	22	13						12			
Hexatoma sp.				1			4	10			1	1
Pupae												
Psychodidae												
Pericoma /Telmatoscopus		4										
Athericidae												
Atherix sp.												3
Nematoda												
Oligochaeta												
Naididae							5	8	8	16		
Specaria sp.		12									32	4
Lumbriculidae												
Lumbriculus sp.												
Pelecypoda												
Sphaeriidae												
Sphaerium							1					
Pisidium sp.												
Arachnida												
Acari												
Hydrachnidia	8	48	6	22	13	5	12	24	20		8	40
Stygothrombididae												
Hydrothrombium sp.												
Araneae												
Pisauridae												
Dolomedes triton												
Crustacea												
Ostracoda												
Cyprididae	4		6	19	9	7						
Ilyocyprididae												

Organism counts at Test Sites ME4, MET2, PR2 and PR3 continued

Taxon cont.	ME4-1	ME4-2	ME4-3	MET2-1	MET2-2	MET2-3	PR2-1	PR2-2	PR2-3	PR3-1	PR3-2	PR3-3
Crustacea cont.												
Copepoda												
Cyclopoida												
Malacostraca												
Amphipoda												
Gammarus lacustrus												
Branchiopoda												
Cladocera												
Daphnidae												
Daphnia sp.												
Conchostraca												
Lynceidae												
Cnidaria												
Hydrozoa												
Hydra												
Hydra oligactis												

Organism counts at Test Sites PR4, MC5 and MC6

Taxon	PR4-1	PR4-2	PR4-3	MC5-1	MC5-2	MC5-3	MC6-1	MC6-2	MC6-3
Ephemeroptera									
Baetidae									
Baetis sp.	20	84	79	32	88	80	132	114	161
nymph									
Ephemerellidae									
Drunella sp.		2	2	10	32	16	9	4	2
Ephemerella sp.	4		2						2
Serratella sp.	20	5	4	4		4	21	56	
Heptageniidae									
Rhitrogena sp.	34	77	164	122	233		39	80	38
Cinygmula sp.	102	224	368	147	76	248	312	240	514
Epeorus sp.				1					
Caenidae									
Leptophlebiidae									
Paraleptophlebia sp.							4	4	8
Siphlonuridae									4
Parameletus sp.									
Plecoptera									
Chloroperlidae	33	61	78	37	57	70	46	18	36
Leuctridae	21	41	33	12	9	8	32	8	4
Nemouridae									
Visoka sp.									
Zapada sp.						17	8	12	
Perlidae									
Claassenia sp.							2	2	1
Hesperoperla sp.							2	13	
Perlodidae	39	36	32	8	24	14	20	16	1
Diura sp.									
Cultus sp.		4					4		4
Megarcys sp.									
Isogenoides sp.	1	3	1					1	
Isoperla sp.									
Pteronarcyidae									
Pteronarcella sp.					1				
Capniidae	24		4	16	32	32	44	13	20
Hemiptera									
Veliidae									
Mesoveliidae									
Mesovelia sp.				1	3		8		
adult									
Corixidae, adult									
Lepidoptera									
Noctuidae									
Trichoptera									
Brachycentridae									
Brachycentrus sp.	5		4		1	1	5	8	
Micrasema sp.							1		
Glossosomatidae									
Glossosoma sp.	6								
Hydropsychidae									
Hydropsyche sp.		1							
Cheumatopsyche sp.									
Hydroptilidae									
Hydroptila sp.									
Rhyacophilidae									
Rhyacophila sp.								8	

Organism counts at Test Sites PR4, MC5 and MC6 continued

Taxon cont.	PR4-1	PR4-2	PR4-3	MC5-1	MC5-2	MC5-3	MC6-1	MC6-2	MC6-3
Coleoptera									
Elmidae	4		5	12	9	4		4	
Narpus sp.									
adult									
Hydrophilidae									
adult									
Chrysomelidae									
Hydrophilidae									
Diptera									
Ceratopogonidae									
Ceratopogoninae									
Chironomidae	30	16	21	13	6		8		12
Orthocladiinae									
Tanypodinae									
Tanytarsini	8	8	12						
Chironomini									
Diamesinae	4								
Pupae									
adult	3	9				4	4		
Empididae									
Simuliidae									
Pupae									
adult									
Tipulidae									
Tipulinae									
Tipula sp.									
Limoniinae									
Dicranota sp.									
Antocha sp.	4	5	17	5	1	10			
Hexatoma sp.									
Pupae									
Psychodidae									
Pericoma/Telmatoscopus									
Athericidae									
Atherix sp.									
Nematoda									
Oligochaeta									
Naididae									
Specaria sp.									
Lumbriculidae									
Lumbriculus sp.									
Pelecypoda									
Sphaeriidae									
Sphaerium									
Pisidium sp.									
Arachnida									
Acari	20	12	16		12	15	24	12	12
Hydrachnidia									
Stygothrombididae			5	4	5		16	8	
Hydrothrombium sp.									
Araneae									
Pisauridae									
Dolomedes triton									
Crustacea									
Ostracoda							4		
Cyprididae									
Ilyocyprididae									

Organism counts at Test Sites PR4, MC5 and MC6 continued

Taxon cont.	PR4-1	PR4-2	PR4-3	MC5-1	MC5-2	MC5-3	MC6-1	MC6-2	MC6-3
Crustacea cont.									
Copepoda									
Cyclopoida									
Malacostraca									
Amphipoda									
Gammarus lacustrus									
Branchiopoda									
Cladocera									
Daphnidae									
Daphnia sp.									
Conchostraca									
Lynceidae									
Cnidaria									
Hydrozoa									
Hydra									
Hydra oligactis									

Organism counts at reference sites BD1.2012, BD2.2012, FE1.2012 and FET1.2012

Taxon	BD1-1	BD1-2	BD1-3	BD2-1	BD2-2	BD2-3	FE1- 1	FE1- 2	FE1- 3	FET1-1	FET1-2	FET1-3
Ephemeroptera												
Baetidae												
Baetis sp.	636	120	265	416	437	1059	338	356	305	304	296	172
nymph											1	
Ephemerellidae												
Drunella sp.	7	5	5	4		3	6	10	12			
Ephemerella sp.	3	1	1	4	1	1	5	1				
Serratella sp.		4	12	17	48	39	4					
Heptageniidae												
Rhitrogena sp.	20	3	18	16	21	21	17	15	18	5	4	
Cinygmula sp.	341	461	385	337	240	403	128	91	96	53	72	48
Epeorus sp.								6	3	45	57	18
Caenidae												
Leptophlebiidae												
Paraleptophlebia sp.		4			4		4	4				
Siphlonuridae						12				3	1	
Parameletus sp.										4	3	4
Plecoptera												
Chloroperlidae	35	35	42	28	24	37	12	4	13	4	20	8
Leuctridae				8		8	8	8	4		16	4
Nemouridae												
Visoka sp.							1			6		
Zapada sp.					12	12	46	38	32	248	196	126
Perlidae												
Claassenia sp.	12			1								
Hesperoperla sp.	9	1	1		1		1					
Perlodidae	20	4	4	16	40	64	84	64	24		11	4
Diura sp.												
Cultus sp.	8			4	4							
Megarcys sp.	1									7	9	21
Isogenoides sp.	1			1	4				1			1
Isoperla sp.		2	3		1		4	1				
Pteronarcyidae												
Pteronarcella sp.												
Capniidae	8	4	4	29	20	12	108	68	32	13	12	12
Hemiptera												
Veliidae												
Mesoveliidae												
Mesovelia sp.												
adult										5	5	
Corixidae, adult												
Lepidoptera												
Noctuidae											1	
Trichoptera												
Brachycentridae												
Brachycentrus sp.	2			1		5						1
Micrasema sp.	8	13	17	26	4	45				5	8	4
Glossosomatidae												
Glossosoma sp.										1		
Hydropsychidae												
Hydropsyche sp.												
Cheumatopsyche sp.		1										
Hydroptilidae												
Hydroptila sp.												
Rhyacophilidae												
Rhyacophila sp.	4				1		5	1		17	19	5

Organism counts at reference sites BD1.2012, BD2.2012, FE1.2012 and FET1.2012 continued

Taxon cont.	BD1-1	BD1-2	BD1-3	BD2-1	BD2-2	BD2-3	FE1- 1	FE1- 2	FE1- 3	FET1-1	FET1-2	FET1-3
Coleoptera												
Elmidae	16	14	4	8		4	24	16	12			
Narpus sp.	41	29	28	61	27	47	41	20	9			
adult	2	4		4	8							
Hydrophilidae												
adult			12									
Chrysomelidae											8	1
Hydrophilidae												1
Diptera												
Ceratopogonidae												
Ceratopogoninae			1	1	6	1	12		3			
Chironomidae												
Orthocladiinae		28	16	16	16	8	45	48	41	24	97	81
Tanypodinae				4							4	
Tanytarsini		12	4			5	8	8	24		8	8
Chironomini							7	4		5	22	33
Diamesinae												
Pupae											10	
adult												
Empididae				4		2	4				4	
Simuliidae						4				8	57	26
Pupae											1	2
adult												
Tipulidae												
Tipulinae												
Tipula sp.											5	
Limoniinae												
Dicranota sp.									4			
Antocha sp.												
Hexatoma sp.						3						
Pupae												
Psychodidae												
Pericoma/Telmatoscopus	4			4	8	1		5	8			
Athericidae												
Atherix sp.												
Nematoda												
Oligochaeta												
Naididae												
Specaria sp.								8				
Lumbriculidae												
Lumbriculus sp.												
Pelecypoda												
Sphaeriidae												
Sphaerium					1							
Pisidium sp.												
Arachnida												
Acari												
Hydrachnidia	28	36	32	44	64	36	20	28	24		16	8
Stygothrombididae												
Hydrothrombium sp.		8				4			4			
Araneae												
Pisauridae												
Dolomedes triton											1	
Crustacea												
Ostracoda												
Cyprididae		8								20	16	16
Ilyocyprididae												

Organism counts at reference sites BD1.2012, BD2.2012, FE1.2012 and FET1.2012 continued

Taxon cont.	BD1-1	BD1-2	BD1-3	BD2-1	BD2-2	BD2-3	FE1- 1	FE1- 2	FE1- 3	FET1-1	FET1-2	FET1-3
Crustacea cont.												
Copepoda												
Cyclopoida									3			
Malacostraca												
Amphipoda												
Gammarus lacustrus												
Branchiopoda												
Cladocera												
Daphnidae												
Daphnia sp.												
Conchostraca												
Lynceidae												
Cnidaria												
Hydrozoa												
Hydra												
Hydra oligactis												

Organism counts at reference sites ER3.2012, LD2.5.2012, LD3.5.2012 and LD4.2012

Taxon	ER3-1	ER3-2	ER3-3	LD2.5-1	LD2.5-2	LD2.5-3	LD3.5-1	LD3.5-2	LD3.5-3	LD4-1	LD4-2	LD4-3
Ephemeroptera												
Baetidae												
Baetis sp.	2191	2664	2020	131	385	170	462	402	533	90	112	41
nymph												
Ephemerellidae												
Drunella sp.	4	3	2					10	10			
Ephemerella sp.		2	2									
Serratella sp.	8	20	11				20	11	41	9	30	
Heptageniidae												
Rhitrogena sp.	8			39	1	50						
Cinygmula sp.	275	191	240	342	256	121	160		170	71	32	29
Epeorus sp.	2	1				1	27	12				
Caenidae	1											
Leptophlebiidae												
Paraleptophlebia sp.												
Siphlonuridae		2						10	10	20	2	
Parameletus sp.		8									21	32
Plecoptera												
Chloroperlidae	21	85	31			31		41	40	11		
Leuctridae		30			4	39	30	21	20			
Nemouridae												
Visoka sp.		9										
Zapada sp.	130	101	71				101	10	62	10	19	11
Perlidae												
Claassenia sp.												
Hesperoperla sp.	18	14	11	9	8	3						
Perlodidae	417	217	380	58	24	80	120	51	11	1		
Diura sp.												
Cultus sp.	4		21									
Megarcys sp.		1	1				12	3	12		1	2
Isogenoides sp.	2	1	4				1					
Isoperla sp.			1								2	
Pteronarcyidae												
Pteronarcella sp.												
Capniidae	216	131	80	41	33	140	90	20	180	50	31	30
Hemiptera												
Veliidae												
Mesoveliidae												
Mesovelia sp.												
adult												
Corixidae, adult				1								
Lepidoptera												
Noctuidae												
Trichoptera												
Brachycentridae												
Brachycentrus sp.	4	10										
Micrasema sp.	3	20										
Glossosomatidae												
Glossosoma sp.							2	1	1			
Hydropsychidae												
Hydropsyche sp.												
Cheumatopsyche sp.	1	11	6									
Hydroptilidae												
Hydroptila sp.												
Rhyacophilidae												
Rhyacophila sp.	8	23	10	1			22		1	12		

Organism counts at reference sites ER3.2012, LD2.5.2012, LD3.5.2012 and LD4.2012 continued

Taxon cont.	ER3-1	ER3-2	ER3-3	LD2.5-1	LD2.5-2	LD2.5-3	LD3.5-1	LD3.5-2	LD3.5-3	LD4-1	LD4-2	LD4-3
Coleoptera												
Elmidae	1	11	1						9	10		10
Narpus sp.	80	22	51	11	10	1	43	110	52	12	31	54
adult	9		11				12		9			
Hydrophilidae												
adult												
Chrysomelidae												
Hydrophilidae												
Diptera												
Ceratopogonidae												
Ceratopogoninae		2										
Chironomidae												
Orthocladiinae	19		19	32		20	11	40	20	120	111	101
Tanypodinae												
Tanytarsini												
Chironomini	4						10					
Diamesinae										84	67	34
Pupae											8	
adult												
Empididae	1	3					1	1		13		
Simuliidae	118	123	10			10	10					
Pupae		1							8			
adult												
Tipulidae												
Tipulinae												
Tipula sp.			1			1						
Limoniinae												
Dicranota sp.	4	10				11	12					
Antocha sp.	8	51										
Hexatoma sp.	4	1										
Pupae												
Psychodidae												
Pericoma/ Telmatoscopus	5			9				10				
Athericidae												
Atherix sp.												
Nematoda			10									
Oligochaeta												
Naididae												
Specaria sp.												10
Lumbriculidae												
Lumbriculus sp.												
Pelecypoda												
Sphaeriidae												
Sphaerium												
Pisidium sp.												
Arachnida												
Acari												
Hydrachnidia	32	41	21		4	20	10	11	20	141	110	21
Stygothrombididae												
Hydrothrombium sp.												
Araneae												
Pisauridae												
Dolomedes triton												
Crustacea												
Ostracoda												
Cyprididae										10		
Ilyocyprididae												

Organism counts at reference sites ER3.2012, LD2.5.2012, LD3.5.2012 and LD4.2012 continued

Taxon cont.	ER3-1	ER3-2	ER3-3	LD2.5-1	LD2.5-2	LD2.5-3	LD3.5-1	LD3.5-2	LD3.5-3	LD4-1	LD4-2	LD4-3
Crustacea cont.												
Copepoda												
Cyclopoida												
Malacostraca												
Amphipoda												
Gammarus lacustrus												
Branchiopoda												
Cladocera												
Daphnidae												
Daphnia sp.												
Conchostraca												
Lynceidae												
Cnidaria												
Hydrozoa												
Hydra												
Hydra oligactis												

Organism counts at reference site PET1.2012

Taxon	PET1-1	PET1-2	PET1-3
Ephemeroptera			
Baetidae			
Baetis sp.	25	80	128
nymph			
Ephemerellidae			
Drunella sp.			
Ephemerella sp.			
Serratella sp.			
Heptageniidae			
Rhitrogena sp.			
Cinygmula sp.	160	171	153
Epeorus sp.			
Caenidae			
Leptophlebiidae			
Paraleptophlebia sp.	24	21	36
Siphlonuridae		9	
Parameletus sp.			
Plecoptera			
Chloroperlidae	12	11	1
Leuctridae	28	69	24
Nemouridae			
Visoka sp.			
Zapada sp.			9
Perlidae			
Claassenia sp.			
Hesperoperla sp.			
Perlodidae			4
Diura sp.			
Cultus sp.			
Megarcys sp.	4	10	
Isogenoides sp.			
Isoperla sp.	6		1
Pteronarcyidae			
Pteronarcella sp.			
Capniidae	60	99	68
Hemiptera			
Veliidae			
Mesoveliidae			
Mesovelia sp.			
adult			
Corixidae, adult			
Lepidoptera			
Noctuidae			
Trichoptera			
Brachycentridae			
Brachycentrus sp.			
Micrasema sp.			
Glossosomatidae			
Glossosoma sp.			
Hydropsychidae			
Hydropsyche sp.			
Cheumatopsyche sp.			
Hydroptilidae			
Hydroptila sp.			
Rhyacophilidae			
Rhyacophila sp.			

Organism counts at reference site PET1.2012 continued

Taxon cont.	PET1-1	PET1-2	PET1-3
Coleoptera			
Elmidae			
Narpus sp.	4	21	8
adult			
Hydrophilidae			
adult			
Chrysomelidae			
Hydrophilidae			
Diptera			
Ceratopogonidae			
Ceratopogoninae			
Chironomidae			
Orthocladiinae		10	48
Tanypodinae	13		
Tanytarsini	4	31	8
Chironomini			
Diamesinae			
Pupae			
adult			
Empididae			
Simuliidae		10	
Pupae			
adult			
Tipulidae			
Tipulinae			
Tipula sp.			
Limoniinae			
Dicranota sp.	7		12
Antocha sp.			
Hexatoma sp.			
Pupae			
Psychodidae			
Pericoma/Telmatoscopus			
Athericidae			
Atherix sp.			
Nematoda	8		
Oligochaeta			
Naididae			
Specaria sp.	120	91	4
Lumbriculidae			
Lumbriculus sp.			
Pelecypoda			
Sphaeriidae			
Sphaerium			
Pisidium sp.			
Arachnida			
Acari			
Hydrachnidia	28	30	69
Stygothrombididae			
Hydrothrombium sp.			
Araneae			
Pisauridae			
Dolomedes triton			
Crustacea			
Ostracoda			
Cyprididae	16	19	
Ilyocyprididae			

Taxon cont.	PET1-1	PET1-2	PET1-3
Crustacea cont.			
Copepoda			
Cyclopoida	12	10	8
Malacostraca			
Amphipoda			
Gammarus lacustrus			
Branchiopoda			
Cladocera			
Daphnidae			
Daphnia sp.	20	60	32
Conchostraca			
Lynceidae			
Cnidaria			
Hydrozoa			
Hydra			
Hydra oligactis			

Appendix C

Site Summary Tables of Benthic Invertebrate Data

Test Sites-Count data summaries

Taxon	CC9			CC10			CC11			LR1		
	mean	% total	SE	mean	% total	SE	mean	% total	SE	mean	% total	SE
Ephemeroptera	1242.67	58.32	248.98	1228.00	86.93	108.08	1364.33	65.05	621.66	504.33	49.87	56.63
Plecoptera	528.00	24.78	108.19	87.00	6.16	28.36	338.00	16.12	142.00	345.67	34.18	88.79
Trichoptera	43.00	2.02	14.42	25.33	1.79	10.35	71.33	3.40	32.38	12.00	1.19	2.08
Coleoptera	120.33	5.65	23.13	21.33	1.51	2.60	105.33	5.02	28.15	97.33	9.62	32.32
Chironomidae	144.33	6.77	90.87	24.33	1.72	11.84	95.00	4.53	41.74	9.67	0.96	4.70
Other Diptera	35.00	1.64	13.00	3.67	0.26	0.88	39.33	1.88	3.18	14.00	1.38	7.09
Oligochaeata	1.33	0.06	1.33	3.00	0.21	1.53	5.33	0.25	1.33	0.00	0.00	0.00
Acari	16.00	0.75	10.58	14.67	1.04	4.81	78.67	3.75	30.67	21.33	2.11	11.85
Crustacea	0.00	0.00	0.00	4.00	0.28	2.31	0.00	0.00	0.00	7.00	0.69	1.53
Other	0.00	0.00	0.00	1.33	0.09	1.33	0.00	0.00	0.00	0.00	0.00	0.00
Total Individuals	2130.67	100.00	452.25	1412.67	100.00	134.43	2097.33	100.00	882.06	1011.33	100.00	161.34
Number of Taxa	20.33	100.00	0.88	20.67		1.45	28.67	100.00	2.03	21.67	100.00	2.33
Shannon Index	-1.76	x	0.07	-1.01	x	0.13	-2.10	x	0.16	-2.12	x	0.02

Taxon	LR2			LR3			LR4			MET2		
	mean	% total	SE	mean	% total	SE	mean	% total	SE	mean	% total	SE
Ephemeroptera	608.00	44.04	267.93	372.33	36.52	46.88	570.67	55.32	65.35	410.67	76.19	148.61
Plecoptera	425.33	30.81	164.52	159.33	15.63	39.93	197.33	19.13	6.77	76.00	14.10	44.81
Trichoptera	14.00	1.01	5.51	21.33	2.09	12.72	2.67	0.26	2.67	9.33	1.73	5.49
Coleoptera	155.00	11.23	33.60	118.33	11.61	36.03	109.67	10.63	19.19	7.00	1.30	7.00
Chironomidae	40.33	2.92	18.67	261.67	25.66	159.75	95.67	9.27	10.48	10.67	1.98	0.33
Other Diptera	25.67	1.86	12.72	15.33	1.50	4.70	20.67	2.00	5.78	0.33	0.06	0.33
Oligochaeata	12.00	0.87	2.31	27.00	2.65	15.70	10.67	1.03	5.33	0.00	0.00	0.00
Acari	97.33	7.05	39.35	38.67	3.79	16.71	20.00	1.94	0.00	13.33	2.47	4.91
Crustacea	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.03	0.33	11.67	2.16	3.71
Other	3.00	0.22	2.52	5.67	0.56	5.17	4.00	0.39	2.65	0.00	0.00	0.00
Total Individuals	1380.67	100.00	461.79	1019.67	100.00	245.87	1031.67	100.00	80.47	539.00	100.00	193.41
Number of Taxa	23.67	100.00	2.96	25.00	100.00	2.65	22.33	100.00	1.86	11.33	100.00	1.76
Shannon Index	-2.24	x	0.05	-2.21	x	0.14	-2.26	x	0.10	-1.61	x	0.02

Taxon	ME2			ME4			PR2			PR3		
	mean	% total	SE	mean	% total	SE	mean	% total	SE	mean	% total	SE
Ephemeroptera	223.67	21.97	42.44	624.33	61.19	150.67	475.33	54.59	91.91	478.67	41.96	97.86
Plecoptera	23.33	2.29	3.93	162.33	15.91	47.84	112.67	12.94	26.30	204.67	17.94	53.78
Trichoptera	14.00	1.38	5.29	28.33	2.78	22.36	8.33	0.96	4.18	27.67	2.43	10.73
Coleoptera	15.00	1.47	5.51	55.00	5.39	16.04	36.67	4.21	14.17	16.67	1.46	8.65
Chironomidae	458.67	45.06	73.17	89.00	8.72	26.89	184.00	21.13	17.35	348.33	30.54	89.23
Other Diptera	138.67	13.62	82.32	33.33	3.27	10.73	27.67	3.18	3.93	31.33	2.75	8.09
Oligochaeata	44.67	4.39	22.98	4.00	0.39	4.00	7.00	0.80	1.00	17.33	1.52	8.11
Acari	92.00	9.04	26.63	20.67	2.03	13.68	18.67	2.14	3.53	16.00	1.40	12.22
Crustacea	8.00	0.79	4.62	3.33	0.33	1.76	0.00	0.00	0.00	0.00	0.00	0.00
Other	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.04	0.33	0.00	0.00	0.00
Total Individuals	1018.00	100.00	120.58	1020.33	100.00	257.05	870.67	100.00	133.43	1140.67	100.00	219.61
Number of Taxa	20.33	100.00	1.20	24.67	100.00	3.71	23.00	100.00	2.00	22.67	100.00	0.67
Shannon Index	-2.22	x	0.09	-2.03	x	0.20	-2.40	x	0.08	-2.32	x	0.11

Test Sites-Count data summaries continued

Taxon	PR4 mean	PR4 % total	PR4 SE	MC5 mean	MC5 % total	MC5 SE	MC6 mean	MC6 % total	MC6 SE
Ephemeroptera	397.00	65.55	126.75	364.33	71.16	33.63	581.33	79.82	74.04
Plecoptera	137.00	22.62	9.54	112.33	21.94	20.34	102.33	14.05	28.26
Trichoptera	5.33	0.88	2.96	0.67	0.13	0.33	7.33	1.01	4.67
Coleoptera	3.00	0.50	1.53	8.33	1.63	2.33	1.33	0.18	1.33
Chironomidae	33.00	5.45	5.20	6.33	1.24	3.76	6.67	0.92	3.53
Other Diptera	12.67	2.09	2.96	6.67	1.30	3.84	1.33	0.18	1.33
Oligochaeata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Acari	17.67	2.92	2.85	12.00	2.34	4.04	24.00	3.30	8.33
Crustacea	0.00	0.00	0.00	0.00	0.00	0.00	1.33	0.18	1.33
Other	0.00	0.00	0.00	1.33	0.26	0.88	2.67	0.37	2.67
Total Individuals	605.67	100.00	134.52	512.00	100.00	47.95	728.33	100.00	57.76
Number of Taxa	16.67	100.00	0.33	15.00	100.00	0.58	18.33	100.00	2.03
Shannon Index	-2.09	x	0.18	-1.87	x	0.05	-1.79	x	0.26

Group 1 Reference Sites-Count data summaries

Taxon	MET2.2004 mean	MET2.2004 % total	MC1.2004 mean	MC1.2004 % total	MC6.2004 mean	MC6.2004 % total	MCT1.2004 mean	MCT1.2004 % total	ME2.2004 mean	ME2.2004 % total
Chironomidae	69.3	18.9	102.6	10.7	262.0	34.9	111.0	15.8	119.4	9.9
Ephemeroptera	179.0	48.8	685.8	71.6	360.2	47.9	440.4	62.6	808.6	66.8
Plecoptera	60.0	16.3	117.4	12.3	99.2	13.2	73.6	10.5	198.2	16.4
Trichoptera	9.0	2.5	19	2.0	4.8	0.6	6.2	0.9	1.8	0.1
Coleoptera	2.3	0.6	7	0.7	3.2	0.4	40.6	5.8	26.4	2.2
Crust	31.7	8.6	4	0.4	0.6	0.1	13.4	1.9	18.2	1.5
Misc. Diptera	3.3	0.9	12.2	1.3	14.0	1.9	10.0	1.4	20.8	1.7
Other Groups	12.3	3.4	9.2	1.0	7.6	1.0	8.0	1.1	17.6	1.4
Total Individuals	367.0		957.2		751.6		703.2	100.0	1211.0	100.0
Shannon Index	-1.84		-2.27		-2.27		-2.09		-1.90	
Total Taxa	19.8		30.6		25		24.2	100.0	24.4	100.0

Taxon	CH1.2006 mean	CH1.2006 % total	CH2.2006 mean	CH2.2006 % total	MA1.2004 mean	MA1.2004 % total	MA2.2004 mean	MA2.2004 % total
Chironomidae	19.6	5.7	179.4	27.3	88.0	30.4	111.0	15.8
Ephemeroptera	143.4	41.4	268.8	40.9	129.4	44.7	440.4	62.6
Plecoptera	99.4	28.7	150.4	22.9	42.6	14.7	73.6	10.5
Trichoptera	18.8	5.4	5.6	0.9	0.4	0.1	6.2	0.9
Coleoptera	56.2	16.2	18.2	2.8	8.6	3.0	40.6	5.8
Crust	0.0	0.0	7.2	1.1	1.0	0.3	13.4	1.9
Misc. Diptera	5.2	1.5	10.4	1.6	5.4	1.9	10.0	1.4
Other Groups	4.0	1.2	18	2.7	14.4	5.0	8.0	1.1
Total Individuals	346.6	100.0	658.0	100.0	289.8	100.0	703.2	100.0
Shannon Index	-2.38		-2.28		-2.15		-2.09	
Total Taxa	25.2	100.0	22.4	100.0	17.6	100.0	24.2	100.0

Reference Sites-Count data summaries continued

Taxon	BA3.2006			BA2.2006			ER3.2005			HL2.2006			HL4.2006		
	Mean	% total	SE	Mean	% total	SE	Mean	% total	SE	Mean	% total	SE	Mean	% total	SE
Ephemeroptera	32.4	15.6	8.4	244.4	54.5	52.9	193.2	44.3	47.6	441.4	64.4	95.8	591.6	68.5	104.7
Plecoptera	30.2	14.5	5.6	73.0	16.3	15.2	73.8	16.9	12.1	102.6	15.0	23.9	126.8	14.7	24.5
Trichoptera	3.8	1.8	1.1	10.4	2.3	3.8	0.6	0.1	0.4	33.6	4.9	8.1	1.8	0.2	1.3
Coleoptera	128.4	61.7	15.0	97.4	21.7	22.3	27.4	6.3	8.2	78.8	11.5	17.0	97.2	11.3	24.4
Chironomidae	6.0	2.9	1.4	15.8	3.5	5.2	14.0	3.2	2.5	16.0	2.3	5.8	21.4	2.5	4.9
Misc. Diptera	4.2	2.0	0.5	5.2	1.2	2.0	18.4	4.2	4.3	8.8	1.3	2.0	22.8	2.6	6.3
Acari	1.6	0.8	0.6	0.6	0.1	0.6	0.6	0.1	0.4	3.4	0.5	1.8	1.4	0.2	0.7
Oligochaeta	0.6	0.3	0.3	1.4	0.3	0.7	102.2	23.4	76.5	0.2	0.0	0.2	0.2	0.0	0.2
Nematoda	0.6	0.3	0.2	0.0	0.0	0.0	6.2	1.4	3.9	0.0	0.0	0.0	0.0	0.0	0.0
Crustacea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.2
Other groups	0.2	0.1	0.2	0.4	0.1	0.2	0.2	0.0	0.2	1.0	0.1	1.0	0.0	0.0	0.0
Total Individuals	208.0	100.0	32.3	448.6	100.0	67.0	436.6	100.0	124.4	685.8	100.0	146.7	863.4	100.0	121.3
Total Taxa	18.0		1.4	18.6		1.2	21.6		1.1	25.6		1.7	26.0		1.9
Shannon	-1.76			-1.62			-2.05			-2.18			-2.00		

Taxon	LE2.2006			LE1.2006			LET1.2006			LET3.2006		
	Mean	% total	SE	Mean	% total	SE	Mean	% total	SE	Mean	% total	SE
Ephemeroptera	395.4	62.8	45.4	182.6	53.8	36.2	377.6	45.2	92.6	562.8	66.3	171.6
Plecoptera	77.4	12.3	12.0	80.2	23.6	17.2	144.8	17.3	35.5	197.4	23.3	50.2
Trichoptera	3.4	0.5	1.1	4.8	1.4	1.9	36.0	4.3	9.6	5.6	0.7	1.7
Coleoptera	43.2	6.9	11.8	30.2	8.9	13.8	74.6	8.9	25.5	62.8	7.4	14.9
Chironomidae	90.4	14.3	17.8	31.6	9.3	6.9	193.0	23.1	30.4	12.6	1.5	1.9
Misc. Diptera	6.0	1.0	2.0	8.6	2.5	3.1	5.4	0.6	1.6	4.8	0.6	1.9
Acari	0.8	0.1	0.5	1.4	0.4	0.7	4.6	0.6	2.5	1.2	0.1	0.6
Oligochaeta	2.8	0.4	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.2	0.8
Nematoda	0.6	0.1	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Crustacea	1.4	0.2	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other groups	8.6	1.4	6.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Individuals	630.0	100.0	40.2	339.4	100.0	65.3	836.0	100.0	170.0	848.8	100.0	226.5
Total Taxa	30.8		1.7	21.4		2.0	24.2		0.8	19.8		1.7
Shannon	-2.37			-2.25			-2.28			-1.83		

Reference Sites-Count data summaries continued

Taxon	LD3.2007			LD4.2007			LDT1.2007			LDT3.2007			PET1.2007		
	Mean	% total	SE	Mean	% total	SE	Mean	% total	SE	Mean	% total	SE	Mean	% total	SE
Ephemeroptera	590.6	0.5	89.9	145.2	0.2	32.1	160.8	0.3	30.8	273.2	0.4	47.9	595.4	0.6	241.3
Plecoptera	93.0	0.1	17.6	45.0	0.0	6.6	69.4	0.1	16.1	119.4	0.2	32.7	128.8	0.1	37.6
Trichoptera	35.2	0.0	6.9	34.8	0.0	11.2	20.4	0.0	6.7	49.0	0.1	5.1	23.8	0.0	7.4
Coleoptera	126.4	0.1	33.4	32.4	0.0	5.6	204.8	0.4	33.2	35.0	0.1	12.9	197.4	0.2	72.9
Chironomid	337.8	0.3	82.8	575.8	0.6	154.6	51.0	0.1	15.7	79.6	0.1	20.8	13.4	0.0	4.8
Misc Dipteran	16.4	0.0	2.8	24.0	0.0	3.3	28.2	0.1	10.8	5.8	0.0	2.3	15.4	0.0	5.9
Acari	89.8	0.1	21.4	43.2	0.0	16.1	7.2	0.0	5.4	9.6	0.0	3.5	33.6	0.0	3.2
Oligochaeta	1.4	0.0	1.0	2.4	0.0	1.4	0.2	0.0	0.2	0.0	0.0	0.0	0.8	0.0	0.2
Nematoda	0.4	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.4	0.0	2.4
Crustacea	0.8	0.0	0.8	61.6	0.1	24.7	1.6	0.0	1.0	53.6	0.1	15.7	2.4	0.0	1.6
Other Groups	0.2	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0	2.5	508.9	0.0	1.5
Total Individuals	1292.0	1.0	132.0	964.4	1.0	156.8	543.6	1.0	92.0	628.2	1.0	100.7	1015.6	1.0	264.0
Total Taxa	33.6	100.0	1.0	29.0		0.5	29.8		0.9	32.6		1.1	28.4		2.4
EPT%	56.2		6.3	28.2		9.1	45.7		1.8	70.2		4.8	68.7		10.0
Shannon Index	-2.33		0.04	-2.17		0.16	-2.40		0.03	-2.74		0.04	-2.06		0.13

Taxon	PR1.2007	
	mean	% total
Remaining Taxa	0.80	0.1
Ephemeroptera	352.4	45.7
Plecoptera	133	17.3
Trichoptera	9	1.2
Coleoptera	11.6	1.5
Chironomidae	110.4	14.3
Misc. Diptera	128	16.6
Acari	25.8	3.3
Total	771.00	100.0
Mean No. of Taxa	20	100.0
Shannon Index	-2.24	

Taxon	AP7.2010		
	mean	% total	SE
Ephemeroptera	67.8	16.3	24.7
Plecoptera	17.4	4.2	13.0
Trichoptera	22.4	5.4	8.9
Coleoptera	19.2	4.6	10.1
Chironomidae	198.2	47.6	31.3
Other Diptera	18.2	4.4	6.4
Acari	65.6	15.7	33.8
Crustacea	4.8	1.2	3.9
Oligochaeata	1.6	0.4	1.0
Nematoda	0.0	0.0	0.0
Other	1.4	0.3	0.7
Total Individuals	416.6	100.0	73.3
Number of Taxa	17.2	100.0	1.3
Shannon Index	-2.2	x	0.1

Reference Sites-Count data summaries continued

Taxon	WH1.2010			WH3.2010			BR1.2010			BR2.2010		
	mean	% total	SE	mean	% total	SE	mean	% total	SE	mean	% total	SE
Ephemeroptera	66.4	11.1	10.2	374.8	36.0	95.1	803.8	63.0	115.8	515.2	53.1	51.0
Plecoptera	31.6	5.3	7.2	25.2	2.4	10.2	272.8	21.4	42.8	242.6	25.0	43.7
Trichoptera	45.4	7.6	8.7	15.2	1.5	6.6	17.8	1.4	7.2	8.6	0.9	1.7
Coleoptera	10.8	1.8	4.0	9.2	0.9	2.4	35.0	2.7	8.9	124.4	12.8	43.9
Chironomidae	328.8	55.1	56.2	523.6	50.3	125.5	72.6	5.7	9.8	42.4	4.4	13.1
Misc. Diptera	35.2	5.9	7.0	32.2	3.1	5.0	21.4	1.7	6.2	24.2	2.5	8.7
Oligochaeta	4.2	0.7	2.2	1.2	0.1	1.0	2.6	0.2	1.5	6.4	0.7	4.7
Acari	74.4	12.5	8.9	54.4	5.2	11.9	31.2	2.4	13.5	4.8	0.5	1.5
Crustacea	0.0	0.0	0.0	2.4	0.2	1.6	7.2	0.6	2.0	0.0	0.0	0.0
Other Groups	0.0	0.0	0.0	2.0	0.2	1.2	11.2	0.9	5.7	1.6	0.2	1.0
Total Individuals	596.8	100.0	62.8	1040.2	100.0	124.0	1275.6	100.0	139.0	970.2	100.0	113.7
Number of Taxa	23.4	n/a	1.0	23.4	n/a	1.1	28.0	n/a	3.4	22.8	n/a	1.5
EPT%	24.7	n/a	2.5	40.6	n/a	7.8	85.6	n/a	1.6	79.2	n/a	3.0
Shannon Index	-2.3	n/a	0.1	-2.3	n/a	0.1	-1.9	n/a	0.1	-2.3	n/a	0.1

Taxon	BD1.2012			BD2.2012			FE1.2012			FET1.2012			ER3.2012		
	mean	% total	SE	mean	% total	SE	mean	% total	SE	mean	% total	SE	mean	% total	SE
Ephemeroptera	763.67	79.85	124.29	1027.67	79.42	255.47	473.00	58.93	20.26	363.33	46.17	60.94	2551.67	73.45	180.56
Plecoptera	64.67	6.76	14.85	108.67	8.40	13.35	184.33	22.97	45.62	239.33	30.41	31.92	665.67	19.16	71.24
Trichoptera	15.00	1.57	1.00	27.33	2.11	12.99	2.00	0.25	1.53	20.00	2.54	5.13	32.00	0.92	16.00
Coleoptera	54.00	5.65	3.61	53.00	4.10	11.02	40.67	5.07	12.91	3.33	0.42	2.40	62.00	1.78	16.46
Chironomidae	20.00	2.09	11.55	16.33	1.26	2.03	61.67	7.68	1.67	97.33	12.37	34.60	14.00	0.40	7.09
Other Diptera	1.67	0.17	1.20	11.33	0.88	1.45	12.00	1.50	3.51	34.33	4.36	17.32	114.00	3.28	53.56
Oligochaeata	0.00	0.00	0.00	0.00	0.00	0.00	2.67	0.33	2.67	0.00	0.00	0.00	0.00	0.00	0.00
Acari	34.67	3.62	4.81	49.33	3.81	7.42	25.33	3.16	2.67	8.00	1.02	4.62	31.33	0.90	5.78
Crustacea	2.67	0.28	2.67	0.00	0.00	0.00	1.00	0.12	1.00	17.33	2.20	1.33	0.00	0.00	0.00
Other	0.00	0.00	0.00	0.33	0.03	0.33	0.00	0.00	0.00	4.00	0.51	2.08	3.33	0.10	3.33
Total Individuals	956.33	100.00	126.41	1294.00	100.00	271.59	802.67	100.00	75.06	787.00	100.00	108.66	3474.00	100.00	237.45
Number of Taxa	18.00	100.00	0.58	22.00	100.00	1.00	20	100.00	1.15	21.67	100.00	2.33	25	100.00	2
Shannon Index	-1.58	x	0.05	-1.72	x	0.11	-2.11	x	0.05	-2.12	x	0.18	-2.12	x	0.02

Reference Sites-Count data summaries continued

Taxon	LD2.5.2012			PET1.2012			LD3.5.2012			LD4.2012		
	mean	% total	SE	mean	% total	SE	mean	% total	SE	mean	% total	SE
Ephemeroptera	498.67	71.34	86.86	269.00	42.12	31.75	626.00	60.02	94.56	163.00	30.26	30.57
Plecoptera	156.67	22.41	69.09	135.33	21.19	26.85	275.00	26.37	65.04	56.00	10.40	8.50
Trichoptera	0.33	0.05	0.33	0.00	0.00	0.00	9.00	0.86	7.51	4.00	0.74	4.00
Coleoptera	7.33	1.05	3.18	11.00	1.72	5.13	78.33	7.51	16.41	39.00	7.24	12.77
Chironomidae	17.33	2.48	9.33	38.00	5.95	11.36	27.00	2.59	6.51	175.00	32.49	20.66
Other Diptera	10.33	1.48	6.39	9.67	1.51	1.45	14.00	1.34	4.58	4.33	0.80	4.33
Oligochaeata	0.00	0.00	0.00	71.67	11.22	34.85	0.00	0.00	0.00	3.33	0.62	3.33
Acari	8.00	1.14	6.11	42.33	6.63	13.35	13.67	1.31	3.18	90.67	16.83	35.96
Crustacea	0.00	0.00	0.00	59.00	9.24	15.18	0.00	0.00	0.00	3.33	0.62	3.33
Other	0.33	0.05	0.33	2.67	0.42	2.67	0.00	0.00	0.00	0.00	0.00	0.00
Total Individuals	699.00	100.00	14.73	638.67	100.00	59.43	1043.00	100.00	140.34	538.67	100.00	85.60
Number of Taxa	10.67	100.00	1.76	17	100.00	0.58	16.6667	100.00	0.67	12.3333	100.00	0.88
Shannon Index	-2.24	x	0.05	-2.30	x	0.06	-1.90	x	0.08	-2.19	x	0.04

Appendix D

Statistical Analysis: Results of Multi-dimensional Scaling

Proximities

Case Processing Summary(a)

Cases							
Valid		Rejected				Total	
		Missing Value		Negative Value			
N	Percent	N	Percent	N	Percent	N	Percent
47	100.0%	0	.0%	0	.0%	47	100.0%

a Phi-square between Sets of Frequencies used

Proxscal

Credit

Proxscal
Version 1.0
by
Data Theory Scaling System Group (DTSS)
Faculty of Social and Behavioral Sciences
Leiden University, The Netherlands

Case Processing Summary

Cases		47
Sources		1
Objects		47
Proximities	Total Proximities	1081(b)
	Missing Proximities	0
	Active Proximities(a)	1081

a Active proximities include all non-missing proximities.
b Sum of all strictly lower-triangular proximities.

Goodness of Fit

Stress and Fit Measures

Normalized Raw Stress	.01657
Stress-I	.12873(a)
Stress-II	.33185(a)
S-Stress	.03925(b)
Dispersion Accounted For (D.A.F.)	.98343
Tucker's Coefficient of Congruence	.99168

PROXSCAL minimizes Normalized Raw Stress.
a Optimal scaling factor = 1.017.
b Optimal scaling factor = .991.

Common Space-Final Coordinates

Group 1 Reference Sites / **Group 1Test Sites**

Site	Dim 1	Dim 2	Dim 3	Site	Dim 1	Dim 2	Dim 3
BR1.2010	0.594	0.64	-0.048	CC9.2012	-0.649	-0.394	0.026
BR2.2010	0.157	0.012	-0.203	CC10.201	-1.103	-0.133	-0.125
PR1.2007	0.119	0.34	0.511	CC11.201	-0.309	-0.038	-0.03
EM1.2005	-0.94	0.041	-0.062	LR1.2012	-0.019	-0.032	-0.564
EM2.2005	-0.791	0.097	-0.061	LR2.2012	0.168	-0.067	-0.434
ER3.2005	-0.433	0.749	0.273	LR3.2012	-0.016	-0.309	0.334
BA3.2006	0.381	-1.057	-0.556	LR4.2012	0.376	0.013	-0.085
BA2.2006	0.678	-0.131	-0.469	ME2.2012	0.132	-0.512	1.342
HL2.2006	0.364	-0.054	-0.278	ME4.2012	-0.471	-0.138	0.087
HL4.2006	0.02	0.176	-0.356	PR2.2012	-0.071	-0.057	0.381
LE2.2006	0.074	0.024	0.108	PR3.2012	-0.167	-0.014	0.573
LE1.2006	0.32	0.017	0.055	PR4.2012	0.504	0.564	-0.178
LET1.2006	0.734	-0.457	0.339	MC5.2012	0.427	0.464	-0.24
LET3.2006	0.066	0.305	-0.384	MC6.2012	0.26	0.594	-0.237
LD4.2007	-0.233	-0.313	-0.222	MET2.201	-0.705	-0.059	0.14
LDT1.2007	0.608	-0.554	-0.33				
LDT3.2007	0.682	0.108	0.058				
PET1.2007	-0.356	-0.274	-0.412				
ME2.2004	0.344	-0.726	0.183				
MC1.2004	0.239	0.291	0.186				
MC2.2004	0.516	0.068	0.611				
MCT1.2004	0.189	-0.211	0.394				
CH1.2006	0.348	-0.36	-0.21				
CH2.2006	0.04	-0.509	-0.028				
BD1.2012	-0.136	0.403	-0.31				
BD2.2012	-0.35	0.215	-0.219				
FE1.2012	-0.307	0.014	0.036				
FET1.2012	-0.592	0.107	0.578				
ER3.2012	-0.706	0.01	-0.262				
LD2.5.2012	-0.13	0.509	-0.156				
PET1.2012	0.527	0.742	0.409				
LD3.5.2012	-0.383	-0.104	-0.165				

Report #9

Pisces Environmental Consulting Services Ltd.
• Unit 118, 239 Spruce Street • Red Deer County • Alberta • T4E 1B4 •
• Phone 403-347-5418 • Fax 403-347-0681 •
• www.piscesenvironmental.com •

MEMO

Date: 4 February 2014

To: Mr. Les LaFleur

From: Mr. Erik Stemo

RE: Preliminary results for fish sampling conducted in the Embarras Lakes System.

INTRODUCTION

Coal Valley Resources Inc. (CVRI) developed several end pit lakes in the headwaters of the Embarras River as part of the reclamation strategy for the Mercoal Phase 1 Project. The objective was to develop a self-sustaining Athabasca Rainbow Trout (*Oncorhynchus mykiss)* population in the lakes. The purpose of this memo is to provide a brief update regarding fish sampling that has been conducted within and adjacent to the lake system to date.

BACKGROUND

The Embarras Lakes are located in the extreme headwaters of the Embarras River southwest of Robb, Alberta. Baseline habitat assessment in the area of the lakes indicated that habitat conditions were poor and fish densities were low (Boorman 2003).

CVRI completed the majority of physical works to reclaim the lake system in 2010 and 2011. As part of this reclamation, CVRI installed a fish exclusion barrier downstream of the lakes and Pisces Environmental Consulting Services Ltd. (Pisces) conducted intensive fish sampling upstream of the barrier to capture and remove Brook Trout that had moved into the diversion channel. During the latter stages of reclamation (in early 2011) approximately 80 to 100 Rainbow Trout were found to have colonized the Lower Embarras Lake (Dean Woods Personal Communication).

In September 2011, Alberta Environment and Sustainable Resource Development (AESRD) stocked 208 native Athabasca Rainbow Trout into the Upper Embarras Lake (Ryan Cox Personal Communication). The stocked fish ranged in size from 29 mm to 119 mm with a mean length of 80 mm (Ryan Cox Personal Communication).

At the request of CVRI, Pisces implemented an annual monitoring program that included seasonal assessment of the lakes and connecting channels starting in the summer of 2011. The first annual report that included assessment results for the period of summer 2011 to spring 2012 was completed in early 2013 (Sonnenberg and Stemo 2013). The second annual report (summer 2012 to spring 2013) is currently being prepared.

RESULTS SUMMARY

Fish sampling has been conducted at an established monitoring section (the Hinton Wood Products (HWP) Bridge Section) downstream of the fish exclusion barrier and also at several locations within the connecting channels and end pit lakes upstream of the exclusion barrier (Figure 1).

Fish Sampling Downstream of End Pit Lake System

Sampling of the Embarras River near the HWP Bridge has been completed on several occasions starting in 2002 (Table 1). The upstream limit of this sample section is located approximately 100 metres downstream of the exclusion device that was constructed on the Embarras River (Figure 1). Results indicate that Rainbow Trout density (n/100m^2) and catch per unit effort (CPUE) in the Embarras River downstream of pit lakes have increased substantially since the lake system was reclaimed.

Table 1. Summary of electrofishing results for the Embarras River HWP Bridge Section.

Date	Method	Section Length (m)	# RNTR	# BKTR	RNTR CPUE (fish/min/ 100m^2)	BKTR CPUE (fish/min/ 100m^2)	RNTR Density (n/100m^2)	BKTR Density (n/100m^2)
16-Jul-02	E-Fish Removal (4 pass) [1]	305	10	2	0.010	0.005	2.6[1]	0.3
15-Aug-02	E-Fish Removal (2 pass)	305	13	3	0.054	0.010	2.2	0.5
23-Jun-08	E-Fish Survey	305	6	1	0.044	0.007	n/a	n/a
18-Aug-11	E-fish Survey	300	21	50	0.081	0.194	n/a	n/a
04-Sep-12	E-Fish Mark/Recap	400	76	179	0.135	0.317	16.2[2]	49.3
27-Sep-13	E-Fish Mark/Recap	300	367	152	1.205	0.499	180.8[2]	41.0

[1]16-Jul-2002 removal estimate exhibited low capture probability (Boorman 2003)
[2]Mark/recapture estimate utilizing Chapman variation of the Lincoln-Peterson Method.

Fish Sampling Within the End Pit Lake System

Preliminary sampling indicates that relatively large Athabasca Rainbow Trout are occupying the end-pit lakes. Test angling completed by Pisces' personnel in the Upper Embarras Lake on August 20, 2013 resulted in the capture of 23 Rainbow Trout ranging in size from 213 mm fork length and 95 grams to 521 mm fork length and 1024 grams. Table 2 provides a summary of fish capture events in stream channels upstream of the fish exclusion device.

Table 2. Summary of results for single-pass electrofishing conducted in the Embarras Lake System.

Sample Section	Date	n	RNTR CPUE (fish/min/$100m^2$)	RNTR Density[1] (n/ $100m^2$)	Section Characteristics and General Comments
ELS-1 (Upstream of Embarras Lakes)	17-Aug-12	10	1.520	8.89	• 75 m section extending upstream from the Upper Lake to a ponded area. Average channel width of 1.5 m
	25-Aug-13	74	6.016	65.78	
ELS-2 (Upstream of Middle Embarras Lake)	16-Aug-12	60	0.340	10.00	• 400 m section between the Middle and Upper lakes. Average channel width of 1.5 m. • Extremely high fish densities encountered in 2013 necessitated a reduction in section length to 150 m.
	25-Aug-13	190	3.221	84.44	
ELS-3 (Upstream of Lower Embarras Lake)	27-Sept-12	6	0.548	4.00	• 150 m section between the Lower and Middle Lakes. Average channel width of 1.0 m.
	9-Aug-13	71	1.902	47.33	
ELS-4 (Upstream of fish exclusion barrier)	18-Aug-11	25	0.087	3.47	• 400 m section extending upstream from the fish exclusion structure to the Lower Embarras Lake. Average channel width of 2 m. • Deep-water pond habitat not sampled. • Capture probability was likely limited due to water depth and small size of average fish captured.
	5-Oct-11	1	0.008	0.16	
	4-Sept-12	13	0.070	1.63	
	27-Sept-12	13	0.058	1.63	
	9-Aug-13	41	0.071	5.13	

[1] Estimated density is based on total catch from single pass electrofishing survey.

Rainbow Trout Spawning in the Vicinity of the End Pit Lake System

Spawning surveys conducted during spring 2012 and 2013 confirmed that Rainbow Trout spawning has occurred upstream and downstream of the fish exclusion structure (Table 3). Schools of Rainbow Trout fry numbering in the hundreds ranging from 25-30 mm length were first observed on July 14th, 2013 in the constructed channel downstream of the Lower Embarras Lake. This suggests that spawning occurred in mid to late May and indicates that successful emergence likely occurred early July.

Table 3. Summary of results for Rainbow Trout spawning surveys conducted in the vicinity of the Embarras Lake System.

Survey Date	Downstream of Exclusion	Upstream of Exclusion
May 26th, 2012	• 2 possible redds[1]	• 1 possible redd upstream of middle lake[1]
June 1st, 2012	• No spawning observed • 3 large RNTR observed attempting to move upstream at the exclusion barrier	• No spawning observed
June 21st, 2012	• No spawning observed	• No spawning observed
May 22nd, 2013	• 8 RNTR pairs observed • Numerous possible redds observed[1]	• 10 RNTR pairs observed upstream of middle lake and upper lake • Possible redds observed at outlet of lower and middle lakes[1]
May 31st, 2013	• No spawning observed	• No spawning observed
June 1st, 2013	• No spawning observed	• No spawning observed

[1]Redd defined as “possible” if there was evidence of disturbed streambed gravels but the distinct pit and tail spill associated with characteristics of a positive redd were absent.

DISCUSSION

Performance of Fish Exclusion Barrier

The fish exclusion barrier appears to be effectively precluding the movement of Brook Trout into the Embarras Lake System since Brook Trout are numerous downstream of the barrier but have not been recorded upstream.

Athabasca Rainbow Trout Population

Results obtained to date indicate that a robust population of Athabasca Rainbow Trout occupy the lake system with all life stages being supported upstream of the fish exclusion barrier. In addition to the newly established Rainbow Trout population upstream of the barrier, populations of Rainbow Trout and Brook Trout downstream of the barrier have increased dramatically compared to baseline conditions. Preliminary results, based on two years of spawning surveys, suggest that conditions in the vicinity of the lake system are beneficial to Rainbow Trout reproduction. It appears that spawning in the vicinity of the lakes may be occurring earlier than in natural systems and the capture of fry in mid-July suggests that emergence and growth of fry is accelerated compared to natural systems.

When compared to Rainbow Trout densities reported in the Alberta Status Report for Athabasca Rainbow Trout (AESRD and ACA 2009) the estimated densities (based on preliminary sampling) within the connecting channels of the lake system and in the natural channel downstream of the fish exclusion barrier appear to be among the highest in the region. For example, the density of Rainbow Trout in the HWP Bridge Section in 2013 ($180.8/100m^2$) compares favorably with the densities reported for Deerlick Creek ($23.9/100m^2$) and Wampus Creek ($31.1/100m^2$) (AESRD and ACA 2009). Both Deerlick and Wampus Creeks report some of the highest densities of Athabasca Rainbow Trout in the region and are considered low risk systems (ASRD and ACA 2009). The status report classified stream fish populations across the region as low risk (>5 fish/$100m^2$), medium risk (2-5 fish/$100m^2$), or high risk (<2 fish/$100m^2$) based on fish density. Prior to mining, densities of Rainbow Trout in the HWP Bridge Section ranged from 2.2 to $2.6/100m^2$ while fish were uncommon or possibly absent within the proposed mine area (Boorman 2003). Based on this information it appears that the Athabasca Rainbow Trout population in the vicinity of the Embarras Lakes System has shifted from a medium to high risk population to a low risk population.

While additional monitoring will be required to assess the development of this fish community over the longer term and the initial monitoring results should be considered preliminary, it appears that habitat conditions for Athabasca Rainbow Trout in the upper Embarras River have improved post-reclamation.

CLOSURE

I trust that the foregoing meets your requirements at this time. Please do not hesitate to contact me if you have any questions.

<original signed by>

Erik Stemo, P.Biol.
Senior Fisheries Biologist
Pisces Environmental Consulting Services Ltd.

REFERENCES

Boorman, J. 2003. Baseline Fisheries Resource Assessment of Waterbodies on and Adjacent to the Proposed Mercoal East Mine Extension. Report by Pisces Environmental Consulting Services Ltd. for Luscar Ltd. Coal Valley Mine Edson, AB. 35pp+App

Sonnenberg, R. 2011. Development of Aquatic Communities in High-Altitude Mine Pit Lake Systems of West-Central Alberta. Master of Science Thesis Submitted to the University of Lethbridge. 175pp+App

Alberta Sustainable Resource Development and Alberta Conservation Association. 2009. Status of the Athabasca Rainbow Trout (Oncorhynchus mykiss) in Alberta. Alberta Sustainable Resource Development Wildlife Status Report No. 66. Edmonton, AB. 32 pp.

PERSONAL COMMUNICATIONS

Cox, Ryan. December 2012. Fisheries Biologist Alberta Environment and Sustainable Resource Development Foothills Area, Edson, Alberta.

Woods, Dean. December 2012. Reclamation Specialist D&T Woods. Edson, Alberta.

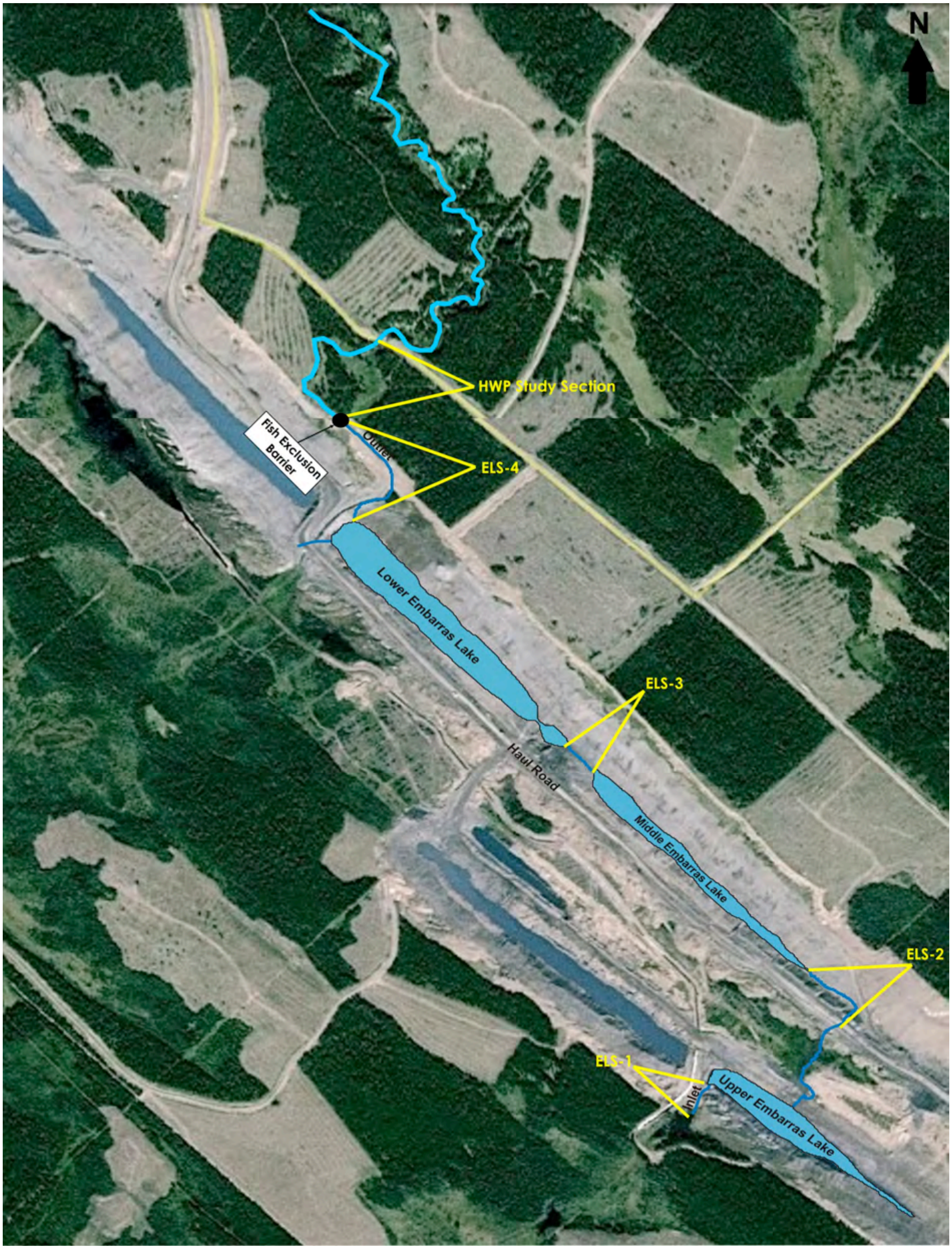


Figure 1. Embarras Lakes System

Report #10

Pisces Environmental Consulting Services Ltd.
•Unit 118, 239 Spruce Street• Red Deer County • Alberta • T4E 1B4•
• Phone 403-347-5418 • Fax 403-347-0681•
•www.piscesenvironmental.com•

March 17, 2014

Coal Valley Resources Inc.
Box 5000 Stn Main
Edson, AB
T7E 1W1

Atten: Les Lafleur

Re: Erith River fish trap reporting data from July 3rd, 2013 to October 2nd, 2013 located downstream of the Bacon and Halpenny Creek confluences in SE 30-48-19 W5M.

Coal Valley Resources Inc. (CVRI) retained Pisces Environmental Consulting Services Ltd. (Pisces) to run a fish trap on the Erith River downstream of the confluence of Bacon and Halpenny Creek located in SE 30-48-19-W5M during the summer and early fall of 2013. The trap was run to collect additional baseline fisheries information for the area.

Results

A two way upstream and downstream fish trap was installed in conjunction with a conduit fish fence on July, 3rd, 2013 when water conditions were first suitable to allow fish trapping. The fish trap operated continuously until October 2nd, 2013 aside from short periods during summer flood events which occurred from July 16-17th and from July 29-30th during which time the trap was non-operational due to high discharge and debris loads.

A total of thirteen fish species accounted for the 723 fish captured during the trapping period (Table 1). Mountain Whitefish (Prosopium williamsoni) were the most abundant fish species with the majority of movement (97 %) being in the downstream direction while the second most plentiful species was Rainbow Trout (Oncorhynchus mykiss) which were found to be moving downstream 73 % of the time; forage fish species accounted for the majority of other fish movements with Arctic Grayling (Thymallus arcticus), Bull Trout (Salvelinus confluentus), and Burbot (Lota lota) encountered within the trap only occasionally (Table 1).

Table 1. Erith River fish trapping summary for July 3rd to October 2nd, 2013 trapping period.

Species	Total Catch (n)	Moving Upstream (n)	Moving Downstream (n)	[1]Average fork Length (mm)	Average weight (g)
Arctic Grayling	3	1	2	235.0 (210-255)	144.0 (104-166)
Bull Trout	1	1	0	410.0	687.0
Burbot	2	1	1	290.5 (273-308)[1]	131.0 (108-154)
Lake Chub	68	29	39	86.0 (57-122)	8.5 (2-23)
Longnose Dace	50	24	26	93.8 (67-192)	11.4 (3-81)
Longnose Sucker	82	10	72	171.8 (105-367)	68.1 (13-650)
Mountain Whitefish	402	14	388	209.4 (73-343)	121.2 (4-461)
Pearl Dace	3	1	2	81.0 (73-85)	6.7 (6-7)
Rainbow Trout	108	30	78	176.9 (69-266)	68.3 (3-188)
Spoonhead Sculpin	1	0	1	72.0	3.0
Spottail Shiner	1	1	0	109.0	14.0
Trout-perch	1	0	1	84.0	7.0
White Sucker	1	0	1	171.0	56.0

[1]Total length measurement for Burbot.

Timing of fish movement varied over the 2013 trapping season but some concerted fish movements did occur. Between September 25th and October 2nd, 2013 a total of 66 downstream Rainbow Trout movements were observed, this represents 62 % of the Rainbow Trout movements recorded during the trapping period. Fifty-five Longnose Suckers were also captured moving downstream during this period, this represents 67% of the total movements for this species during the trapping period. This migration may represent movement towards wintering areas as it coincided with the first heavy frost and some ice formation.

Mountain Whitefish regularly moved downstream throughout the trapping season indicating this species is highly migratory within the Erith River during the open water season. Forage fish species capture events were considered incidental as many would be capable of migrating through the conduit fence. It is likely only the largest specimens of each species were captured on a regular basis. Worthy of mention was a 192 mm/81 g Longnose Dace. Nelson and Paetz (1992) suggests the maximum length of this species in Alberta to be approximately 170 mm.

In conjunction with fish trapping, opportunistic test angling was completed immediately upstream and downstream of the fish trap on July 8th, 2013 and between August 22nd and August 24th, 2013. On July 8th a large congregation of fish near the mouth of Halpenny Creek was observed while completing habitat surveys in the area. Pisces personnel expended 0.5 hours of fishing effort and captured three Bull Trout ranging from 350-390 mm fork lengths and a single Rainbow Trout measuring at a 250 mm fork length. These fish were never captured moving through the fish trap located downstream.

Approximately 12 hours of angling effort was expended between August 22 and August 24th, 2013 resulting in the capture of a total of 29 fish (Table 2). In addition to the above fish captured, two Mountain Whitefish, one Arctic grayling, one large Bull Trout, and five additional Rainbow Trout were lost at shore during netting.

Table 2. Test angling survey summary for August 22 to 24th, 2013.

Species	Total Catch	Average Length (mm)	Average weight (g)
Arctic Grayling	5	229.6 (152-266)	145.6 (44-199)
Bull Trout	1	415.0	780.0
Mountain Whitefish	5	218.8 (184-242)	132.2 (80-146)
Rainbow Trout	18	201.6 (158-249)	98.1 (54-148)

Also of note, while completing several surveys during low flow periods in early September large congregations of fish were observed to be utilizing deep water habitat areas at the confluences of Halpenny Creek and Bacon Creek. Up to five large (>350 mm) Bull Trout were observed in this run as were large numbers of Mountain Whitefish and Rainbow Trout. Arctic grayling were also observed in these habitat units and also within a short distance upstream. No further sampling occurred in this time period as a precaution to prevent disturbing Bull Trout during potential spawning migrations.

Summary

Fish trapping and test angling efforts in 2013 showed there is a significant amount of fish movement within the Erith River adjacent to the Coal Valley Mine Robb Trend lease potential disturbance area. Arctic Grayling and Bull Trout capture events confirm these species are still present within the study area at least during the open water period. Size variance among the Arctic Grayling captured indicates several age classes are present in the Erith River; no Arctic Grayling had been captured during other baseline inventories on the Erith River although they were known to be present historically.

The Erith River is a Class C waterbody with a Restricted Activity Period extending from Sept 1 to July 15 (Alberta Environment 2006) indicating that both spring and fall spawning species are found within. The large proportion of downstream movements during the summer and fall indicates there is most likely a significant upstream fish migration in the spring during the high flow period. As discharge levels can pose a hindrance to installation of a fish trap during this period other sampling methods would likely be necessary to document precise migration timing and patterns.

The fish trapping operations carried out with these investigations during 2013 did help in describing current fish communities adjacent to the Robb Trend Lease area. More discussion of the impacts to these fish species in regards to mining in the area will follow in the report pertaining to the HIS data collected in 2013.

References

Alberta Environment. 2006. Code of Practice for Watercourse Crossings (made under the Water Act and the Water (Ministerial) Regulation). Queen's Printer for Alberta.

Nelson, J.S. & M.J. Paetz. 1992. The Fishes of Alberta. 2nd Edition. Published by The University of Alberta Press. Edmonton, AB. 437 pp.

If you require any further information or have any questions please contact me at our office.

<original signed by>

Joe Sonnenberg
Fisheries Biologist
Author

<original signed by>

Ricki-Lynn Boorman, P.Biol.
Senior Fisheries Biologist

Report #11

Pisces Environmental Consulting Services Ltd.

•Unit 118, 239 Spruce Street• Red Deer County • Alberta • T4E 1B4•
• Phone 403-347-5418 • Fax 403-347-0681•
•www.piscesenvironmental.com•

MEMO

Date: 18 February 2014

To: Mr. Les LaFleur

From: Mr. Joe Sonnenberg

RE: Preliminary results for investigations conducted on existing end pit lakes in the South Block Area of the Coal Valley Mine.

INTRODUCTION

Coal Valley Resources Inc. (CVRI) has established several end pit lakes in the South Block Area of the Coal Valley Mine (CVM). Reclamation in this area is ongoing and CVRI would like to develop more specific reclamation objectives for the end pit lakes. To assist CVRI with their ongoing effort to improve the design and functionality of end pit lakes, Pisces Environmental Consulting Services Ltd (Pisces) initiated some preliminary investigations to assess the fisheries potential of a number of the end pit lakes. This document provides a summary of results for investigations completed in 2013.

STUDY AREA

Investigations in 2013 were focused on five end pit lakes (Figure 1 - attached). Summary information for the lakes is provided in Table 1.

Table 1. Summary information for CVRI lakes (Hatfield 2011, Hatfield 2014).

Lake	Year Created	Approximate Surface Area (ha)	Maximum Depth (m)	Mean Depth (m)	Inflow	Outflow
Pit 44	1998	8.76	18.5	7.4	Yes	Yes
Pit 25S	1999	6.8	12.5	4.7	Yes	Yes
Pit 25E	1996	6.8	16.2	7.4	Yes	Yes
Pit 43W	unknown	unknown	unknown	unknown	Yes	Yes
Pit 34	unknown	5.9	5.5	2.9	Yes	Yes

OBJECTIVES AND METHODS

The principal objectives of the 2013 investigations were to:

- Obtain information regarding fish use of inlet/outlet streams adjacent to the end pit lakes;
- To gain a general understanding of fish habitat potential and the feasibility of establishing fish populations within the end pit lakes;
- To contribute to an overall plan for reclamation of end pit lakes on CVM.

Fish Sampling

Fish sampling consisted of single pass electrofishing surveys on streams adjacent to the end pit lakes (Table 2).

Table 2. Summary of fish sampling in 2013.

Lake	Sample Section	UTM's (zone 11U)	Date (all 2013)	Section Size (m)	Electrofishing Duration (s)	Comments
Pit 44	Pit 44 Outlet	523398E 5872396N	Jul 15	250 x 0.5	871	• Fish exclusion barrier located approximately 250 meters downstream of pit.
Pit 25S	Pit 25S Outlet (upper 25E Creek)	520806E 5872969N	Jul 17	150 x 1	408	• Habitat not suitable for sampling further downstream due to extensive overhanging bank and vegetation.
Pit 25E	Pit 25E Outlet (middle 25E Creek)	522691E 5821560N	Jul 17	200 x 1.5	1399	• All available habitat was sampled, excessive cover/ depth precluded sampling further downstream. • Numerous fish observed in lake.
	Lower 25 E Creek	523272E 5871040N	Jun 7th	50 x 2	242	• Sampled immediately downstream of Hwy 47. • Fish observed trying to pass Hwy culvert, which appears to be a barrier at high flows.
Pit 43W	Pit 43W Outlet	521219E 5875396N	Jul 18	200 x 1.5	1392	• Sampled from confluence of Lovett River to Pit 43W. • Numerous fish observed in lake.
Pit 34	Pit 34 Outlet	51973E 5874417N	Jul 18	205 x 2	1243	• Sampled from road culvert to Pit 34. • Culvert may be a partial barrier at some flows.

Habitat Potential

Habitat was visually assessed to identify major limiting factors to fisheries productivity (i.e. flows and habitat diversity). In addition, temperature loggers were deployed throughout the area to see if the thermal regime is suitable for target species.

RESULTS

Fish Sampling and Habitat Potential

Pit 44

Rainbow Trout was the only species captured from the Pit 44 outlet channel in 2013 (Table 3). All fish were captured near a patch of gravel located close to the lake outlet; these fish likely represent young of the year (YoY) fish, which suggests that stocked Rainbow Trout have successfully reproduced in the system. Rainbow Trout, Brook Trout and Brown Trout have all been stocked in Pit 44 in the past (FWMIS 2013, Miller 2011).

Table 3. Pit 44 outlet sampling summary for July 15th, 2013.

Species	Number Captured	Length (mm)	Weight (g)
RNTR	12	24.1 (21-29)	<1

Low flows likely limit habitat potential during most of the year. The Pit 44 outlet channel had minimal flow during the summer and was dry on several occasions. Based on the local habitat conditions it seemed likely that Rainbow Trout spawning occurred in an area that was back-flooded by the lake. Although there were a few deeper pools located throughout the outlet channel, no fish were captured or observed in these areas.

Pit 25S and Pit 25E and 25E Creek

There is no record of fish stocking in this system. Sampling of the channel downstream of Pit 25S failed to capture any fish, which suggests that fish have yet to colonize upper 25E Creek or Pit 25S.

Brook Trout were captured in middle 25E Creek (Table 4) and are known to occupy Pit 25E lake (Pisces 2010). Large schools of Brook Trout were observed feeding near the lake outlet on July 17th, 2013.

Table 4. Pit 25E outlet sampling summary for July 17, 2013.

Species	Number Captured	Length (mm)	Weight (g)
Brook Trout	18	144.8 (59-191)	37.6 (2-85)

Investigations on June 7, 2013 found a large congregation of fish downstream of the Highway 47 culvert. Electrofishing of the habitat resulted in the capture of Brook Trout and Mountain Whitefish (Table 5) however, sampling effectiveness was limited due to high stream flows.

Table 5. 25E Creek downstream of HWY 47 sampling summary June 7th, 2013.

Species	Number Captured	Length (mm)	Weight (g)
Brook Trout	5	181.4 (118-344)	99.4 (2-354)
Mountain Whitefish	1	283	97

25E Creek originates in the 25S Pit and flows through a small channel and reclaimed wetland area before entering Pit 25S. The outlet channel from Pit 25S contained gravel and cobble substrates but lacked instream cover and riparian vegetation. A short distance downstream of Pit 25S the creek flows through a muskeg area where beaver activity was very evident and the channel was poorly defined in places. Fines were the dominant substrate throughout this section. The habitat in the inlet to Pit 25E consisted mainly of riffle – pool complexes with cobble and boulder substrates. 25E Creek outlets from the south end of the 25S Pit, flowing over a relatively steep boulder section. The natural channel further downstream is generally low gradient with fines substrates dominant. The Highway 47 culvert appeared to be a barrier to fish movements during high flows but may be passable when discharges are lower. Downstream of this culvert the creek meanders through washed out beaver ponds.

Pit 43W

There is no record of fish stocking in this system but fish resident to the Lovett River appear to be able to access the area. A number of fish species were captured in the outlet channel from Pit 43W (Table 6). Brook Trout and Longnose Dace were the most abundant while White Sucker and Lake Chub were only captured once each.

Table 6. Pit 43W outlet sampling summary for July 17, 2013

Species	Number Captured	Length (mm)	Weight (g)
Brook Trout	33	127.8 (46-183)	32.2 (1-183)
Lake Chub	1	83	7
Longnose Dace	19	88.3 (83-93)	7.3 (4-12)
White Sucker	1	140	36

Shallow runs with cobble and boulder substrate dominated habitat within the outlet channel. There was one section, located approximately 75 metres downstream of Pit 43W, where the channel was quite steep and fish movement may be impeded at certain times of the year. Further downstream the channel transitioned to a small wetland area before flowing through a short channel that entered into the Lovett River. A limited amount of spawning gravel (suitable for salmonids) was identified downstream of the culvert located at the outlet of the lake.

Pit 34

There is no record of fish stocking for Pit 34 or Pit 43-2 (that outlets to Pit 34). Fish sampling conducted in the Pit 34 outlet channel captured Brook Trout and Longnose Dace (Table 7).

Table 7. Pit 34 outlet sampling summary for July 18th, 2013.

Species	Number Captured	Length (mm)	Weight (g)
Brook Trout	31	154.1 (103-207)	59.9 (15-140)
Longnose Dace	1	76	5

Reconnaissance conducted in the summer found that habitat within the inlet channel (from Pit 43-2) was extremely shallow and generally lacked cover for fish. Habitat within the outlet channel consisted mainly of shallow runs when assessed in the spring. Substrates consisted mainly of cobble and boulder. A culvert located in the outlet channel may impede fish movements at some flows.

Temperature Logging

Data was collected from June 11th to September 18th, 2013 (Table 8). The logger installed in the Lovett River downstream of the lakes was unusable since the logger was not submerged for long periods of time.

Table 8. Temperature logging results for end pit lake systems in the South Block Area.

			June 11- Sept 18th 2013		
Site	**Start**	**End**	**Average Daily (^{0} C)**	**Max Hourly Temperature (^{0} C)**	**Average Hourly Daily Fluctuation (^{0} C)**
Upper Lovett River	10-Jun	21-Sep	11.98	18.25	4.21
Pit 25S Lake Outlet	10-Jun	21-Sep	16.9	22.1	2.53
Pit 25E Lake Inlet	7-Jun	21-Sep	12.56	19.63	4.44
Pit 25E Lake Outlet	7-Jun	21-Sep	15.92	21.03	2.01
Lower 25E Creek	7-Jun	21-Sep	14.89	20.29	2.64
Pit 43W Pond Outlet	10-Jun	21-Sep	15.53	21.41	3.28
Pit 34 Lake Outlet	10-Jun	21-Sep	15.85	22.54	2.66

The highest stream temperatures recorded during the summer 2013 monitoring period occurred in the Pit 34 outlet and Pit 25S outlet respectively (Table 8). Under existing conditions, these channels have a high degree of sun exposure and bank cover has not been established. A significant cooling trend occurred between the Pit 25S outlet and the Pit 25E inlet in 2013 (Table 8). This is mostly attributable to cold water flow inputs from surrounding muskeg areas as well as a significant tributary which enters a short distance downstream of Pit 25S Lake.

The suitability of the systems for selected fish species is provided in the summary section of this report (Table 9) while ongoing monitoring will assess early spring conditions in 2014.

SUMMARY

The preliminary assessment data suggests that in most cases there is a moderate to high potential for development of sport fisheries in the end pit lake systems that were investigated (Table 9). Hatfield (2011) found physical characteristics and water quality values were sufficient for fish survival in Pit 44, 25S, and 25E lakes while lake investigations have not been completed in the other systems. The existing inlet and outlet channels are in reasonable condition but most would benefit from implementation of habitat enhancement. In some cases, habitat enhancement would likely be a critical step in establishing self-sustaining salmonid populations. Measurements taken during the 2013 investigations indicate that water temperatures were suitable and/or near optimal when compared to the requirements of fish species that could occupy these systems.

Table 9. Preliminary summary of fisheries potential for select pit lakes systems at the Coal Valley Mine.

Pit	Sample Section	Temperature Regime Suitability	Fisheries Potential of Inlet/Outlet Streams
Pit 44	Pit 44 Outlet	Insufficient water depth to submerge temperature logger	• Limited potential, primarily due to chronically low discharge. • Currently managed as put and take fishery by AESRD. • Some limited potential for salmonid reproduction at lake outlet during optimal years. • Evidence of RNTR reproduction in 2013.
Pit 25S	Pit 25S Outlet (upper 25E Creek)	RNTR – High BKTR – Mod ARGR - High	• High potential during spring and summer when there is sufficient discharge. Limited potential during the fall and winter when flows are lower. • No fish captured or observed in 2013. • Habitat potential of channels could be improved by increasing amount of coarse substrates and installing instream and riparian habitat enhancements.
Pit 25E	Pit 25E Lake Outlet (middle 25E Creek)	RNTR – High BKTR – High ARGR - High	• High potential. • Currently supports BKTR population but population size and production have not been assessed. • BKTR reproduction is known to occur in the outlet of Pit 25E. • Habitat potential of channels could be improved by increasing amount of coarse substrates and installing instream and riparian habitat enhancements.
	Lower 25 E Creek	RNTR – High BKTR – High ARGR - High	• High potential. • Currently supports BKTR population. Mountain Whitefish present downstream of Hwy 47. • Potential to enhance habitat upstream of Hwy 47 by increasing amount of coarse substrates.
Pit 43W	Pit 43W Lake Outlet	RNTR – High BKTR – High ARGR - High	• Moderate potential, flows are limiting factor in some months. • Appeared to support BKTR reproduction in 2013. • Existing fish community has not been assessed but appears substantial. • Habitat potential of channels could be improved by increasing amount of coarse substrates and installing instream and riparian habitat enhancements.
Pit 34 and Pit43-2	Pit 34 Lake Outlet	RNTR – High BKTR – High ARGR - High	• High potential during spring and summer when there is sufficient discharge. Limited potential during the fall and winter when flows are lower. • BKTR/forage fish utilize channel seasonally. • Habitat potential of channels could be improved by increasing amount of coarse substrates and installing instream and riparian habitat enhancements.
	Pit 43-2 Lake Outlet	RNTR – High[1] BKTR – High[1] ARGR – High[1]	• Low to moderate potential due to low flows and lack of habitat diversity (high width to depth ratio).

1. Data logger exposed during monitoring period, partial data set applied.

CLOSURE

I trust that the foregoing meets your requirements at this time. Please do not hesitate to contact me if you have any questions.

<original signed by>

Joe Sonnenberg B.Sc.
Fisheries Biologist
Author

<original signed by>

Erik Stemo, P.Biol.
Senior Fisheries Biologist
Review

REFERENCES

Hatfield. 2011. An evaluation of water quality in existing end-pit lakes in the Coal Valley Mine Area. Prepared by Hatfield Consultants for Coal Valley Resources Inc. 46 pp+ App

Hatfield. 2014. Bathymetric map of Pit 34 Lake. Prepared by Hatfield Consultants for Coal Valley Resources Inc.

Hubert, W.A., R.S Helzner, L.A. Lee, and P.C. Nelson. 1985. Habitat suitability index models and instream flow suitability curves: Arctic grayling riverine populations. U.S. Fish and Wildl. Serv. Biol. Rep. 82(10.110). 34 pp

Miller, L.L. 2011. Species Differences in Selenium Toxicity: Linking Cellular Responses to Population Effects. Thesis submitted to the School of Graduate Studies of the University of Lethbridge. 171 pp.

Pisces 2010. Determination of fish presence in Pit 25E Lake. Prepared by Pisces Environmental Consulting Services Ltd. for Coal Valley Resources Ltd.

Pisces. 2013. Aquatic Monitoring Program for End Pit Lakes in the Headwaters of the Embarras River, 2012-13. Prepared by Pisces Environmental Consulting Services Ltd. for Coal Valley Resources Ltd. 39pp+App

Pisces. 2014. Aquatic Monitoring Program for End Pit Lakes in the Headwaters of the Embarras River, 2013-14. Prepared by Pisces Environmental Consulting Services Ltd. for Coal Valley Resources Ltd. 37pp+App

Raleigh, R.F. 1982. Habitat Suitability models: Brook Trout. US Dept. Int., Fish Wildl. Serv. FWS/OBS-82/10.24. 42pp

Raleigh, R.F., T. Hickman, R.C. Solomon, and P.C. Nelson. 1984. Habitat suitability information: Rainbow Trout. US Fish Wildl. Serv. FWS/OBS-82/10.60. 64pp

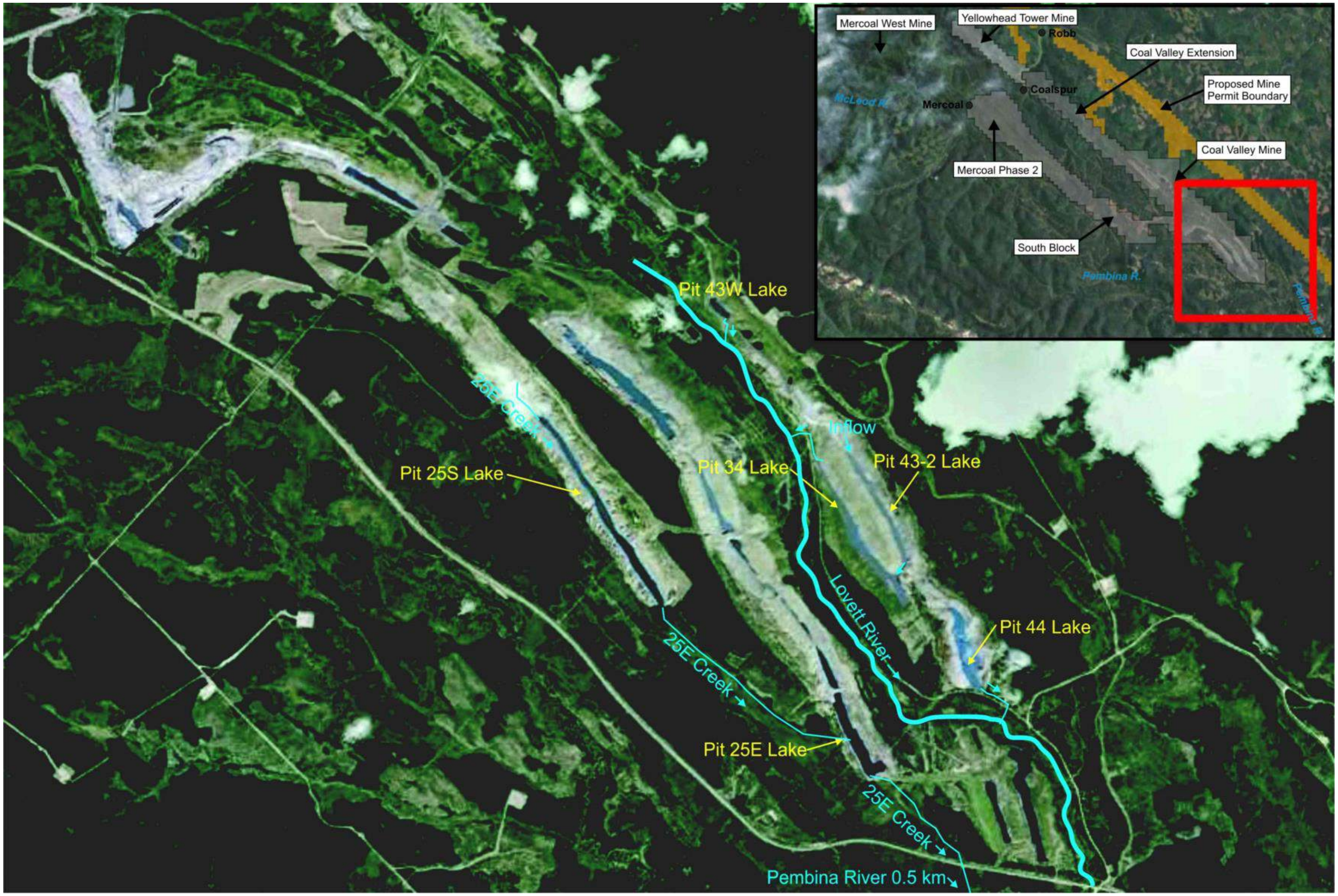


Figure 1. Location of lake systems.

Report #12

2013 Revised Benthic Invertebrate Biomonitoring Program for the Coal Valley Mine: The Embarras River Drainage Basin

Prepared for: Coal Valley Resources Inc.

April, 2014

PISCES ENVIRONMENTAL CONSULTING SERVICES LTD.

--this page left blank for printing purposes--

2013 Revised Benthic Invertebrate Biomonitoring Program for the Coal Valley Mine: The Embarras River Drainage Basin

Submitted to:

Coal Valley Resources Inc.
April, 2014

Prepared by:

Pisces Environmental Consulting Services Ltd.
Unit 118, 239 Spruce Street
Red Deer County, Alberta
T4E 1B4

--this page left blank for printing purposes--

Table of Contents

APPENDICES

Appendix A- Benthic Invertebrate Sample Processing Methods

Appendix B- Raw Benthic Invertebrate Identification Data

Appendix C- Site Summary Tables of Benthic Invertebrate Data

Appendix D- Statistical Analysis: Results of Multi-dimensional Scaling

List of Tables

List of Figures

1.0 INTRODUCTION

Coal Valley Resources Inc. (CVRI) operates the Coal Valley Mine (CVM) in the foothills of the Rocky Mountains southwest of Edson, Alberta. The CVM has been in operation since 1978 and recently received Environmental Protection and Enhancement Act (EPEA) Approval (11066-02-00) for ongoing operations extending to November 2020. One of the requirements of the EPEA Approval was submission of a Revised Benthic Invertebrate Biomonitoring Program (RBIBP). Additional test sampling for the RBIBP was conducted in September 2013 for the purpose of monitoring the efficacy of mine effluent mitigation and controls surrounding mining activity in the Embarras River drainage basin. The RBIBP sampling for the Pembina River and McLeod River Basins was conducted in 2012.

2.0 OBJECTIVES

The RBIBP is designed to meet the terms and conditions of the EPEA Approval which state that:

> *The Benthic Invertebrate Biomonitoring Program shall include, at a minimum, all of the following requirements:*
>
> a) *Monitoring of all major receiving waterbodies as identified in the receiving water monitoring program and their proposed sampling frequency;*
> b) *Shall determine significant changes in the benthic invertebrate community which are attributable to the effects of the mine effluent and the length of impact along the creek;*
> c) *Shall quantify variables that include epilithic algae (i.e. chlorophyll a), substrate conditions, flow velocities, water levels, and effluent plume distribution;*
> d) *Follow the protocol set out in: Guidelines for Monitoring Benthos in Freshwater Environments, Environment Canada, January 1993 and;*
> e) *Be submitted to the Director by May 1st of the year following sampling.*

Specific objectives of the RBIBP are to:

- Establish the range of natural variability (based on select measurement endpoints) of the benthic invertebrate communities in watercourses in the vicinity of the CVM.
- Compare data from test reaches (potentially impacted) with reaches designated as reference (un-impacted) to determine how the communities compare to natural variability.
- Determine whether there is a detrimental effect on the benthic invertebrate community downstream of mining activity.

3.0 STUDY AREA

Field sampling was conducted from September 26th to the 29th of 2013 and included the establishment of additional reference sites (not expected to be affected by mining activity) and of test sites (potentially influenced by mining activity) within the Embarras River drainage basins. Reference and test sites are delineated on Figure 1. For the 2013 biomonitoring, test sites were established on Chance Creek, Dummy Creek and the Embarras River (Table 3.1). A list of the reference sites sampled in 2013 and 2012 are provided in Tables 3.2 and 3.3 respectively. A list of the historical reference sites (sites sampled prior to 2012) included in the Coal Valley Mine Biomonitoring Project is provided in Table 3.4.

The naming convention for sites has been slightly altered from the RBIBP report on the Pembina and McLeod Rivers (Pisces 2013). For this report the site name/code was shortened so that the entire name is visible on statistical testing outputs and easier to manage in general. Codes that were used previously included all 4 digits of the sampling year in the name but have been reduced to only the last two digits of the year (e.g. BD1.2012 is now BD1.12).

Table 3.1. Biomonitoring test sites sampled in 2013

Site Code	Waterbody	Date sampled	UTM Coordinates NAD 83 Zn 11U
EM0.5.13	Embarras River	Sep. 28/2013	503460E 5882512N
EM1.13	Embarras River	Sep. 28/2013	500548E 5887867N
EM2.13	Embarras River	Sep. 28/2013	499412E 5891399N
EM3.13	Embarras River	Sep. 28/2013	501103E 5895649N
EM4.13	Embarras River	Sep. 26/2013	502861E 5898801N
CH1.13	Chance Creek	Sep. 29/2013	495874E 5894300N
CH2.13	Chance Creek	Sep. 27/2013	498763E 5892525N
DU1.13	Dummy Creek	Sep. 28/2013	502020E 5889738N

Table 3.2. Biomonitoring reference sites sampled in 2013

Site Code	Waterbody	Date sampled	UTM Coordinates NAD 83 Zn 11U
FE1.13	Felton Creek	Sep. 27/2013	486378E 5902260N
FET1.13	Tributary to Felton Creek	Sep. 27/2013	487799E 5897096N
FET2.13	Tributary to Felton Creek	Sep. 27/2013	486559E 5899841N
WH1.13	White Creek	Sep. 27/2013	489522E 5909911N
HA1.13	Hay Creek	Sep. 26/2013	502945E 5897669N

Table 3.3. Biomonitoring reference sites sampled in 2012

Site Code	Waterbody	Date sampled	UTM Coordinates NAD 83 Zn 11U
BD1.12	Beaverdam Creek	Sep. 23/2012	493170E 5881794N
BD2.12	Beaverdam Creek	Sep. 23/2012	493513E 5881966N
FE1.12	Felton Creek	Sep. 23/2012	486393E 5902256N
FET1.12	Tributary to Felton Creek	Sep. 23/2012	487799E 5897092N
ER3.12	Erith River	Sep. 21/2012	512351E 5890167N
LD2.5.12	Lund Creek	Sep. 20/2012	526510E 5879652N
LD3.5.12	Lund Creek	Sep. 20/2012	528531E 5875984N
LD4.12	Lund Creek	Sep. 20/2012	529420E 5874550N
PET1.12	Tributary to the Pembina River	Sep. 20/2012	531835E 5871593N

Table 3.4. Historical sampling-benthic invertebrate reference sites sampled prior to 2012

Site Code	Waterbody	Date sampled	UTM Coordinates NAD 83 Zn 11U
AP7.10	Plante Creek	Sep. 21/2010	482484E 5945383N
BA2.06	Bacon Creek	Sep. 20/2006	514387E 5888340N
BA3.06	Bacon Creek	Sep. 21/2006	513556E 5887389N
BR1.10	Bryan Creek	Oct. 02/2010	500791E 5897904N
BR2.10	Bryan Creek	Oct. 02/2010	498580E 5899357N
CH1.06	Chance Creek	Sep. 19/2006	495064E 5895959N
CH2.06	Chance Creek	Sep. 19/2006	498453E 5892578N
EM1.05	The Embarras River	Sep. 16/2005	501103E 5895562N
EM2.05	The Embarras River	Sep. 18/2005	502843E 5898831N
ER3.05	The Erith River	Sep. 16/2005	512333E 5889910N
HL2.06	Halpenny Creek	Sep. 20/2006	515986E 5887021N
HL4.06	Halpenny Creek	Sep. 21/2006	516053E 5884248N
LD3.07	Lund Creek	Sep. 12/2007	527093E 5877484N
LD4.07	Lund Creek	Sep. 12/2007	529414E 5874575N
LDT1.07	Tributary to Lund Creek	Sep. 11/2007	525352E 5878989N
LDT3.07	Tributary to Lund Creek	Sep. 12/2007	527458E 5875031N
LE1.06	Lendrum Creek	Sep. 21/2006	520985E 5882791N
LE2.06	Lendrum Creek	Oct. 06/2006	521911E 5881256N
LET1.06	Tributary to Lendrum Creek	Oct. 05/2006	519625E 5882133N
LET3.06	Tributary to Lendrum Creek	Oct. 05/2006	520851E 5881867N
ME2.04	Mercoal Creek	Oct. 13/2004	491682E 5890330N
MA1.04	McCardell Creek	Oct. 15/2004	480119E 5896691N
MA2.04	McCardell Creek	Oct. 15/2004	478736E 5897973N
MC1.04	The McLeod River	Oct. 21/2004	492909E 5887604N
MC6.04	The McLeod River	Oct. 20/2004	481446E 5901298N
MCT1.04	Tributary to the McLeod River	Oct. 23/2004	480758E 5892032N
MET2.04	Tributary to Mercoal Creek	Oct. 14/2004	490918E 5891478N
PET1.07	Tributary to the Pembina River	Sep. 12/2007	531835E 5871593N
PR1.07	The Pembina River	Sep. 19/2007	521560E 5870478N
WH1.10	White Creek	Oct. 01/2010	489524E 5909949N
WH3.10	White Creek	Oct. 02/2010	490695E 5906869N

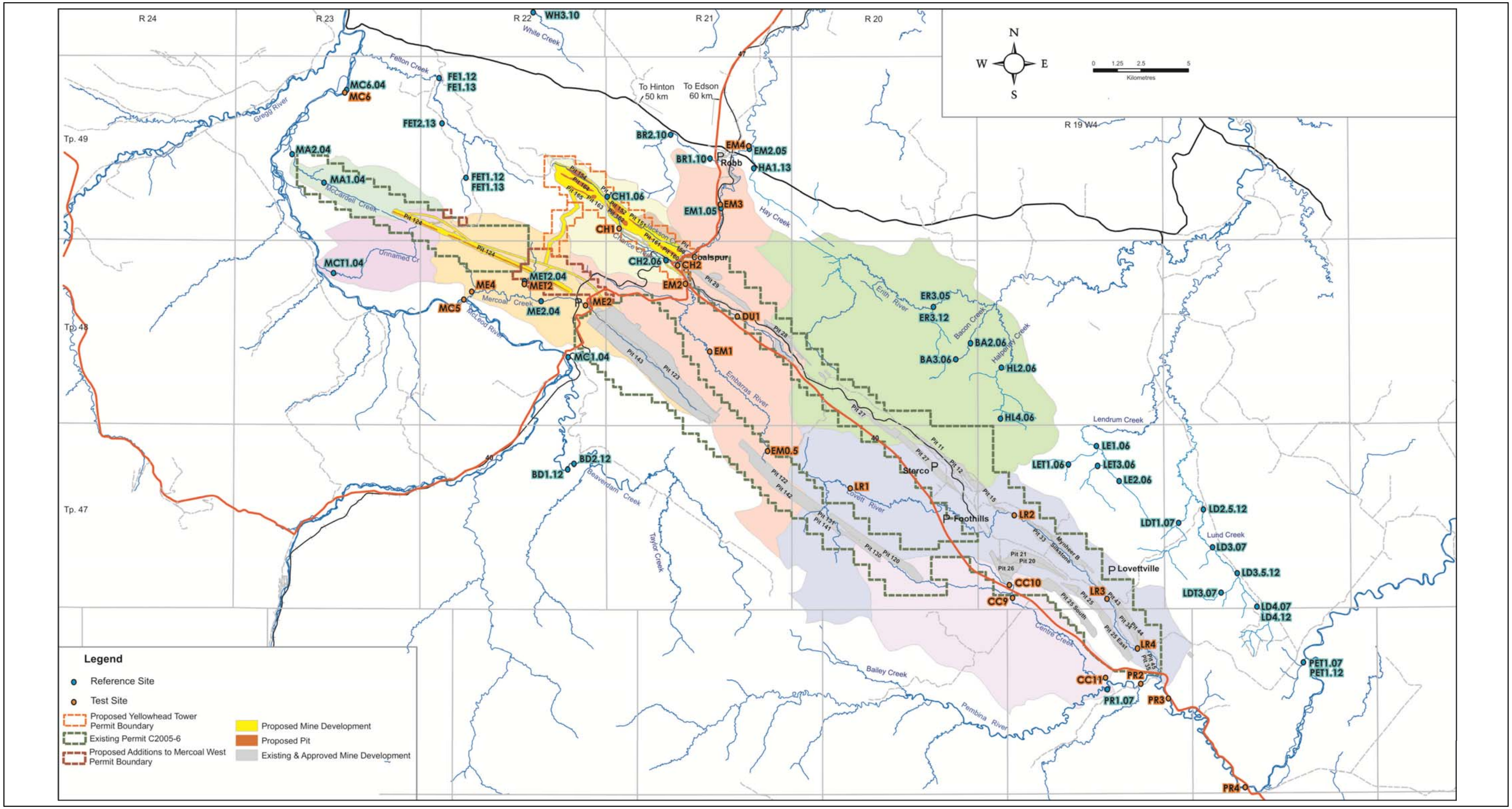


Figure 1. Monitoring Locations (2012 + 2013) and the majority of the reference sites for the Coal Valley Mine Benthic Invertebrate Biomonitoring Program

Reference sites WH1.10, WH1.13 and AP7.10 not located on map-Locations described in Table 3.3.

4.0 METHODS

4.1 GENERAL APPROACH

The proposed monitoring program will employ the Reference Condition Approach (RCA) whereby *test sites* which have the potential of being impacted are compared to an appropriate *group* of *reference sites* (that represent the normal condition) to determine if there is an impact. The degree of potential impairment is determined by how far the benthic communities at the *test sites* deviate from those at *reference sites.* Further analysis of test sites will incorporate common metrics that will use indicator groups to determine if the community structure is indicative of impairment. Key elements of the RCA approach include:

1. Selection of a pool of candidate *reference sites* that includes locations sampled during monitoring or baseline assessment work and new sites that could be sampled in the future.
2. Selection of *test sites* (based on mine plans) that will be established in the immediate vicinity of an effluent discharge point and additional *test sites* will be established at locations downstream (depending on the size of the water body) to determine the linear extent of an impact.
3. Use of existing regional benthic data that CVM has accumulated during previous monitoring and baseline investigation to:
    a. Develop a model that explains the natural variability of the benthic populations in the region.
    b. Determine (through statistical analysis described in Section 4.6, the number of reference sites (from the candidate pool) that need to be sampled in a given monitoring year.
    c. Identify data gaps in the model (e.g. additional reference site information may be required to ensure the model is accurate)
4. Implementation of the monitoring program whereby:
    a. *test sites* will be sampled.
    b. A subset of reference sites will be sampled and included in the model to account for effects of natural temporal variation.
5. Employment of statistical analysis to match *test sites* with the appropriate group of *reference sites* (*Reference Group*) for comparison and assessment of effects.
6. Analysis of the community structure of test sites identified to be divergent from their assigned reference group through the use of metrics. The metrics used will employ indicator benthic groups in the calculations to ascertain whether the benthic community exhibits characteristics of an impaired community.

7. Review of the RCA biomonitoring model for the CVM, post assessment, to identify data gaps. There is potential for additional reference information to be required as prescribed test sampling continues for the CVM biomonitoring program to account for reference group(s) that require a higher number of samples.

4.2 MONITORING CHRONOLOGY

Due to the size and scope of this program, a staged approach will be undertaken whereby a portion of the program is completed in a given year (Table 5.3). The 10 year schedule is devised with the following guiding principles in mind:

- The five year monitoring frequency will be continued in the Pembina drainage where mining has ceased. Under this scenario monitoring will be conducted again in 2017.
- A three year monitoring frequency will take place within the Embarras and McLeod drainage basins where active mining is ongoing in the Mercoal West and Yellowhead Tower areas.
- A sub set of reference sites will be selected from the pool of candidate sites and sampled in each monitoring year. New candidate sites may be chosen for the purpose of increasing the sample size in low sample reference groups.

4.3 FIELD SAMPLING

4.3.1 Benthic Invertebrates

Field sampling protocols for the Benthic Invertebrate Monitoring were based largely on methodology described by Alberta Environment (2006) which included the collection of random, replicate samples at each location using a Neil-Hess Cylinder with a 250 micron mesh. Sampling was conducted in the fall with all samples preserved with a minimum 80% ethanol prior to shipment. At each site, three replicate samples were taken within erosional streambed habitat.

4.3.2 Habitat and Water Quality

General habitat conditions, including substrate type and size, water depth and velocity, and bankfull and wetted width, were characterized at each site. In addition, at each site, basic water quality parameters including conductivity, water temperature, pH, dissolved oxygen and turbidity were measured and recorded in the field.

4.3.3 Epilithic Algae

Epilithic algae were sampled at each site by randomly scraping a 2 x 2 cm area on randomly selected rocks. Epilithic algae field sampling methods were completed as described by Alberta Environment (2006). A composite sample was sent to an independent laboratory (Bio-Aquatics Research and Consulting) for analysis of total chlorophyll ‘*a*’. Epilithic algae samples were taken at all the benthic invertebrate monitoring sites visited in September of 2013.

4.4 BENTHIC INVERTEBRATE IDENTIFICATION

Samples were processed by an independent taxonomist following standard procedures (appendix A). Taxonomic resolution is provided in Table 4.1.

Table 4.1. Taxonomic level of identification (minimum) for biological groups for the CVM Benthic Invertebrate Biomonitoring Program

Biological Group	Level of identification	Biological Group	Level of Identification
Ephemeroptera	Genus	Arachnida	Suborder
Plecoptera	Genus	Cnidaria	Genus
Trichoptera	Genus	Crustacea	Order
Chironomidae	Subfamily	Gastropoda	Genus
Diptera	Subfamily	Pelecypoda	Genus
Coleoptera	Family	Oligochaeta	Genus
Megaloptera	Genus	Nematoda	Phylum

4.5 EPILITHIC ALGAE-LABORATORY METHODS

Algae samples were analysed using the spectrophotometric method to quantify chlorophyll 'a'. The methods used by Bio-Aquatics Research and Consulting are based upon methodology provided in Moss, B. 1967(a) and in Moss, B. 1967(b).

4.6 MONITORING STUDY DESIGN

4.6.1 Reference Sites

Selection of Reference Sites

Reference sites were selected on the requirements that they were within the same ecoregion as the test sites (Western Alberta Upland), that they would not be influenced by mine activity (ongoing or recently reclaimed), and that they exhibited erosional streambed habitat. All of the reference sites have influences to some degree from development by forestry and oil and gas activity (i.e. roads, cutlines, well pads, and harvested cut blocks) due to the fairly widespread nature of these industries throughout this area of the province. The reference sites are not pristine but do exemplify the common baseline condition of the majority of watercourses within this ecoregion. The RCA Model was constructed from reference data collected from baseline or monitoring studies conducted for CVRI between the years of 2004 and 2010 (31 sites). In addition to these sites additional reference data used to construct the RCA model was also collected in 2012 (9 sites) and in 2013 (5 sites).

Reference Groups

A group of reference sites is required by the RCA to determine the reference condition. As indicated in section 4.1, test sites will be compared with this *reference group* (group of reference sites) to determine effects. The number of reference sites required to complete the monitoring program will depend on the number of *reference groups* needed to accurately depict the natural stream environment (Bowman and Sommers 2005, Environment Canada 2010). To accomplish this, discriminant analysis (Environment Canada 2010) can be used in conjunction with hierarchical clustering to determine the number of necessary reference groups based on habitat attributes at sites and existing community composition data.

Reference Sites

A power analysis (as suggested by Environment Canada 2010) was applied using the following formula to estimate the likelihood of detecting effects with the chosen number of reference sites per reference group.

$$N = 2(t_\alpha + t_\beta)^2(SD/ES)^2$$

> where, N is the number sites per *group*, t_α and t_β are the critical t values at significance levels for Type 1 and Type 2 error rates respectively, SD is the within reach standard deviation, and ES is the critical effect size (where ES is the mean reference condition ± 2 SDs assuming that effects exceeding ±2 SDs are of interest)

Power analysis calculated at a 5 % chance of type 1 error (t-alpha) and a 5 % chance of type 2 error (t-beta), with the assumption that critical effect size is >2 SD's, determined that >9 sites per group are required.

Similarly, Environment Canada (2010) suggests that there be a minimum of 10 *sites* within each reference group which would translate to 20 sites if there were two reference groups (as described above). It should be noted that this requirement represents the number of "data points" required to characterize the reference group and not necessarily the number of "reference sites required per monitoring year". As such, historical data from suitable sites will also be utilized to characterize the reference group when possible. To elaborate, information from the pool of historical reference sites (Table 3.4) was used to develop the model that describes the natural variability of benthic invertebrate populations in the region. The historical reference site data was sourced from information that the mine collected during previous baseline and monitoring work in the area.

4.6.2 Test Sites

The program consists of 23 test sites on 8 different water bodies. The location of the existing synoptic (*test*) sites on the Pembina River, Lovett River, Centre Creek, Embarras River, and Mercoal Creek (Figure 1) will essentially remain unchanged from previous monitoring. In addition to these sites, new test sites have been established on the Embarras River, McLeod River, Chance Creek and Mercoal Creek (Figure 1).

4.6.3 Number of Sub-Samples (Replicates) per Site

With the RCA approach, replication is at the sample site scale and since variation within a site is often much lower than among sites, a single sample can be taken at each site and variation among sites is used to describe the reference condition (Environment Canada 2010). However, additional sub-samples or *site replicates* may be required to accurately reflect organism abundance and species richness. If required, the following formula (Environment Canada 2010) will be applied to existing benthic invertebrate data (from the previous monitoring program) to determine the number of sub-samples needed to provide confidence that a representative number of organisms have been captured.

$$N=s^2/D^2\,\bar{X}^2$$

where $\bar{X}$ is equal to the sample mean, n is equal to the number of field sub-samples, s^2 is equal to the sample variance and D is equal to the index of precision.

The 2012 and 2013 data was collected using the minimum number of sub-samples (3) recommended by Environment Canada (2010).

4.7 RCA MODEL DEVELOPMENT

The Canadian Aquatic Biomonitoring Network (CABIN) program was developed in response to the need for a nationally standardized method to assess the ecological condition of Canada's freshwater. Procedures for designing a biomonitoring study, analyzing the data, and results interpretation provided in the training modules for the use in the program were consulted for the CVM monitoring study. The data analysis procedures used in Environment Canada's Benthic Assessment of Sediment (BEAST) analysis model used by the CABIN program were largely adhered to in regards to constructing and utilizing the RCA model.

4.7.1 Sample Data

The benthic invertebrate data collected from reference sites (historical, 2012, and 2013) was statistically analyzed in its raw form in line with CABIN procedures (CABIN 2010) as defined groupings could be determined without transforming the data. The mean of the count data for each taxon was calculated for each site. Sampling completed prior to 2012 included 5 replicates for each site whereas, the 2012 and 2013 sampling involved three replicates per site as determined from power analysis of historic data and in line with the minimum required by Environment Canada (2010). The mean of the appropriate data from all replicates of one site was used for any data analysis and site summaries. The raw count data was organized into families or less specific (as per CABIN BEAST analysis procedures). Those taxonomic groups not identified to the family level were instead identified to the level commonly used for each group (as in Table 4.1). Rare families were included in the data as some rare families can be indicative of ecological stress (CABIN 2010). For the site summary and metric calculations, taxonomic resolution was identified to the level as described in Table 4.1.The raw benthic data is provided in Appendix B and the summarized benthic data in Appendix C.

4.7.2 Cluster analysis

Hierarchical cluster analysis was used to group the reference site benthic invertebrate count data. The cluster analysis was done using IBM SPSS 13.0 to create dendrograms using various linkage and distance measure combinations that best define groups of similar sites graphically. Sites found to have less distance between them (more similar benthic communities) are found closer together on the dendrogram, as sites found to have larger differences between their count data are located farther away. Numerous dendrograms were created and those that showed a large relative distance between one or more groups of sites were considered for further testing to determine if they would be found to have a high correlation with the habitat data collected for each site. The Ward's linkage using a Phi square distance measure was found to provide the clusters that were well correlated to the habitat data as further described in 4.7.3. This was a different linkage than was used for the 2012 data but was found to provide a higher correlation with the habitat data than the within groups linkage once the addition of the 2013 reference sites was made. The reference model will continue to evolve as reference sites are added and the natural variation of reference sites is more wholly represented.

4.7.3 Discriminant Function Analysis

The habitat data was organized by site and by the reference site groups (determined through the cluster analysis and the creation of dendrograms), and then tested using discriminant function analysis (DFA). The DFA completed on the habitat data determined which habitat variables are the most discriminating between the assigned reference groups by comparing the raw habitat data using a distance measure. The Mahalanobis distance measure was used for the DFA using IBM SPSS 13.0 statistical software. The Mahalanobis distance reflects the similarity between a case and the mean of each reference group, and is commonly used for multivariate analysis of normal distributions.

The habitat parameters (variables) included in the DFA are provided in Table 4.2.

Table 4.2. The habitat variables included in the DFA of the assigned reference groups

Depth (m)	Velocity (m/s)	Water Temp (^{0}C)	pH	Conductivity (µS)
Dissolved oxygen (mg/L)	Turbidity (NTU's)	Wetted width (m)	Bank-full width (m)	Mean diameter of stones (mm)
Stone count* (# >50 mm)	Discharge (m^3/L)	Boulder (%)	Cobble (%)	Gravel (%)
FN (%)	Stream order (Strahler 1964)			

*The number of stones within the Hess sample area that were greater than 50 mm in diameter along their longest axis.

The stepwise DFA builds discriminant functions (with the number depending on the possible number of reference group categories) from the reference group data through iterative tests, combining only the most highly correlated and discriminating variables to predict group membership. Stepwise DFA allows for the ability to choose the variables included in the classification process by allowing for the manipulation of the limit of the minimum significance at which variables are included in the creation of the discriminant functions. Limiting the inclusion of only the most discriminating variables helps maximize the predictive power of the discriminant function(s) created. The final variables were chosen by noting which grouping of variables produced the highest accuracy of site prediction by the cross validation method, as well as which grouping best met Box's M test for homogeneity of variances. An error rate is determined through the cross-validated method (as it has less potential to overestimate the predictive power of the discriminant function) and is equal to the percentage of sites that are placed incorrectly into a reference group by the discriminant functions.

4.8 ASSESSMENT OF TEST SITES USING THE RCA MODEL

4.8.1 Classification of Test Sites

The test sites are assigned to the reference group that has the most similar habitat qualities. The test site habitat data membership is predicted using the same discriminant function(s) determined in the reference site DFA. Once the test sites are assigned a reference group, the test site invertebrate count data are compared to the invertebrate count data of its assigned reference group through multidimensional scaling, which is further described in 4.8.2.

4.8.2 Assessment of Test Sites

The reference site count data was reduced to three variables using multidimensional scaling (PROXSCAL algorithms) in IBM SPSS 13.0 due to there being a high number of independent variables and because a majority of the variables did not possess a normal distribution. Each combination of the three variables (dimensions) created from the scaling process were plotted in 2 dimensional space in order to determine how similar the test sites coordinate compared to the reference group centroid (mean coordinate). This comparison was done through the graphing of density ellipses (also known as confidence ellipses) around the reference group of coordinates.

Density ellipses were created for each of the scatterplots (i.e. three combinations of the three variables) for the reference group at 90.0 %, 99.0 % and 99.9 % confidence using SAS Institute Inc. JMP IN Software. Test site values for the same variables were plotted against the reference sites density ellipses to determine how comparable the test sites were to the reference group.

The location of the test site plots relative to the reference group and their interpretation are provided in Table 4.3.

Table 4.3. Interpretation of test site scaling score in reference to density ellipses determined from the group of reference sites (as per CABIN 2010)

Within the 90 % range	**Between 90 % and 99.0 %**	**Between 99.0 % and 99.9 %**	**Outside of the 99.9 % range**
• Similar to reference group • Not considered to be impaired	• Mildly divergent • 10 % probability of type 1 error	• Divergent from reference group • 1 % probability of type 1 error	• Severely divergent from reference group • 0.1 % probability of type 1 error

4.8.3 Metric calculations

Metric calculations are complimentary to the RCA analysis in that they provide another way in which impaired communities can be detected and also serve to aid in the interpretation of the results of the RCA analysis. The metric calculations used were chosen from those suggested in CABIN (2010). The raw benthic invertebrate count data provided by the taxonomist was used to calculate five separate metrics for each reference site within the reference group and for all the test sites. The mean of the replicate counts for each site was used for all metrics except for the Shannon Diversity Index which was calculated for each replicate and then averaged. The metrics used were as follows:

- Total Abundance- Sum of all organisms
- Total Taxa Richness- Number of taxa present at the selected taxonomic level (see 4.1.2 for taxonomic resolution)
- Ephemeroptera, Plecoptera and Trichoptera (EPT) abundance-Abundance of EPT individual organisms
- EPT/Chironomidae + EPT-Abundance of EPT individuals divided by the abundance of Chironomids and EPT individuals
- Shannon Diversity Index- Index to measure the relative abundance and the distribution amongst the taxa present (eveness). The Shannon Diversity Index is a measure of species diversity based on the number of species as well as the evenness of distribution of organisms (Shannon and Weaver 1949) and is used as a metric by CABIN (2010) as a descriptor of the benthic community. A high diversity value indicates a healthy population consisting of a number of individuals from a variety of taxa. Low species diversity suggests an uneven distribution of individuals between taxa indicating an unstable population. The Shannon Diversity Index was calculated for all sites as follows:

$$H' = -\sum_{i=1}^{s} p_i \ln p_i$$

where “s” = number of species

“p_i” = proportion of the total number of individuals consisting of the i^{th} species

“ln” = natural logarithm

The mean of each metric for each reference group will be calculated so that the test site value for each of the five metrics can be compared to this value. The comparison involves calculating the ratio of the test site value to the reference group mean value for each metric (i.e. the observed value divided by the expected value).

5.0 RESULTS

5.1 CLUSTER ANALYSIS

Cluster analysis was conducted on the raw data (at a resolution of family or less specific) for the 45 reference sites that met the reference site criteria. The hierarchical cluster analysis used the Ward's linkage and a distance measure of Phi-square. The results of this analysis are depicted graphically in the dendrogram provided in Figure 2. The division between groups was chosen at approximately 40 % dissimilarity which formed 2 separate groups. Reference Group 1 contains 35 sites and Reference Group 2 contains 10 sites.

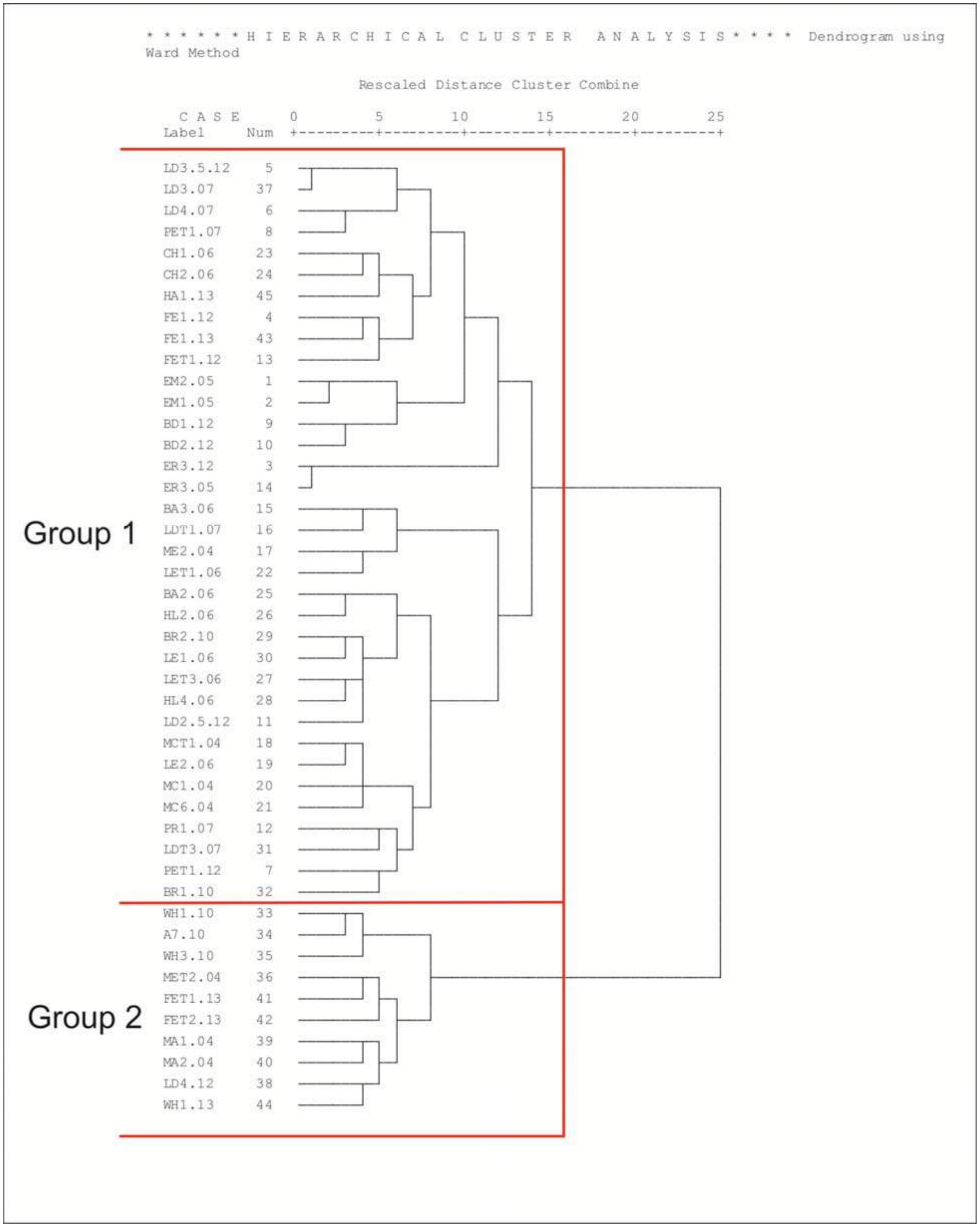


Figure 2. Dendrogram showing classification of reference site invertebrate count data using Ward's method and a distance measure of Phi-square

5.2 DISCRIMINANT FUNCTION ANALYSIS

The stepwise DFA for the habitat data determined that a combination of eight habitat variables best discriminate between the two assigned groups determined in the cluster analysis.

The variables were screened by a minimum significance of F to enter of 0.55 and a maximum significance of F to remove of 0.56. The eight habitat variables determined to be the most discriminating between the two groups are provided below in Table 5.1.

Table 5.1. SPSS Table of the variables included in the stepwise DFA for the reference habitat data

Variables Entered/Removed[a,b,c,d]

Step	Entered	Min. D Squared					
		Statistic	Between Groups	Exact F			
				Statistic	df1	df2	Sig.
1	Velocity	.565	1.00 and 2.00	4.392	1	43.000	.042
2	Rock Count	.894	1.00 and 2.00	3.394	2	42.000	.043
3	Depth	1.322	1.00 and 2.00	3.268	3	41.000	.031
4	Bank	1.691	1.00 and 2.00	3.059	4	40.000	.027
5	Stream Order	2.009	1.00 and 2.00	2.834	5	39.000	.028
6	Temp	2.139	1.00 and 2.00	2.450	6	38.000	.042
7	AvgDiam	2.229	1.00 and 2.00	2.131	7	37.000	.064
8	Boulder	2.385	1.00 and 2.00	1.941	8	36.000	.084

At each step, the variable that maximizes the Mahalanobis distance between the two closest groups is entered.

a. Maximum number of steps is 28.

b. Maximum significance of F to enter is .55.

c. Minimum significance of F to remove is .56.

d. F level, tolerance, or VIN insufficient for further computation.

Canonical correlation for the functions is provided below in Table 5.2.

Table 5.2. Table of Eigenvalues for the DFA on the reference site habitat data

Eigenvalues

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	.431(a)	100.0	100.0	.549

a First 1 canonical discriminant functions were used in the analysis.

The classification results show the number of sites predicted to be classified within each of the two reference groups and the percentage of sites that this prediction represents (Table 5.3). Also within the table the 'cases not selected' represent the test sites and their assignment to the most similar reference group. Seven test sites sampled in 2013 were assigned to Reference Group 1, and one test site was assigned to Reference Group 2. Using the cross validation method, it was found that 75.6 % of the sites were correctly classified. Cross validation predicts site membership to a reference group, but leaves out the site being tested for from the reference group. This method is a more stringent test than the original method which includes the subject site in the reference group for the prediction calculation.

Table 5.3. Classification results of the DFA for the reference habitat data using assigned groups from the cluster analysis

Classification Results[b,c]

			Predicted Group Membership		
		WardPhi2014	1.00	2.00	Total
Original	Count	1.00	29	6	35
		2.00	4	6	10
		Ungrouped cases	7	1	8
	%	1.00	82.9	17.1	100.0
		2.00	40.0	60.0	100.0
		Ungrouped cases	87.5	12.5	100.0
Cross-validated[a]	Count	1.00	28	7	35
		2.00	4	6	10
	%	1.00	80.0	20.0	100.0
		2.00	40.0	60.0	100.0

a. Cross validation is done only for those cases in the analysis. In cross validation, each case is classified by the functions derived from all cases other than that case.

b. 77.8% of original grouped cases correctly classified.

c. 75.6% of cross-validated grouped cases correctly classified.

5.3 Classification of Test Sites

As provided in Table 5.3, each of the test sites were assigned a reference group through the DFA of the habitat data. The assigned reference group has the most similar measurements of each of the eight variables (Table 5.1) when compared to the test site. Of the 8 test sites, 7 were assigned to Reference Group 1 and 1 test site (DU1) was assigned to Reference Group 2.

5.4 Assessment of the Test Sites using the RCA Model

The count data for each reference group with its assigned test site(s) were reduced using multidimensional scaling (MDS), down to three variables (D-scores). Once MDS was completed for each group, the assigned test sites were analyzed to determine if they fell within the 90 %, 99 % or 99.9 % confidence ellipse of the three dimensions (variables) of the appropriate reference group. Scatterplots with density ellipses were created in two dimensions in order to determine if any test sites data points were located outside the 90 % confidence density ellipse. If any test site data points (plotted coordinates of 2 of the 3 D-scores) was found to be outside any of the three ellipses it was considered to be divergent from the reference group. Each of the three dimensions, using only reference site D-scores from its group, were found to have normal distributions as provided in table 5.4 using the Kolmogorov-Smirnov and Shapiro-Wilk tests. A significance result of 0.05 or less from either test would indicate a non-normal distribution.

Table 5.4. Results of the Kolmogorov-Smirnov and Shapiro-Wilk tests for normality on the combined D-scores for each reference group

Reference Group 1-Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Dim1	.077	35	.200*	.985	35	.902
Dim2	.140	35	.079	.954	35	.148
Dim3	.089	35	.200*	.981	35	.805

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Reference Group 2-Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Dim1	.185	10	.200*	.940	10	.557
Dim2	.125	10	.200*	.974	10	.927
Dim3	.157	10	.200*	.929	10	.437

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

For the RCA assessment of the test sites, any test site that is outside of the 90 % confidence interval of the reference group distribution is considered to be divergent from the reference group and is considered to be impaired (CABIN 2010).

Scatterplots of the dimensions produced from the multidimensional scaling are provided in Figures 3, 4 and 5. The innermost ellipse encloses the densest 90.0 % of the estimated distribution, with the nearest larger ellipse enclosing 99.0 %, and the largest ellipse enclosing 99.9 %.

The test site data plotted with the reference group density ellipses for Group 1 indicate that sites CH1.13 and EM2.13 were the most divergent from the Reference Group 1 centroid (Figures 3, 4 and 5). Test site CH1 is considered to be severely divergent as per interpretation through CABIN (2010), as it is outside of the 99.9 % reference group density ellipse. As per interpretation through CABIN (2010), test site EM2 would be considered mildly divergent as it is located between the 90.0 % and 99.0 % reference group density ellipses. Other points (sites) located outside the 90.0 % density ellipse that are not labelled are reference sites and not test sites.

The test site data points plotted with the Reference Group 2 data points and density ellipses indicate that site DU1 was divergent from the Reference Group 2 centroid (Figure 8.) where dimension 1 and dimension 3 have been plotted. The other two density ellipse charts do not place DU1 outside of the 90 % confidence interval (Figures 6 and 7) but CABIN (2010) only requires a site coordinate to be outside in any of the three D-score combinations for it to be considered divergent. Test site DU1 is considered to be mildly divergent as per interpretation through CABIN (2010), as it is located between the 90.0 % and 99.0 % reference group density ellipses.

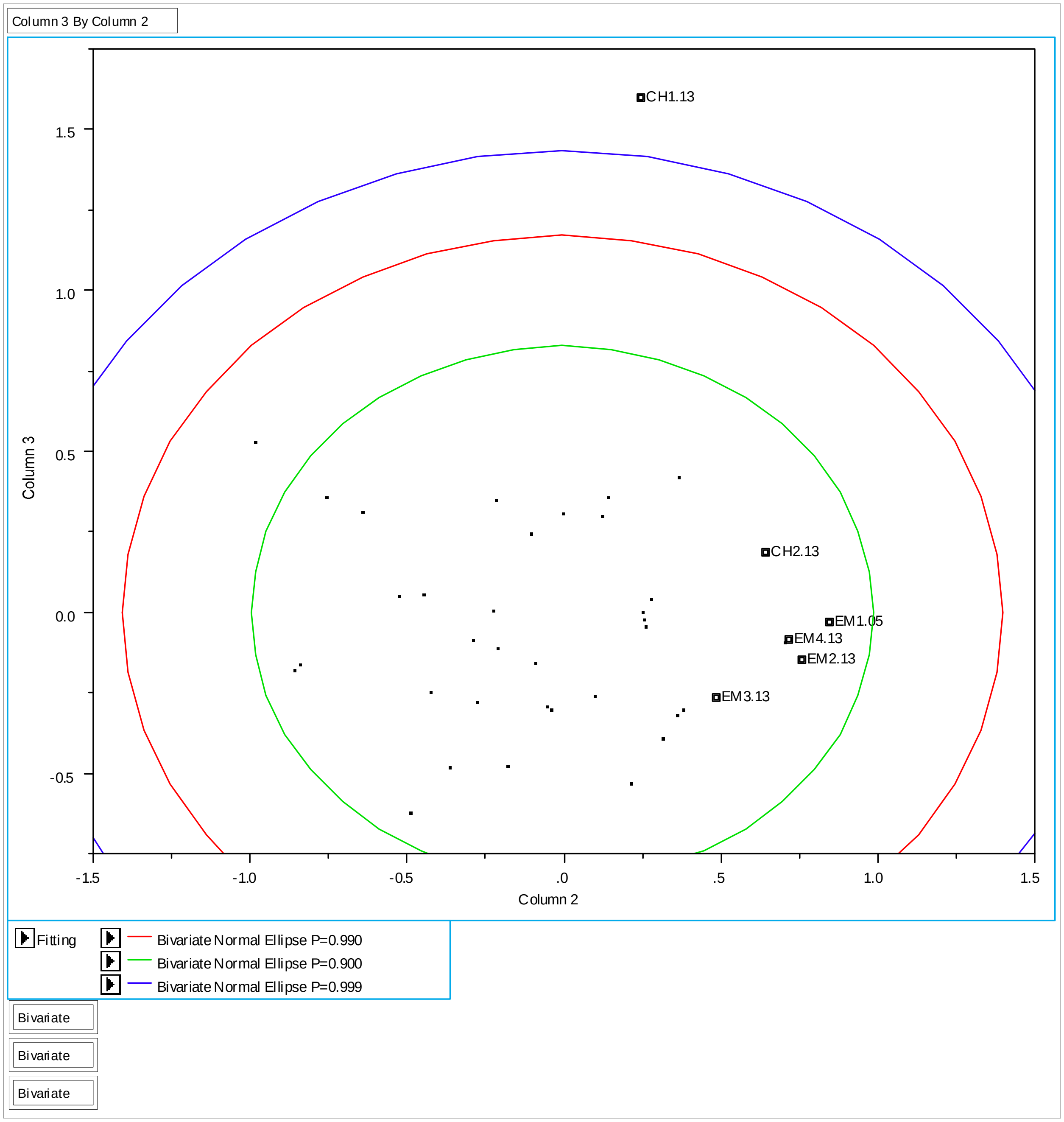


Figure 3. Reference Group 1- Scatterplot of dimension 1 vs. dimension 2 with density ellipses plotted at 90.0 %, 99.0 % and 99.9 %

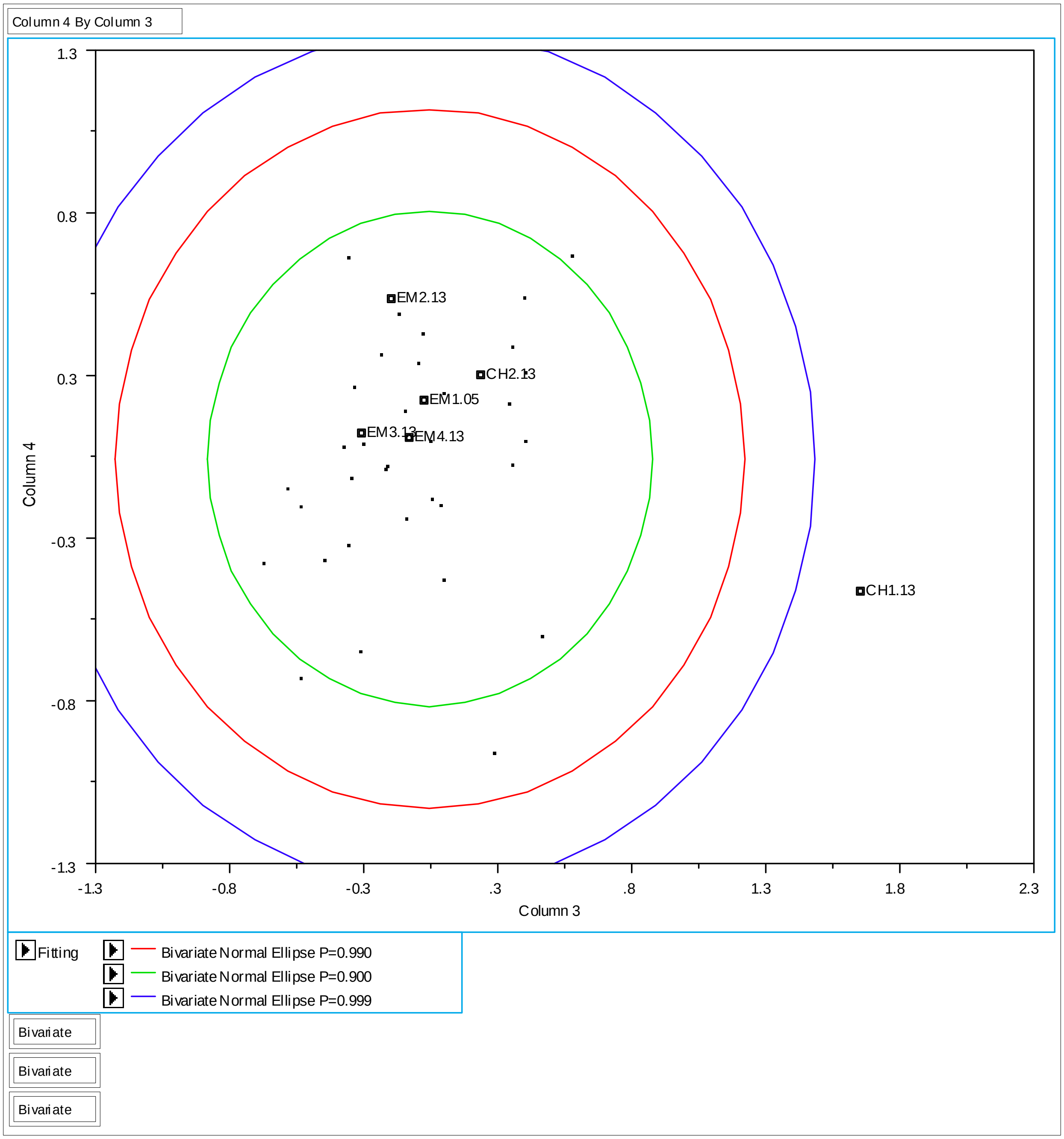


Figure 4. Reference Group 1- Scatterplot of dimension 2 vs. dimension 3 with density ellipses plotted at 90.0 %, 99.0 % and 99.9 %

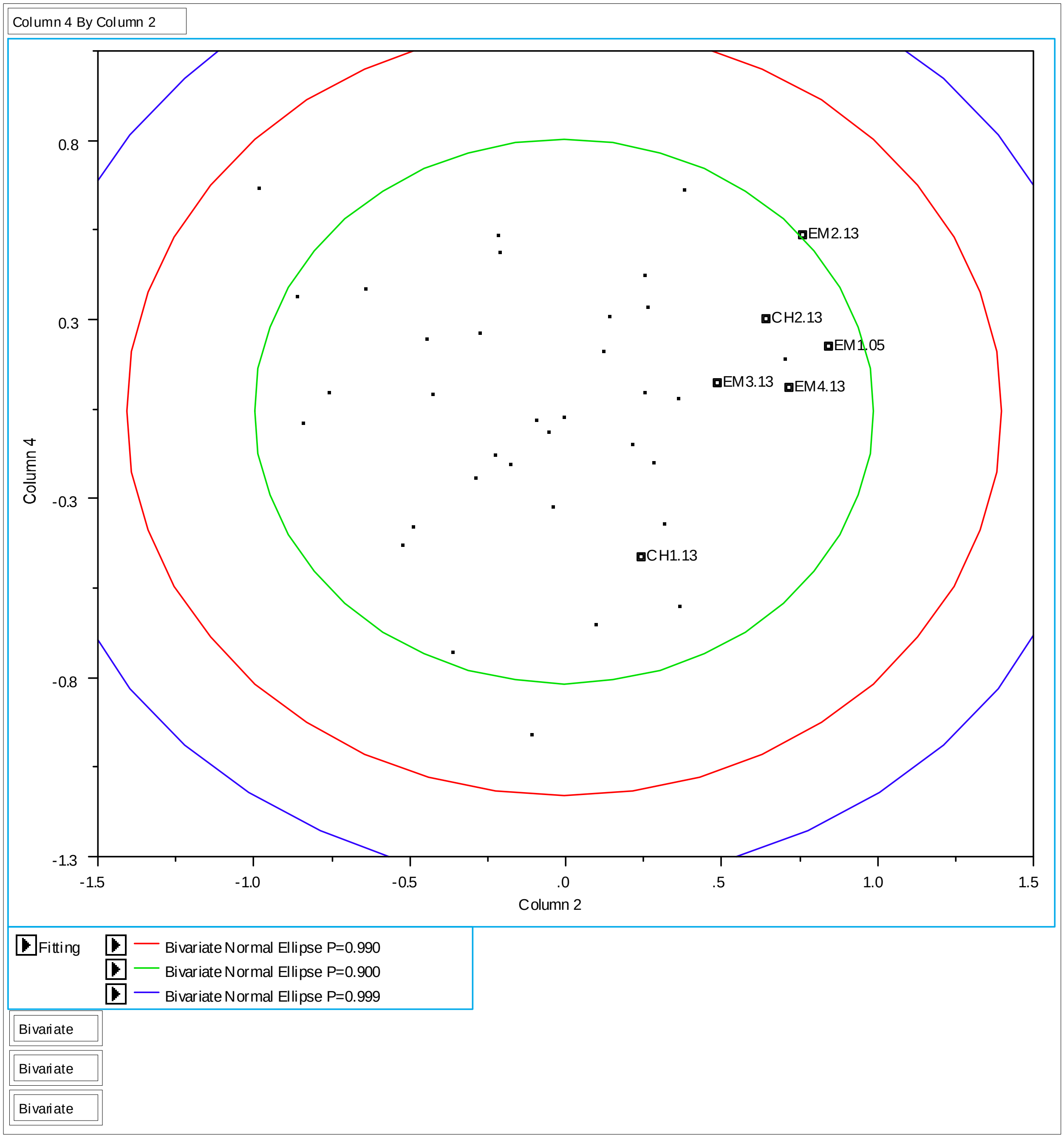


Figure 5. Reference Group 1- Scatterplot of dimension 1 vs. dimension 3 with density ellipses plotted at 90.0 %, 99.0 % and 99.9 %

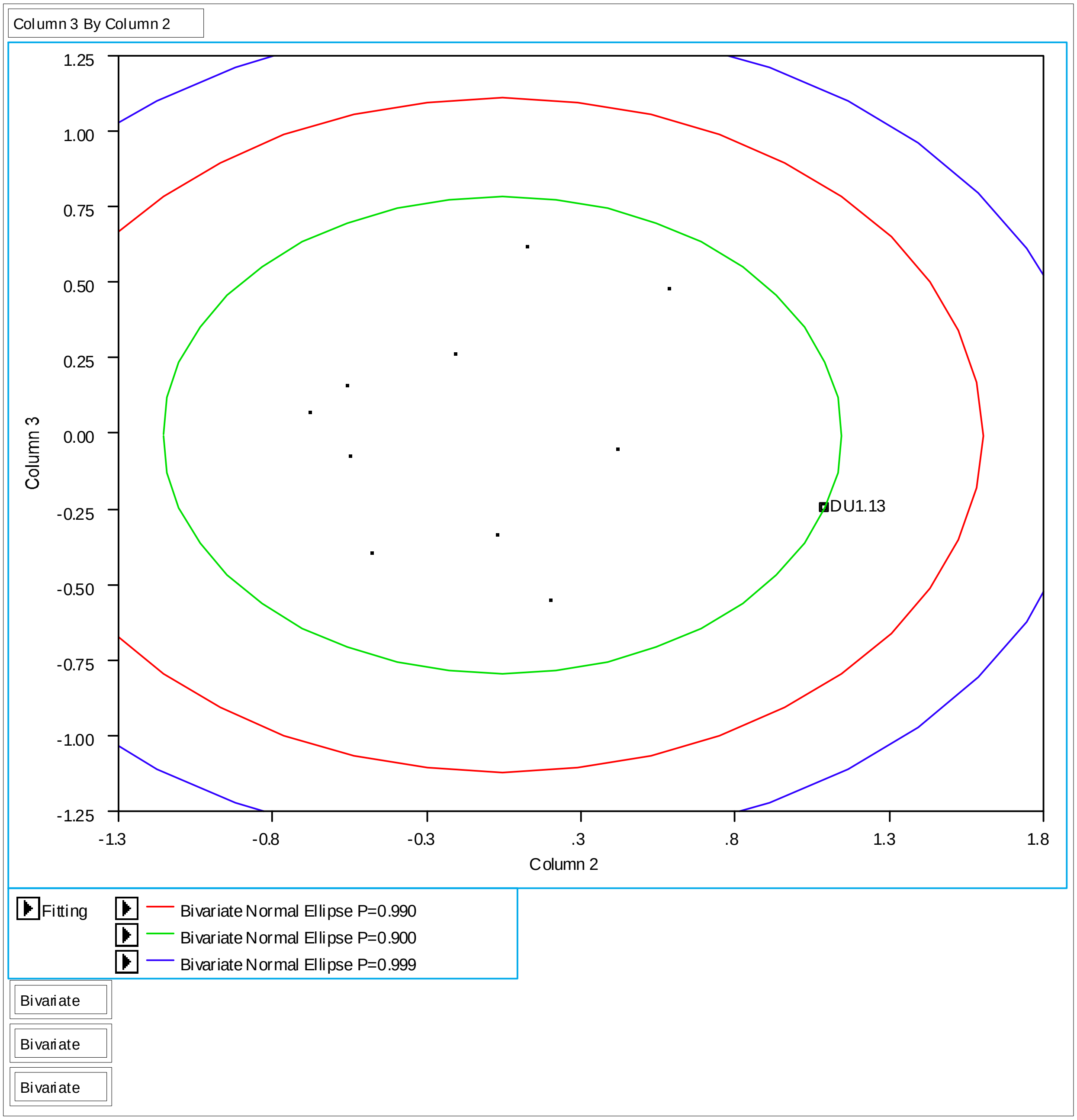


Figure 6. Reference Group 2- Scatterplot of dimension 1 vs. dimension 2 with density ellipses plotted at 90.0 %, 99.0 % and 99.9 %

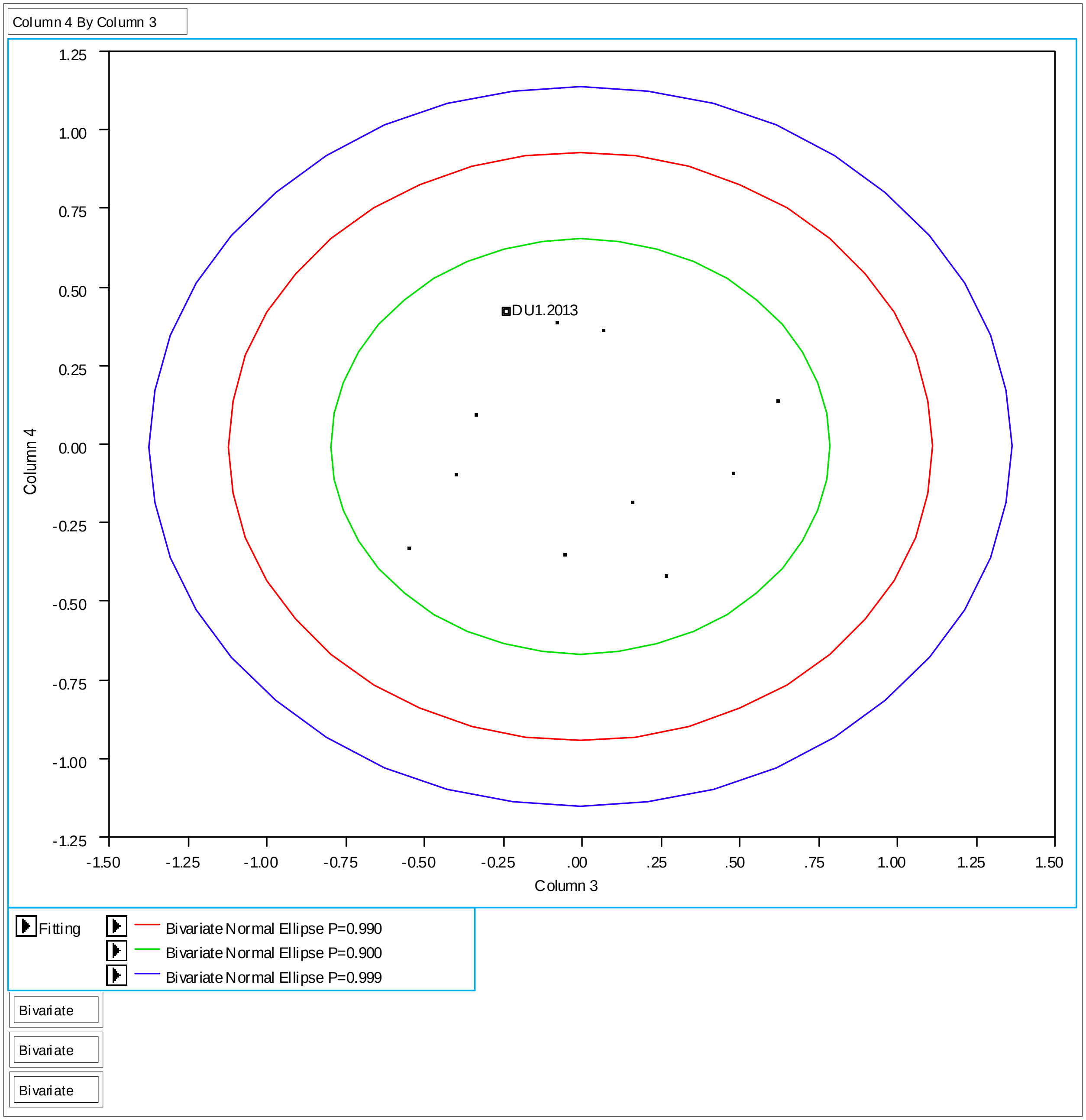


Figure 7. Reference Group 2- Scatterplot of dimension 2 vs. dimension 3 with density ellipses plotted at 90.0 %, 99.0 % and 99.9 %

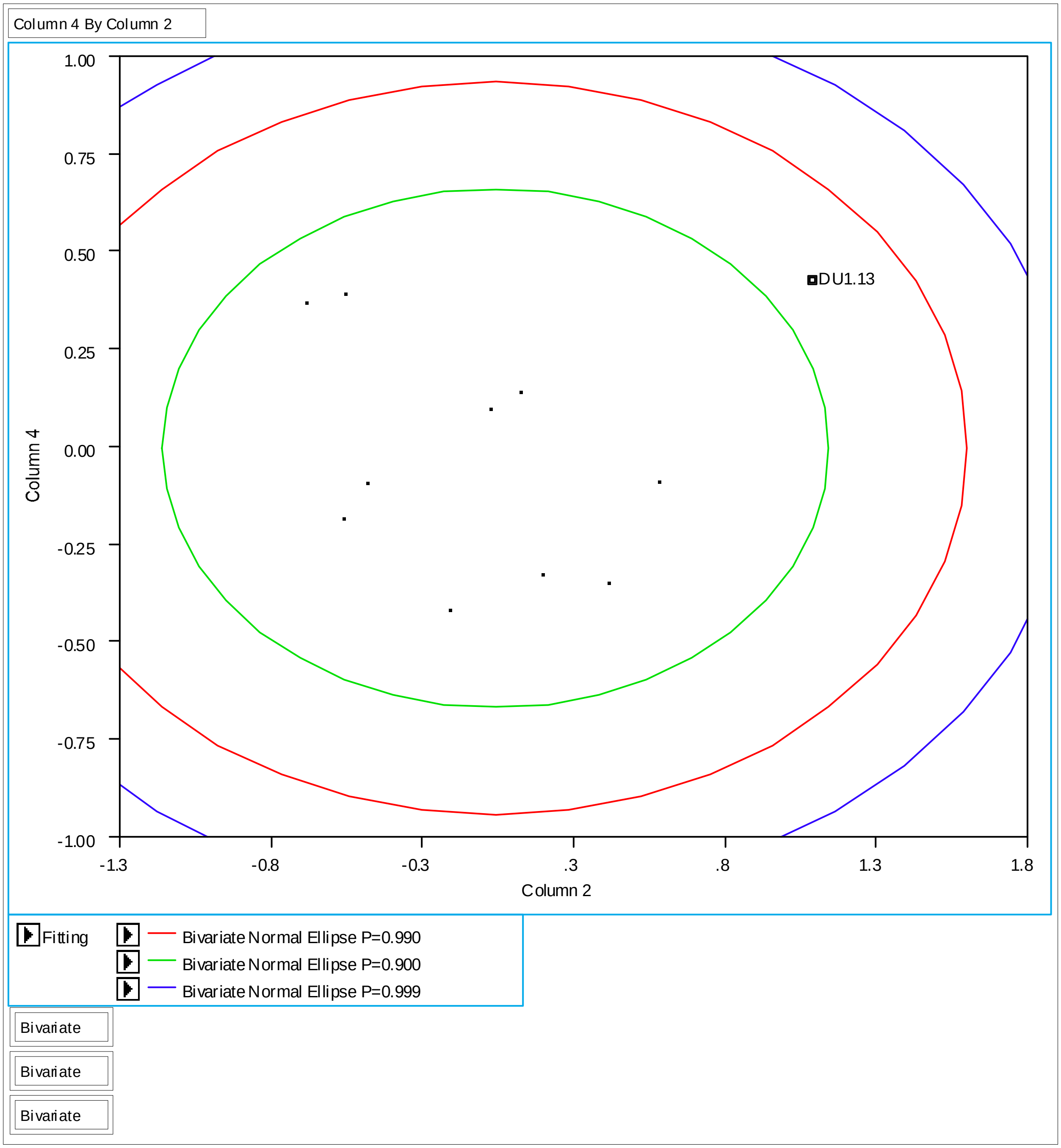


Figure 8. Reference Group 2- Scatterplot of dimension 1 vs. dimension 3 with density ellipses plotted at 90.0 %, 99.0 % and 99.9 %

5.5 Metric Calculations

The results of the metric calculations for Reference Groups 1 and 2 are provided in Tables 5.5 and 5.6 respectively.

Table 5.5. Results of the five metric calculations for Reference Group 1

Reference Group 1	EPT/ Chir.* + EPT	Shannon Index	EPT abundance	Total abundance	Mean # of taxa
BA2.06	0.95	-1.62	327.8	448.6	18.6
BA3.06	0.92	-1.76	66.4	208.00	18.0
BD1.12	0.98	-1.58	843.3	956.3	18.0
BD2.12	0.99	-1.72	1163.7	1294.0	22.0
BR1.10	0.94	-1.90	1094.4	1275.6	28.0
BR2.10	0.95	-2.30	766.4	970.2	22.8
CH1.06	0.93	-2.38	261.6	346.6	25.2
CH2.06	0.92	-2.32	696.4	899.6	24.2
EM1.05	1.00	-1.83	326.6	359.2	19.6
EM2.05	1.00	-1.14	311.8	336.8	16.2
ER3.05	0.95	-2.05	267.6	436.6	21.6
ER3.12	1.00	-2.12	3249.3	3474.0	25.0
FE1.12	0.91	-2.11	659.3	802.7	20.0
FE1.13	0.91	-2.42	582.3	757.7	24.3
FET1.12	0.86	-2.12	622.7	787.0	21.7
HA1.13	0.96	-2.41	1100.3	1315.7	21.7
HL2.06	0.97	-2.18	577.6	685.8	25.6
HL4.06	0.97	-2.00	720.2	863.4	26.0
LD2.5.12	0.97	-2.24	655.7	699.0	10.7
LD3.07	0.68	-2.33	718.8	1292.0	33.6
LD3.5.12	0.97	-1.90	910.0	1043.0	16.7
LD4.07	0.28	-2.17	225.0	964.4	29.0
LDT1.07	0.85	-2.40	294.6	543.6	29.8
LDT3.07	0.85	-2.74	441.6	628.2	32.6
LE1.06	0.89	-2.25	267.6	339.4	21.4
LE2.06	0.84	-2.37	476.2	630.0	30.8
LET1.06	0.74	-2.28	558.4	836.0	24.2
LET3.06	0.98	-1.83	765.8	848.8	19.8
MC1.04	0.89	-2.27	822.2	957.2	30.6
MC6.04	0.64	-2.27	464.2	751.6	25.0
MCT1.04	0.82	-2.09	520.2	703.2	24.2
ME2.04	0.89	-1.90	1008.6	1211.0	24.4
PET1.07	0.98	-2.06	595.4	1015.6	28.4
PET1.12	0.91	-2.30	404.3	638.7	17.0
PR1.07	0.82	-2.24	494.4	771.0	20.0
Mean	0.89	-2.10	664.6	859.7	23.33

*Chir.= Chironomidae

Table 5.6. Results of the five metric calculations for Reference Group 2

Ref. Group 2	EPT/Chir*+ EPT	Shannon Index	EPT abundance	Total abundance	Mean # of taxa
AP7.10	0.35	-2.22	107.6	416.6	17.2
FET1.13	0.49	-2.24	444.3	1016.3	20.0
FET2.13	0.71	-2.21	375.3	564.0	16.3
LD4.12	0.56	-2.19	223.0	538.7	12.3
MA1.04	0.70	-2.28	64.6	658.0	22.4
MA2.04	0.66	-2.15	172.4	289.8	17.6
MET2.04	0.78	-1.84	248.0	367.0	19.8
WH1.10	0.30	-2.30	143.4	596.8	23.4
WH1.13	0.73	-2.82	1220.7	1997.3	29.7
WH3.10	0.44	-2.26	415.2	1040.2	23.4
Mean	0.57	-2.25	341.45	748.47	20.21

*Chir.= Chironomidae

The results of the metric comparisons between each test site and the mean of their respective reference group is provided in Tables 5.7 and 5.8. The ratios of the observed value (test site metric) to the expected value (mean of the reference sites metric values from the assigned reference group) for each test site are provided in the coloured columns. Ratios that are less than 0.70 have been highlighted. The value of 0.70 was chosen arbitrarily as a threshold for presentation purposes that would indicate if a ratio was substantially lower than the mean. Ratios that are substantially higher could be indicating either an enriched community or a biodiversity hotspot (CABIN 2010). It is evident that the metrics for Reference Group 1 are in alignment with the multidimensional scaling results that showed that CH1.13 was severely divergent from the reference group condition.

Table 5.7. Comparison of Group 1 test site metrics with the mean of the Group 1 reference site metrics

Group 1	Observed	Expected	Ratio	Obs.	Exp.	Ratio	Obs.	Exp.	Ratio	Obs.	Exp.	Ratio	Obs.	Exp.	Ratio
Site	EPT/ Chir + EPT	Ref. mean	O/E	Shannon Index	Ref. mean	O/E	EPT abundance	Ref. mean	O/E	Total abundance	Ref. mean	O/E	Mean # of taxa	Ref. mean	O/E
CH1.13	0.17	0.89	0.19	-2.01	-2.10	0.96	4.3	664.6	0.01	108.3	859.7	0.13	10.0	23.3	0.43
CH2.13	0.96	0.89	1.08	-1.74	-2.10	0.83	2713.3	664.6	4.08	2966.7	859.7	3.45	24.3	23.3	1.04
EM0.5.13	0.92	0.89	1.03	-2.33	-2.10	1.11	3015.3	664.6	4.54	3464.7	859.7	4.03	32.0	23.3	1.37
EM1.13	0.93	0.89	1.04	-2.24	-2.10	1.07	797.7	664.6	1.20	975.7	859.7	1.13	25.7	23.3	1.10
EM2.13	0.99	0.89	1.11	-1.89	-2.10	0.90	1333.3	664.6	2.01	1674.3	859.7	1.95	26.0	23.3	1.12
EM3.13	0.97	0.89	1.09	-2.27	-2.10	0.95	1784.0	664.6	2.68	1913.3	859.7	2.23	22.3	23.3	0.96
EM4.13	0.94	0.89	1.06	-1.64	-2.10	0.78	1261.0	664.6	1.90	1424.3	859.7	1.66	21.3	23.3	0.92

Table 5.8. Comparison of Group 2 test site metrics with the mean of the Group 2 reference site metrics

Group 2	Observed	Expected	Ratio	Obs.	Exp.	Ratio	Obs.	Exp.	Ratio	Obs.	Exp.	Ratio	Obs.	Exp.	Ratio
Site	EPT/ Chir + EPT	Ref. mean	O/E	Shannon Index	Ref. mean	O/E	EPT abundance	Ref. mean	O/E	Total abundance	Ref. mean	O/E	Mean # of taxa	Ref. mean	O/E
DU1.13	0.98	0.57	1.71	-2.21	-2.25	0.98	3033.3	341.4	8.88	3323.7	748.5	4.44	28.3	20.2	1.40

5.6 Epililithic Algae

The results of the laboratory analysis of the epilithic algae samples collected are provided in Tables 5.9 and 5.10.

Table 5.9. Results of chlorophyll ‘a’ determined through spectrophotometry of epilithic algae scrapings from the 2013 test sites

Site Code (Test Sites)	Chlorophyll ‘a’ mg/m^2
CH1.13	6.280
CH2.13	38.810
EM0.5.13	30.930
EM1.13	0.691
EM2.13	4.595
EM3.13	4.404
EM4.13	12.297
DU1.13	1.697

Table 5.10. Results of chlorophyll ‘a’ analysis through spectrophotometry of epilithic algae scrapings from all the reference sites

Site Code (Reference Sites*)	Chlorophyll ‘a’ mg/m^2	Site Code (Reference Sites)	Chlorophyll ‘a’ mg/m^2	Site Code (Reference Sites)	Chlorophyll ‘a’ mg/m^2
BD2.12	8.600	FET1.13	12.583	LE2.06	39.790
BA2.06	11.36	FET2.13	18.995	LET1.06	10.870
BA3.06	2.270	HA1.13	21.254	LET3.06	16.650
BD1.12	4.834	HL2.06	5.770	MA1.04	15.837
CH1.06	21.060	HL4.06	3.590	MA2.04	19.220
CH2.06	11.53	LD2.5.12	4.443	MC1.04	43.547
EM1.05	0.418	LD3.07	11.133	MC6.04	1.760
EM2.05	9.541	LD3.5.12	6.659	MCT1.04	47.660
ER3.05	0.565	LD4.07	35.380	ME2.04	14.540
ER3.12	3.736	LD4.12	8.613	MET2.04	18.0430
FE1.12	6.208	LDT1.07	5.157	PET1.07	6.323
FE1.13	17.599	LDT3.07	18.547	PET1.12	6.156
FET1.12	11.160	LE1.06	6.430	WH1.13	44.661

*Six reference sites were not included because the samples did not preserve properly.

6.0 DISCUSSION

6.1 BENTHIC INVERTEBRATES

The RCA analysis found the benthic invertebrate community at test sites CH1, EM2, and DU1 to be divergent from their assigned reference groups (outside of the 90 % density ellipse as per CABIN 2010). CH1 is considered to be severely divergent and EM2 to be mildly divergent as per CABIN (2010). Test site DU1 was found to be mildly divergent from Reference Group 2. These results indicate that there are significantly different benthic invertebrate communities at these sites as compared to the test site's assigned reference group at 90 % confidence.

The metric comparisons for test site CH1 show that observed values for this site were much lower than the expected value for four of the five metrics with the Shannon Index of Diversity being the only metric that was not substantially lower. The EM2 and DU1 sites did not have substantially lower observed values relative to the expected reference for any of the five metrics. Both of these sites had higher than expected values for EPT abundance and total abundance. This may be due to nutrient enrichment upstream or possibly a hotspot within the creek where conditions are optimal.

Site CH1 exhibits a drastically altered benthic community. There was almost no EPT taxa organisms present in any of the three samples taken at the site. The EPT taxa represent the aquatic invertebrates that are considered to be generally the most sensitive to pollution and sediment (though there is a range in tolerance between different species within this group of orders). In addition to the lack of EPT members, Oligochaeta counts were found to be quite a bit higher than is common in the Group 1 reference sites. Typically, benthic environments rich in organic materials (such as algae and bacteria stimulated by sewage or nutrient runoff) support a disproportionately large abundance of oligochaetes (Hynes 1971). Tubificidae especially have long been recognized as pollution-tolerant because of their ability to thrive under poor water quality conditions and sites CH1 and CH2 were the only sites in 2013 to have this family present. At the time of sampling, this site had a covering of algae mixed with sediment present on top of the erosional substrate. The sediment and the algae were present in thickness and area that it would appear to have both greatly reduced the available habitat on surface of streambed rocks as well as the interstitial spaces between them that are usually present.

The length of impact from the CH1 site ends at the CH2 site as this site was not considered to be divergent from Reference Group 1. The zone of impact related to the DU1 test site would continue past the EM 2 site, which is the next test site downstream of Dummy Creek, and would be considered to end in the Embarras River before reaching the EM3 site.

6.2 EPILITHIC ALGAE

Results from the 2013 sampling show a large variability in algal biomass levels indicated through the chlorophyll 'a' lab analysis. The CH2 site was found to have much higher amounts of algal biomass from the samples taken as compared to reference sites and other test sites. This may indicate enrichment but could be caused by a number of different variables including low depth, low velocity and possibly a lack of cover from direct sunlight in the general area. Temperature at the time of sampling does not indicate that it was higher than average as compared to the other test sites. The water velocity is often the most influential factor of algal biomass due to removal of benthic algae from scouring by high velocity water or by ice. Other physical factors that are known to affect algal biomass are temperature, light penetration, sediment type, and turbidity. The manipulation of discharge rates or water velocities can greatly affect the epilithic algae of a watercourse. The timing of sampling and the techniques used can also influence results and preclude comparisons between historic data sets. As such, it is difficult to assess the source of the variability due to the multiple number of factors or groups of factors that can influence measurement results.

The EM0.5 site also had higher algal biomass results than all the other Embarras River test sites and the majority of the Reference Group 1 sites. The presence of three pit lakes a short distance upstream of this site is expected to contribute nutrients downstream. The pit lakes would certainly be more productive than a lotic environment in the same area and is likely the reason for the higher biomass at the EM0.5 site.

6.3 DATA GAPS AND FUTURE DESIGN

The mean variance calculated from all the sites sampled in 2012 and 2013 indicates (through power analysis) that 5 replicates per site will enable 83 % of the sites to be sampled with 95 % confidence and a precision index of 20 %. Through power analysis it was found that 7 sites had a higher variance than the other 40 sites sampled in 2012 and 2013 and would require a higher number of replicates to achieve 95 % confidence and a precision index of 20 %. Also to note is that a large number of the sample sites would not have enough erosional area to allow for more than 5 samples to be taken without the establishment of an additional site on the same watercourse. The increase from 3 to 5 replicates sampled per site is recommended for future sampling due to the high variance present in a portion of the benthic habitat sampled in 2012 and 2013.

The calculation of additional metrics from the list suggested in CABIN (2010) is recommended to provide more information for the use of interpretation of the RCA analysis. New metrics would be screened so that they were ecologically relevant to the biological community and sensitive to the stressors in a way that is distinguishable from natural variation.

7.0 REFERENCES

Alberta Environment 2006. Aquatic Ecosystems Field Sampling Protocols. Alberta Environmental Protection, Surface Water Assessment Branch.

Bowman, F. M. and K. M. Somers. 2005. Considerations when using the Reference Condition Approach for bioassessment of freshwater ecosystems. Water Quality Resources Journal of Canada. Vol 40, n3, 347-360.

CABIN. 2010. Canadian Aquatic Biomonitoring Network website. (http://www.ec.gc.ca/rcba-cabin/default.asp?lang=En&n=72AD8D96-1)

Environment Canada. 2010. Pulp and paper EEM guidance document. Environment Canada, National EEM Office, Gatineau, Quebec.

Environment Canada. 1993. Guidelines for Monitoring Benthos in Freshwater Environments. Prepared for Environment Canada by EVS Consultants.

Hynes, H.B.N. 1971. The Biology of Polluted Waters. Toronto, Ontario: University of Toronto Press.

Moss, B., 1967(a). A note on the estimation of chlorophyll ‘a’ in freshwater algal communities. Limnol. Oceanogr. 12:340-342.

Moss, B., 1967(b). A spectrophotometric method for the estimation of percentage degradation of chlorophylls to pheo-pigments in extracts of algae. Limnol. Oceanogr. 12:335-340.

Pisces 2013. Benthic Invertebrate Biomonitoring Program for the Coal Valley Mine: Pembina River and McLeod River Drainages. Prepared for Coal Valley Resources Inc. 24 pp. + Appendices.

Strahler, A.N. 1964. Quantitative geomorphology of drainage basins and channel networks; section 4-2, in Handbook of Applied Hydrology, ed. Ven te Chow, McGraw-Hill, New York.

Appendix A

Benthic Invertebrate Sample Processing Methods

Method Used for Picking Animals and Taxonomy

The picking of animals was performed in accordance with the process developed by Wrona et al. (1982), with slight modifications. This procedure has been used for many years. It provides a good estimate of animal population in aquatic systems based on samples.

The Picking and Sub Sampling Process

The whole sample is washed through double stacked 2 mm and 106 μm meshes. All the animals that remain on the 2 mm mesh (coarse fraction) are picked. The fine fraction from the 106 μm mesh is put into an aeration apparatus and diluted with water until the total sample plus water volume is 1 litre. The sample is aerated, and when well mixed, five 50 mL sub samples are taken out of the aeration apparatus. The entire sub samples are picked using a compound microscope at 10 times magnification for the course fraction and 40 times magnification for the fine fraction. Once picking has been completed, the course and fine fraction are saved for quality assurance. The total of animals in each sub sample is determined for all taxa. After the samples are picked, quality assurance is performed to confirm that no visible animals are left in the sample.

All the animals are classified using the keys: '*Aquatic Invertebrates*' of Alberta by Hugh F. Clifford (1991), '*Ecology and Classification of North American Freshwater Invertebrates*' by James H. Thorp and Alan P. Covich (1991), and '*Fresh Water Invertebrates of the United States*' by Robert W. Pennak (1978).

The complete hierarchical classification through Phylum, Class, Order, Family, Genus, and Species is attempted for all taxa. However, in some cases when parts of the animals are missing, complete classification cannot be performed. In that case, classification was performed to the level recognizable to the taxonomer.

Reference:

Wrona, F.J., Culp, J.M. and Davies, R.W. 1982. *Macroinvertebrate subsampling: a simplified apparatus and approach*. Can. J. Fish. Aquat. Sci. 39:1051-1054

Appendix B

Raw Benthic Invertebrate Identification Data

Sites EM0.5.13, EM1.13 and EM2.13

Taxon	EM0.5-1	EM0.5-2	EM0.5-3	EM1-1	EM1-2	EM1-3	EM2-1	EM2-2	EM2-3
Ephemeroptera									
Baetidae									
Baetis sp.	595	1619	2162	210	604	425	627	1103	921
nymph									
Ephemerellidae									
Drunella sp.	1		1	3	10	8	6	2	3
Ephemerella sp.	16	11	22	11	2	34	36	17	21
Serratella sp.	112	161	133	16	32	23	41	32	51
Heptageniidae									
Rhithrogena sp.	1	1		6	10	29	32	1	13
Cinygmula sp.	139	110	118	99	31	98	130	95	58
Stenonema sp.									
Pseudiron sp.		90	85	45	30	85	30	15	25
Epeorus sp.					3	1			
Leptophlebiidae									
Paraleptophlebia sp.	96	100	103	12					
Siphlonuridae									
Parameletus sp.	24	10							
Plecoptera									
Chloroperlidae	14	61	21	25	2	10	18	10	12
Leuctridae	13	30							
Nemouridae									
Nemoura sp.	14		30						
Zapada sp.	205	155	294	36	62	73	73	40	81
Perlidae									
Claassenia sp.									
Hesperoperla sp.	1	1	4	4	10	21	10	4	1
Perlodidae	104	250	482	56	50	60	72	71	80
Diura sp.									
Cultus sp.	20	41	13	8	11	20	1	21	20
Megarcys sp.			1	2	1		1		
Isogenoides sp.				1					
Isoperla sp.	8	95	49	8	20	1	1		11
Perlinodes sp.	1								
Capniidae	53	60					4		
Hemiptera									
Veliidae									
adult							1		
Mesoveliidae									
Mesovelia sp.			10						
adult									
Corixidae									
adult									
Notonectidae									
Saldidae									

Sites EM0.5.13, EM1.13 and EM2.13

Taxon	EM0.5-1	EM0.5-2	EM0.5-3	EM1-1	EM1-2	EM1-3	EM2-1	EM2-2	EM2-3
Trichoptera									
Brachycentridae									
Brachycentrus sp.	13	40	122				34	102	11
Micrasema sp.	21	71	613	24		1	4		10
Glossosomatidae									
Glossosoma sp.	2	62	40	8	1		8		
Hydropsychidae									
Hydropsyche sp.									
Arctopsyche sp.					2			4	3
Parapsyche sp.					2	17	2	1	
Hydroptilidae									
Oxyethira sp.									
Hydroptila sp.	8	30	61						
Limnephilidae									
Rhyacophilidae									
Rhyacophila sp.	31	55	147	4	5	21	5	23	3
Polycentropodidae									
Polycentropus sp.									
pupae									
Coleoptera									
Elmidae	19	3	11	2	1	11	1	1	10
Narpus sp.	20	99	81	51	42	120	15	9	21
adult		9	11		1		10	9	
Hydrophilidae									
adult									
Chrysomelidae									
Hydrophilidae									
Haliplidae									
Diptera									
Ceratopogonidae									
Ceratopogoninae			1			1		11	1
Chironomidae									
Orthocladiinae	16	70	103	8	30	51		10	11
Tanypodinae			2						
Tanytarsini	4	41	31		10	20			
Chironomini	40	69	443	8	50	10			
Pupae	1							10	
adult									
Empididae								1	
Simuliidae	8	10					4	722	57
Pupae							4		
adult									

Sites EM0.5.13, EM1.13 and EM2.13

Taxon	EM0.5-1	EM0.5-2	EM0.5-3	EM1-1	EM1-2	EM1-3	EM2-1	EM2-2	EM2-3
Diptera continued									
Tipulidae									
Tipulinae									
Tipula sp.									
Limoniinae									
Dicranota sp.	9	30	12				4		
Antocha sp.					10		8	10	
Hexatoma sp.									
Pupae									
Tabanidae									
Psychodidae									
Pericoma/ Telmatoscopus	4		11	12		12	4		20
Athericidae									
Atherix sp.									
Chaoboridae									
Chaoborus sp.									
Nematoda									
Oligochaeta									
Naididae									
Specaria sp.					10				
Lumbriculidae									
Lumbriculus sp.									
Tubificidae									
Arachnida									
Acari									
Hydrachnidia	24	39	51	12	52	10	16		50
Stygothrombididae									
Hydrothrombium sp.									
Araneae									
Pisauridae									
Dolomedes triton									
Crustacea									
Ostracoda									
Cyprididae	16	30	30						
Copepoda									
Cyclopoida							4		
Harpacticoida									
Gastropoda									
Valvatidae			1						
Hydrobiidae								1	

Sites EM3.13, EM4.13 and DU1.13

Taxon	EM3-1	EM3-2	EM3-3	EM4-1	EM4-2	EM4-3	DU1-1	DU1-2	DU1-3
Ephemeroptera									
Baetidae									
Baetis sp.	780	461	1606	302	680	1769	1041	850	845
nymph									
Ephemerellidae									
Drunella sp.	6	1	3	1	2	5	27	14	33
Ephemerella sp.				2				10	
Serratella sp.	10		1			1	210	230	99
Heptageniidae									
Rhithrogena sp.	19	49	45	13	41	39			
Cinygmula sp.	299	228	306	65	201	15	384	501	714
Stenonema sp.									
Pseudiron sp.	27	70	60	25	63	5	63	30	65
Epeorus sp.						2	3		1
Leptophlebiidae									
Paraleptophlebia sp.			10						
Siphlonuridae									
Parameletus sp.	10	30					20		20
Plecoptera									
Chloroperlidae	76	39	82	32	36	17			11
Leuctridae	10		40						
Nemouridae									
Nemoura sp.									
Zapada sp.	83	76	188	20	10	73	640	713	661
Perlidae									
Claassenia sp.									
Hesperoperla sp.	19	17	11	2	4	29			
Perlodidae	71	60	201		10	70	450	460	222
Diura sp.									
Cultus sp.	21		10					1	1
Megarcys sp.							4	2	18
Isogenoides sp.		1		1	10				
Isoperla sp.				10					
Perlinodes sp.									
Capniidae	10	30	111	30	10	20	110	60	100
Hemiptera									
Veliidae									
adult									
Mesoveliidae									
Mesovelia sp.									
adult									
Corixidae							11		
adult									
Notonectidae									
Saldidae									

Sites EM3.13, EM4.13 and DU1.13

Taxon	EM3-1	EM3-2	EM3-3	EM4-1	EM4-2	EM4-3	DU1-1	DU1-2	DU1-3
Trichoptera									
Brachycentridae									
Brachycentrus sp.	32	50	10			102	11		2
Micrasema sp.	10	20	9				1		1
Glossosomatidae									
Glossosoma sp.						1	50	50	30
Hydropsychidae									
Hydropsyche sp.									
Arctopsyche sp.		2		1		41	11	11	
Parapsyche sp.					1			21	21
Hydroptilidae									
Oxyethira sp.									
Hydroptila sp.									
Limnephilidae							40	22	22
Rhyacophilidae									
Rhyacophila sp.	32	10			21	1	58	66	67
Polycentropodidae									
Polycentropus sp.									
pupae									3
Coleoptera									
Elmidae	4						27	5	6
Narpus sp.	6	10	2	10			33	55	81
adult							16	59	14
Hydrophilidae									
adult									
Chrysomelidae									
Hydrophilidae									
Haliplidae									
Diptera									
Ceratopogonidae									
Ceratopogoninae									
Chironomidae									
Orthocladiinae	20	20		101	50	22	74	22	40
Tanypodinae									9
Tanytarsini	31	10	10					10	
Chironomini	40		31	10	10	30			
Pupae						19		1	11
adult							11	5	
Empididae			10	11	11	1			10
Simuliidae	30		113			43	10		
Pupae									
adult									

Sites EM3.13, EM4.13 and DU1.13

Taxon	EM3-1	EM3-2	EM3-3	EM4-1	EM4-2	EM4-3	DU1-1	DU1-2	DU1-3
Diptera continued									
Tipulidae									
Tipulinae									
Tipula sp.									
Limoniinae									
Dicranota sp.				10	9			30	10
Antocha sp.						11			
Hexatoma sp.		1						6	1
Pupae									
Tabanidae									
Psychodidae									
Pericoma/ Telmatoscopus								20	3
Athericidae									
Atherix sp.				1					
Chaoboridae									
Chaoborus sp.									
Nematoda								39	1
Oligochaeta									
Naididae									
Specaria sp.				20	10	11		11	
Lumbriculidae									
Lumbriculus sp.								1	
Tubificidae									
Arachnida									
Acari									
Hydrachnidia	20	20	10	50	21	20	90	131	60
Stygothrombididae									
Hydrothrombium sp.						9			
Araneae									
Pisauridae									
Dolomedes triton									
Crustacea									
Ostracoda									
Cyprididae									
Copepoda									
Cyclopoida									
Harpacticoida									9
Gastropoda									
Valvatidae									
Hydrobiidae									

Sites CH1.13, CH2.13 and FET1.13

Taxon	CH1-1	CH1-2	CH1-3	CH2-1	CH2-2	CH2-3	FET1-1	FET1-2	FET1-3
Ephemeroptera									
Baetidae									
Baetis sp.				2002	704	1568	10	130	30
nymph									
Ephemerellidae									
Drunella sp.					3				
Ephemerella sp.				6	6	11			
Serratella sp.				40	5	10			
Heptageniidae									
Rhithrogena sp.									
Cinygmula sp.	11			120	99	188	121	58	
Stenonema sp.									
Pseudiron sp.				20	5	15	30	23	
Epeorus sp.							2	9	
Leptophlebiidae									
Paraleptophlebia sp.									
Siphlonuridae									
Parameletus sp.							30		
Plecoptera									
Chloroperlidae			1	10	9	19			1
Leuctridae				1			1	11	1
Nemouridae									
Nemoura sp.									
Zapada sp.				890	166	466	157	333	159
Perlidae									
Claassenia sp.									
Hesperoperla sp.									
Perlodidae				807	145	390	22	31	
Diura sp.									
Cultus sp.					13				
Megarcys sp.							13	11	12
Isogenoides sp.							1		
Isoperla sp.				1	2	1			
Perlinodes sp.									
Capniidae				60	24	121	10	10	10
Hemiptera									
Veliidae									
adult									
Mesoveliidae									
Mesovelia sp.									
adult									
Corixidae				2					
adult									
Notonectidae				10					
Saldidae									

Sites CH1.13, CH2.13 and FET1.13

Taxon	CH1-1	CH1-2	CH1-3	CH2-1	CH2-2	CH2-3	FET1-1	FET1-2	FET1-3
Trichoptera									
Brachycentridae									
Brachycentrus sp.				40	4	144			30
Micrasema sp.					1				20
Glossosomatidae									
Glossosoma sp.									
Hydropsychidae									
Hydropsyche sp.									
Arctopsyche sp.				1		3			
Parapsyche sp.				1					
Hydroptilidae									
Oxyethira sp.									
Hydroptila sp.									
Limnephilidae								1	1
Rhyacophilidae									
Rhyacophila sp.			1	11	8		21	20	14
Polycentropodidae									
Polycentropus sp.									
pupae									
Coleoptera									
Elmidae				12					
Narpus sp.	21	12	14		32	54	9	1	31
adult	1			11	5	11	20	11	
Hydrophilidae									
adult									
Chrysomelidae									
Hydrophilidae									
Haliplidae									
Diptera									
Ceratopogonidae									
Ceratopogoninae									
Chironomidae									
Orthocladiinae	20	10	16	101	56	62	162	363	257
Tanypodinae									
Tanytarsini							151	40	50
Chironomini		11	4	99	4		42	96	191
Pupae				1				11	12
adult			1						
Empididae		11		20					1
Simuliidae				1		40		10	41
Pupae			5				1		1
adult									

Sites CH1.13, CH2.13 and FET1.13

Taxon	CH1-1	CH1-2	CH1-3	CH2-1	CH2-2	CH2-3	FET1-1	FET1-2	FET1-3
Diptera continued									
Tipulidae									
Tipulinae									
Tipula sp.	1					2			
Limoniinae									
Dicranota sp.	1		20		4	20	10	21	11
Antocha sp.									
Hexatoma sp.	11							1	
Pupae									
Tabanidae									
Psychodidae									
Pericoma/ Telmatoscopus						1			
Athericidae									
Atherix sp.									
Chaoboridae									
Chaoborus sp.			1						
Nematoda		9	1	1					
Oligochaeta									
Naididae									
Specaria sp.	34	21	6	60	4	10			
Lumbriculidae									
Lumbriculus sp.				2		1			
Tubificidae	32	19		1	4				
Arachnida									
Acari									
Hydrachnidia	31		5	50	40	40	40	30	30
Stygothrombididae									
Hydrothrombium sp.									
Araneae									
Pisauridae									
Dolomedes triton			5						
Crustacea									
Ostracoda									
Cyprididae					4		51	21	
Copepoda									
Cyclopoida			4		8				
Harpacticoida									
Gastropoda									
Valvatidae									
Hydrobiidae									

Sites FET2.13, FE1.13, WH1.13 and HA1.13

Taxon	FET2-1	FET2-2	FET2-3	FE1-1	FE1-2	FE1-3	WH1-1	WH1-2	WH1-3	HA1-1	HA1-2	HA1-3
Ephemeroptera												
Baetidae												
Baetis sp.	1	40	53	251	194	165	80	183	131	191	420	110
nymph												
Ephemerellidae												
Drunella sp.			1	3	7	5						
Ephemerella sp.						1	11	3	30	20		10
Serratella sp.			10	1			21	7	71	160	61	61
Heptageniidae												
Rhithrogena sp.				31	24	15	10					1
Cinygmula sp.	165	146	119	60	121	162	9	71	41	19	30	11
Stenonema sp.				20	8	16	72	11	1			
Pseudiron sp.	35	45	21				40	90	190	110	30	61
Epeorus sp.		4		3	18	1						
Leptophlebiidae												
Paraleptophlebia sp.				30	4	12	90	111	247			
Siphlonuridae												
Parameletus sp.			20				11	30	72		11	
Plecoptera												
Chloroperlidae	1	11	11	10	8	5	21	11	53	181	204	102
Leuctridae		10	10	10	8	12			21		20	10
Nemouridae	30											
Nemoura sp.												
Zapada sp.	50	193	73	111	70	68	50	115	63	106	378	83
Perlidae												
Claassenia sp.							11	5	13			
Hesperoperla sp.				12	8	1	14	42	121		2	
Perlodidae		20	11	30	64	28		20		50	20	30
Diura sp.			8									
Cultus sp.							11	44	72		10	
Megarcys sp.	10	15		1		1					1	1
Isogenoides sp.										1		
Isoperla sp.							10	15	12	14	24	10
Perlinodes sp.												
Capniidae	11			20	40	28	30	20	51	180	280	201
Hemiptera												
Veliidae												
adult												
Mesoveliidae												
Mesovelia sp.			10									
adult												
Corixidae												
adult												
Notonectidae												
Saldidae									20	1		

Sites FET2.13, FE1.13, WH1.13 and HA1.13

Taxon	FET2-1	FET2-2	FET2-3	FE1-1	FE1-2	FE1-3	WH1-1	WH1-2	WH1-3	HA1-1	HA1-2	HA1-3
Trichoptera												
Brachycentridae												
Brachycentrus sp.								11				
Micrasema sp.							150	415	365			
Glossosomatidae												
Glossosoma sp.										10	10	10
Hydropsychidae												
Hydropsyche sp.									1			
Arctopsyche sp.							2					
Parapsyche sp.				1	1	1						
Hydroptilidae												
Oxyethira sp.							10		30			
Hydroptila sp.												
Limnephilidae			1						31			
Rhyacophilidae												
Rhyacophila sp.	1			20	28	9	21	74	84	11	45	1
Polycentropodidae												
Polycentropus sp.									10			
pupae												
Coleoptera												
Elmidae									3	30	2	
Narpus sp.	10			10	4	12		10	69	131	58	51
adult	9	8		9		11		31	11	20	35	40
Hydrophilidae												
adult												
Chrysomelidae												
Hydrophilidae												
Haliplidae											1	
Diptera												
Ceratopogonidae												
Ceratopogoninae							10					
Chironomidae												
Orthocladiinae	81	30	40	21	4	12	160	314	121	10	61	40
Tanypodinae							11	41	87		10	
Tanytarsini	90	110	60	30	40	48	120	211	200			13
Chironomini	21		11		4	8	23	60	17			
Pupae			6									
adult												1
Empididae	1	10	10	10		4			40		1	
Simuliidae				10	8						72	
Pupae		9										
adult												

Sites FET2.13, FE1.13, WH1.13 and HA1.13

Taxon	FET2-1	FET2-2	FET2-3	FE1-1	FE1-2	FE1-3	WH1-1	WH1-2	WH1-3	HA1-1	HA1-2	HA1-3
Diptera continued												
Tipulidae												
Tipulinae												
Tipula sp.												
Limoniinae												
Dicranota sp.									10			
Antocha sp.									2			
Hexatoma sp.												
Pupae												
Tabanidae						4	12	1	21			
Psychodidae												
Pericoma / Telmatoscopus				9	8	12			21			
Athericidae												
Atherix sp.												
Chaoboridae												
Chaoborus sp.												
Nematoda												
Oligochaeta												
Naididae												
Specaria sp.									12		10	
Lumbriculidae												
Lumbriculus sp.											1	
Tubificidae												
Arachnida												
Acari												
Hydrachnidia	20	30	10	60	112	76	150	251	311	10	20	20
Stygothrombididae												
Hydrothrombium sp.												
Araneae												
Pisauridae												
Dolomedes triton												
Crustacea												
Ostracoda												
Cyprididae										9		
Copepoda												
Cyclopoida												
Harpacticoida												
Gastropoda												
Valvatidae												
Hydrobiidae												

--this page left blank for printing purposes--

Appendix C

Benthic Invertebrate Count Data Summaries

Test Sites-Count data summaries

Taxon	EM0.5.13			EM1.13			EM2.13			EM3.13		
	mean	% total	SE	mean	% total	SE	mean	% total	SE	mean	% total	SE
Ephemeroptera	1903.33	54.94	483.74	609.00	62.42	103.65	1086.33	64.88	104.83	1340.33	70.05	356.89
Plecoptera	673.33	19.43	133.44	160.33	16.43	13.17	177.00	10.57	17.10	385.33	20.14	130.28
Trichoptera	438.67	12.66	277.25	28.33	2.90	9.21	70.00	4.18	30.92	58.33	3.05	19.80
Coleoptera	84.33	2.43	22.78	76.00	7.79	27.62	25.33	1.51	3.48	7.33	0.38	2.67
Chironomidae	273.33	7.89	156.65	62.33	6.39	23.31	10.33	0.62	5.78	54.00	2.82	18.77
Other Diptera	28.33	0.82	5.90	11.67	1.20	0.88	282.00	16.84	231.53	51.33	2.68	36.80
Oligochaeata	0.00	0.00	0.00	3.33	0.34	3.33	0.00	0.00	0.00	0.00	0.00	0.00
Acari	38.00	1.10	7.81	24.67	2.53	13.68	22.00	1.31	14.74	16.67	0.87	3.33
Crustacea	25.33	0.73	4.67	0.00	0.00	0.00	1.33	0.08	1.33	0.00	0.00	0.00
Other	3.67	0.11	3.67	0.00	0.00	0.00	0.67	0.04	0.33	0.00	0.00	0.00
Total Individuals	3464.67	100.00	1049.35	975.67	100.00	153.59	1674.33	100.00	335.38	1913.33	100.00	496.02
Number of Taxa	32.0	100.00	1.00	25.7	100.00	0.67	26.0	100.00	1.5	22.3	100.00	0.9
Shannon Index	2.33	x	0.05	2.24	x	0.16	1.89	x	0.10	2.27	x	0.33
Taxon	EM4.13			DU1.13			CH1.13			CH2.13		
	mean	% total	SE	mean	% total	SE	mean	% total	SE	mean	% total	SE
Ephemeroptera	1077.00	75.61	414.68	1720.00	51.75	43.32	3.67	3.38	3.67	1600.67	53.96	405.77
Plecoptera	128.00	8.99	40.73	1151.00	34.63	69.62	0.33	0.31	0.33	1041.67	35.11	407.64
Trichoptera	56.00	3.93	44.91	162.33	4.88	8.17	0.33	0.31	0.33	71.00	2.39	39.72
Coleoptera	3.33	0.23	3.33	98.67	2.97	12.47	16.00	14.77	3.06	41.67	1.40	12.35
Chironomidae	80.67	5.66	15.50	61.00	1.84	13.58	20.67	19.08	0.33	107.67	3.63	46.67
Other Diptera	32.33	2.27	11.35	30.00	0.90	13.61	16.67	15.38	4.70	29.33	0.99	17.53
Oligochaeata	13.67	0.96	3.18	4.00	0.12	4.00	37.33	34.46	17.37	27.33	0.92	17.85
Acari	33.33	2.34	8.65	93.67	2.82	20.58	12.00	11.08	9.61	43.33	1.46	3.33
Crustacea	0.00	0.00	0.00	3.00	0.09	3.00	1.33	1.23	1.33	4.00	0.13	4.00
Other	0.00	0.00	0.00	18.33	0.55	10.48	5.00	4.62	2.65	0.33	0.01	0.33
Total Individuals	1424.33	100.00	486.25	3323.67	100.00	66.94	108.33	100.00	27.39	2966.67	100.00	876.11
Number of Taxa	21.3	100.00	1.5	28.3	100.00	2.6	10.0	100.00	1.7	24.33	100.00	1.20
Shannon Index	1.64	x	0.24	2.21	x	0.03	2.01	x	0.10	1.74	x	0.03

Reference Sites-Count data summaries

Taxon	FET1.13			FET2.13			FE1.13			WH1.13		
	mean	% total	SE	mean	% total	SE	mean	% total	SE	mean	% total	SE
Ephemeroptera	147.67	14.53	59.35	220.00	39.01	10.02	384.00	50.68	7.51	544.33	27.25	128.17
Plecoptera	261.00	25.68	67.77	154.67	27.42	47.27	178.33	23.54	17.70	275.00	13.77	74.78
Trichoptera	35.67	3.51	14.67	0.67	0.12	0.33	20.00	2.64	5.51	401.33	20.09	109.33
Coleoptera	24.00	2.36	6.03	9.00	1.60	5.51	15.33	2.02	5.78	41.33	2.07	23.96
Chironomidae	458.33	45.10	51.67	149.67	26.54	22.18	55.67	7.35	6.23	455.00	22.78	91.31
Other Diptera	32.33	3.18	12.41	10.00	1.77	5.20	21.67	2.86	3.84	39.00	1.95	28.16
Oligochaeata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00	0.20	4.00
Acari	33.33	3.28	3.33	20.00	3.55	5.77	82.67	10.91	15.38	237.33	11.88	46.98
Crustacea	24.00	2.36	14.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other	0.00	0.00	0.00	3.33	0.59	3.33	0.00	0.00	0.00	0.00	0.00	0.00
Total Individuals	1016.33	100.00	112.83	564.00	100.00	61.09	757.67	100.00	20.54	1997.33	100.00	437.34
Number of Taxa	20.0	100.00	1.0	16.3	100.00	0.9	24.33	100.00	1.20	29.67	100.00	2.67
Shannon Index	2.24	x	0.08	2.21	x	0.01	2.42	x	0.02	2.82	x	0.11

Taxon	HA1.13		
	mean	% total	SE
Ephemeroptera	435.33	33.09	91.90
Plecoptera	636.00	48.34	153.96
Trichoptera	29.00	2.20	13.32
Coleoptera	122.67	9.32	29.20
Chironomidae	45.00	3.42	18.18
Other Diptera	24.33	1.85	24.33
Oligochaeata	3.67	0.28	3.67
Acari	16.67	1.27	3.33
Crustacea	3.00	0.23	3.00
Other	0.00	0.00	0.00
Total Individuals	1315.67	100.00	275.50
Number of Taxa	21.7	100.00	2.3
Shannon Index	2.41	x	0.03

--this page left blank for printing purposes--

Appendix D

Statistical Analysis: Results of Multi-Dimensional Scaling

Proximities

Case Processing Summary[a]

Cases							
		Rejected					
Valid		Missing Value		Negative Value		Total	
N	Percent	N	Percent	N	Percent	N	Percent
42	100.0%	0	.0%	0	.0%	42	100.0%

a. Phi-square between Sets of Frequencies used

Proxscal

Credit

Proxscal
Version 1.0
by
Data Theory Scaling System Group (DTSS)
Faculty of Social and Behavioral Sciences
Leiden University, The Netherlands

Case Processing Summary

Cases		42
Sources		1
Objects		42
Proximities	Total Proximities	861[b]
	Missing Proximities	0
	Active Proximities[a]	861

a. Active proximities include all non-missing proximities.

b. Sum of all strictly lower-triangular proximities.

Goodness of Fit

Stress and Fit Measures

Normalized Raw Stress	.02095
Stress-I	.14475(a)
Stress-II	.35029(a)
S-Stress	.04741(b)
Dispersion Accounted For (D.A.F.)	.97905
Tucker's Coefficient of Congruence	.98947

PROXSCAL minimizes Normalized Raw Stress.
a Optimal scaling factor = 1.021.
b Optimal scaling factor = .991.

Common Space- (D-Scores)

Ref. Sites	Dim1	Dim2	Dim3
EM2.05	0.710798	-0.09376	0.146531
EM1.05	0.84833	-0.02596	0.184296
ER3.12	0.372081	0.420985	-0.54631
FE1.12	0.258517	0.000902	0.054097
LD3.5.12	0.002544	0.30777	-0.01707
LD4.07	0.127523	0.29758	0.167435
PET1.12	-0.10153	0.24417	-0.90559
PET1.07	0.146171	0.360152	0.265921
BD1.12	0.218213	-0.53234	-0.09484
BD2.12	0.366251	-0.31722	0.033935
LD2.5.12	0.320455	-0.39135	-0.31459
PR1.07	0.102841	-0.26004	-0.59525
FE2.12	0.387838	-0.30089	0.620171
ER3.05	0.372081	0.420985	-0.54631
BA3.06	-0.97746	0.530547	0.622867
LDT1.07	-0.75222	0.359988	0.051985
ME2.04	-0.63607	0.311014	0.341834
MCT1.04	-0.26839	-0.28001	0.217494
LE2.06	-0.08595	-0.1581	-0.02394
MC1.04	-0.17146	-0.47815	-0.14818
MC6.04	-0.48247	-0.62023	-0.32448
LET1.06	-0.85477	-0.17848	0.320767
CH1.06	-0.44217	0.055032	0.203175
CH2.06	-0.20546	-0.1116	0.444847
BA2.06	-0.83772	-0.16152	-0.03392
HL2.06	-0.41882	-0.24766	0.047509
LET3.06	-0.0348	-0.303	-0.26679
HL4.06	-0.05068	-0.29139	-0.05912
BR2.10	-0.21776	0.007934	-0.12245
LE1.06	-0.2855	-0.08433	-0.18552
LDT3.07	-0.51981	0.052645	-0.37347
BR1.10	-0.35937	-0.47901	-0.67462
LD3.07	0.002544	0.30777	-0.01707
FE1.2013	0.286975	0.044217	-0.14362
HA1.2013	-0.20957	0.351394	0.493131
Test Sites	**Dim1**	**Dim2**	**Dim3**
EM0.5.13	0.260057	-0.02213	0.382649
EM1.13	0.266694	-0.04158	0.293179
EM2.13	0.761871	-0.14416	0.49587
EM3.13	0.488329	-0.26058	0.081634
EM4.13	0.721175	-0.0809	0.067558
CH1.13	0.246563	1.60228	-0.40483
CH2.13	0.644142	0.189026	0.261094

Report #13

Pisces Environmental Consulting Services Ltd.
•Unit 118, 239 Spruce Street• Red Deer County • Alberta • T4E 1B4•
• Phone 403-347-5418 • Fax 403-347-0681•
•www.piscesenvironmental.com•

Westmoreland Coal Company
Bag 5000
Edson, Alberta T7E 1W1

January 30, 2015

ATTN: Kari McDonald

RE: 2014 interim results for temperature investigations conducted within the Erith River drainage within Coal Valley Mine's Robb Trend Lease and within the reclaimed Southblock area.

Dear Kari,

Pisces Environmental Consulting Services Ltd (Pisces) on behalf of Westmoreland Coal Company (WMCC) initiated supplemental stream temperature monitoring within the Erith River drainage and the Southblock Lake's area in 2013. This document provides a summary of temperature logging results compiled in 2014. Stream temperature loggers are still deployed and intentions are to gather information once again in 2015 as part of baseline fisheries investigations for the Robb Trend Mine Lease area. Understanding temperature regimes in the pre and post mining landscape is a critical component of reclamation planning for the Coal Valley Mine.

STUDY AREA

Investigations in 2014 focused within the Erith River drainage included sites located on the Erith River, Bacon Creek, Erith River Tributary 1 (ERT1), Halpenny Creek, and Lund Creek (Table 1) located south of Robb, Alberta (Figure 1). These sites were established in 2013, many of the sites had been previously monitored during the environmental impact assessment (Pisces 2012).

Table1. Location of Erith River drainage temperature logging sites in 2014.

Site-ID	Site ID	UTM's (NAD 83)
Lund Creek	LU-3	526547 5879708
Lund Creek	LU-4	529413 5874554
Lund Creek	LU-7	528637 5872774
Bacon Creek	BA-1	515550 5890281
Bacon Creek	BA-2	514343 5888272
Halpenny Creek	HA-2	516039 5884924
Halpenny Creek	HA-5	516046 5884252
Erith River	ER-1	515722 5890425
Erith River	ER-3	513860 5890922
Erith River	ER-4	509677 589172
Erith River	ER-7	507499 5889903
Erith River Trib 1	ERT1	512677 5888618
Lendrum Creek	LE-1	522183 5883700
Lendrum Creek	LE-2	521203 5882630

Investigations in 2014 in the Southblock area were focused on four end pit lakes. Summary information for the lakes is provided in Table 2 while locations of temperature logging sites are included in Table 3.

Table 2. Summary information for CVRI lakes (Hatfield 2011, Hatfield 2014).

Lake	Lake Outlet Location	Year Created	Approximate Surface Area (ha)	Maximum Depth (m)	Mean Depth (m)	Inflow	Outflow
Pit 25S	520806E 5872969N	1999	6.8	12.5	4.7	Yes	Yes
Pit 25E	522691E 5821560N	1996	6.8	16.2	7.4	Yes	Yes
Pit 43W	521219E 5875396N	unknown	unknown	unknown	unknown	Yes	Yes
Pit 34	51973E 5874417N	unknown	5.9	5.5	2.9	Yes	Yes

Table 3. Location of Southblock temperature logging sites in 2014.

Site ID	Site ID	UTM's (NAD 83)
Upper Lovett River	LO-2	520984E 5875473N
Lower Lovett River	LO-1	524128E 5871661N
Pit 25S Lake Outlet	25S-O	520806E 5872969N
Pit 25E Lake Inlet	25E-I	522297E 5871923N
Pit 25E Lake Outlet	25E-O	522691E 5821560N
Lower 25E Creek	25E-L	523274E 5871095N
Pit 43W Pond Outlet	43W	521219E 5875396N
Pit 34 Lake Outlet	34-O	51973E 5874417N
Pit 34 Lake Inlet	34-I	522750E 5873374N

OBJECTIVES

The principal objectives of the 2014 investigations were to:

- Obtain additional stream temperature information which may be useful in post reclamation landscape planning;
- To analyze stream temperature information by calculating daily means, hourly maximums, and daily temperature fluctuations;
- To map areas of limiting thermal habitat within the monitoring area.

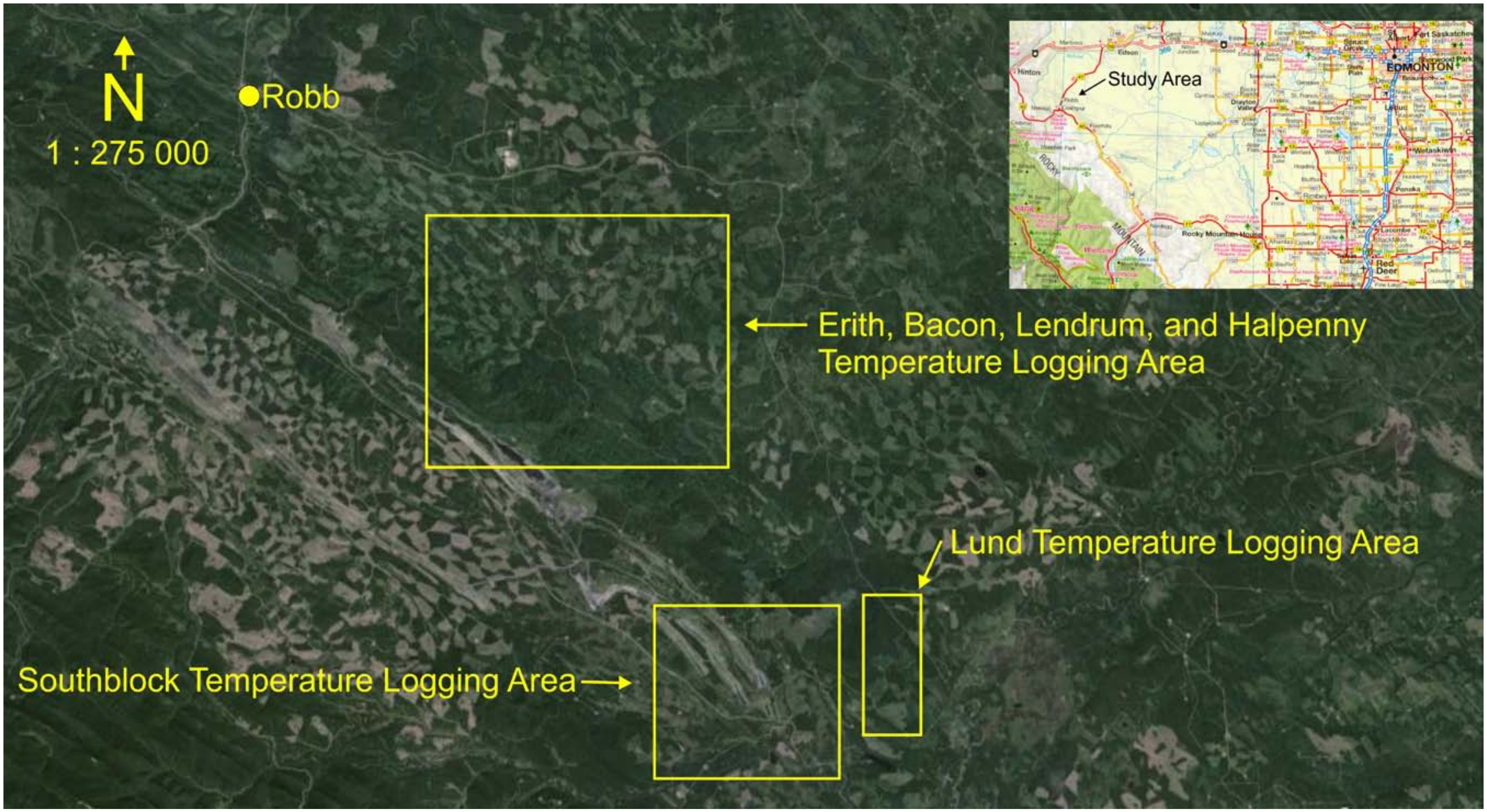


Figure 1. Study Area

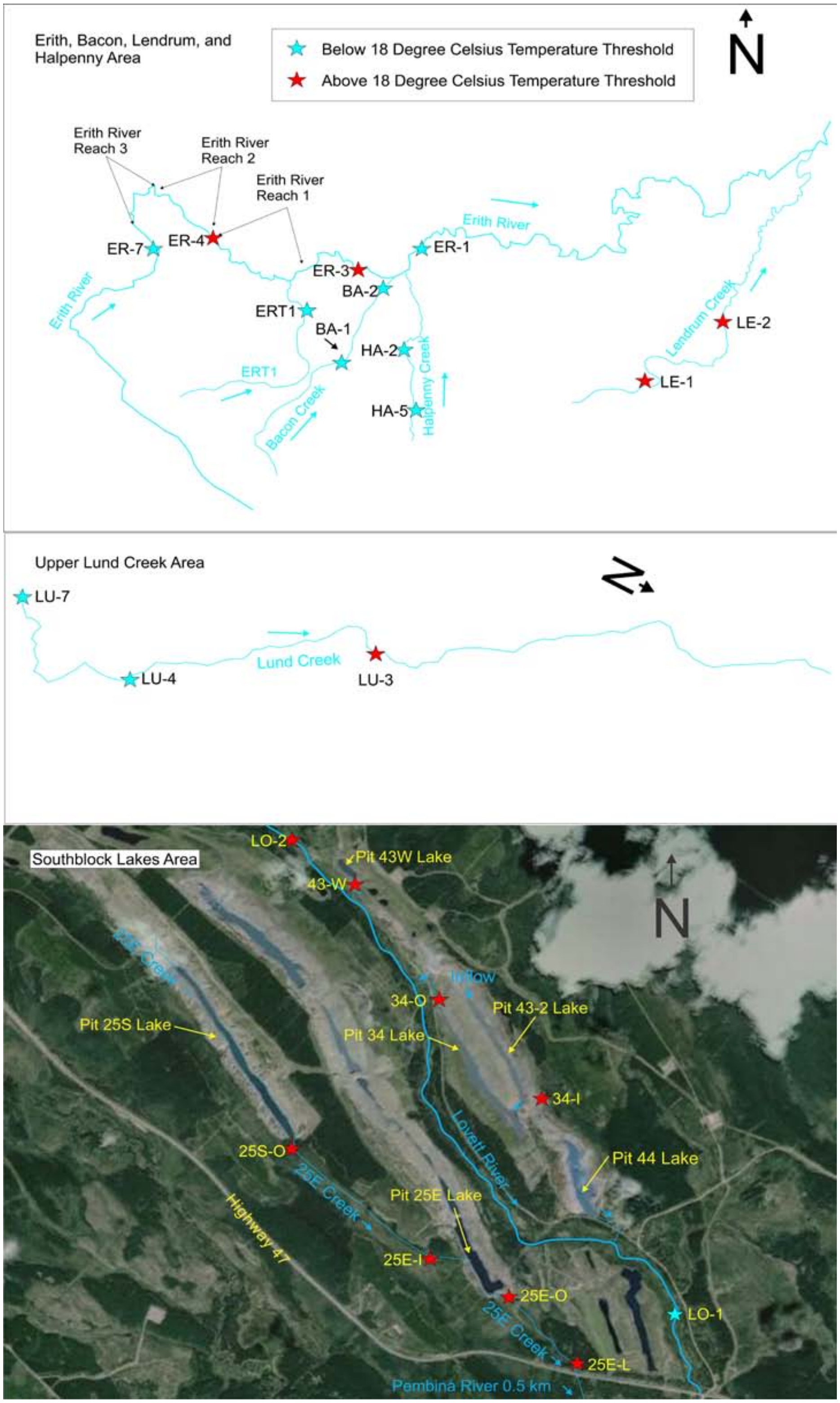


Figure 2. Temperature logging sites and distribution of 18°C temperature threshold in study area.

RESULTS

Loggers were first deployed on June 9th, 2013. Stream sites for 2014 were compared by analyzing data collected between May 1st and October 4th (Table 4). May 1st was selected as the start date in 2014, for presentation of temperature information, as it approximately correlates with the initiation of ice melt and increases in water temperatures from winter conditions. Onset Computer Tidbitv2© temperature data loggers collected measurements at 1 hour intervals over the study period. Temperature parameters as measured in the Erith River drainage are included in Table 4.

Table 4. Erith River drainage temperature monitoring results ranked from coolest (top) to warmest (bottom) based on average daily temperature measured between May 1 and October 4, 2014.

Site	Site ID	Average Daily (⁰C)	Maximum Summer Temp (⁰C)	Average Daily Fluctuation (⁰C)
Lund Creek	LU-7	6.17	11.10	0.31
Lund Creek	LU-4	6.93	13.62	1.85
Bacon Creek	BA-2	8.34	14.15	1.52
Erith River Tributary 1	ERT1	8.47	17.46	3.73
Halpenny Creek	HA-2	8.52	16.18	3.32
Halpenny Creek	HA-5	8.64	16.01	3.15
Bacon Creek	BA-1	8.66	17.37	2.49
Erith River	ER-4	9.14	18.22	2.02
Erith River	ER-1	9.31	15.72	1.58
Lund Creek	LU-3	9.44	20.63	3.64
Erith River	ER-3	9.76	18.25	2.17
Lendrum Creek	LE-2	9.81	19.32	4.26
Lendrum Creek	LE-1	11.03	21.82	4.39
Erith River	ER-7	Logger damaged, replaced Oct 4, 2014		

The upper Lund Creek sites exhibited the coldest mean stream temperatures and lowest summer maximum temperatures within the study area while Lendrum Creek, the middle Erith River sites, and lowest Lund Creek site exhibited the highest summer maximum temperatures (Table 4).

Temperature parameters as measured in the Southblock Lakes area are included in Table 5. Of the temperature logging sites in the Southblock area, the Lovett River sites were coldest while the lake impacted sites were warmer (Table 5).

Table 5. Southblock Area stream temperature monitoring results ranked from coolest (top) to warmest (bottom) based on average daily temperature measured between May 1 and October 4, 2014.

Site	Site ID	Average Daily (°C)	Maximum Summer Temperature (°C)	Average Daily Fluctuation (°C)
Lower Lovett	LO-1	8.65	14.51	1.56
Upper Lovett River	LO-2	9.81	19.48	3.95
Pit 25E Lake Inlet	25E-I	9.93	18.37	4.30
Lower 25E Creek	25E-L	12.15	21.20	2.35
Pit 43W Pond Outlet	43W	12.94	23.62	2.43
Pit 25E Lake Outlet	25E-O	13.07	22.42	1.59
Pit 34 Lake Outlet	34-O	13.23	23.57	2.36
Pit 25S Lake Outlet	25S-O	13.35	21.84	1.43
Pit 34 Inlet	34-I	13.67	23.57	1.78

Temperature Suitability and Thermal Profiles

Temperature preferences, as defined for select local coldwater fish species, are presented in Table 6. The Erith River drainage is located within the range of the native Athabasca Rainbow Trout (ARTR) (*Oncorhynchus mykiss*) while Arctic Grayling (*Thymallus arcticus*)(ARGR), Mountain Whitefish (*Prosopium williamsoni*), and Bull Trout (*Salvelinus confluentus*) are also present. The Southblock Lakes are located in the Pembina River drainage where native Arctic Grayling, Mountain Whitefish and Bull Trout occur. Introduced Brook Trout (*Salvelinus fontinalis*) are relatively common in the area (Sonnenberg and Stemo 2014b) and are also included for comparative purposes.

Table 6. Temperature preferences of select fish species

Species	Maximum Temp Preference	Optimal Mean Daily Temp	Spawning Season & Temperature Preference
Rainbow Trout	25°C[1]	12-18°C[1]	Spring Spawning- 7-12°C[1]
Athabasca Rainbow Trout	25°C[1]	4-15°C[2]	Spring Spawning 6-10°C[2]
Arctic Grayling	25°C[3]	7.5-17°C[3]	Spring Spawning 2-10°C[3]
Mountain Whitefish	23.6°C[4]	13.8°C[4]	Fall Spawning <5.5°C[5]
Bull Trout	18°C[6]	12-13°C[6]	Fall Spawning <9°C[6]
Brook Trout	24°C[7]	11-16°C[7]	Fall Spawning 4.5-10°C[7]

[1]Raleigh et al (1984)
[2]Sterling 2013 (Pers. Comm.)
[3]Hubert et al (1985)
[4]Brinkman et al (2013)
[5]Brown (1952)
[6]Sources in ASRD & ACA (2009)
[7]Raleigh (1982)

Based on the temperature tolerance of the above fish species, thermal regimes within all study areas are suitable for all of the species aside from Bull Trout. Bull Trout generally require maximum stream temperatures below 18°C (Table 6) and often will not occur in streams warmer than this threshold (ASRD and ACA 2009). In order to look at the thermal profiles of the study area, stream reaches exceeding this threshold are delineated in Figure 2.

Data collected in 2014 also allowed for assessment of potential spawning conditions for spring spawning fish species. Arctic Grayling and Rainbow Trout theoretical spawning and emergence times were delineated for the monitoring sites in the Southblock area (Table 7).

Table 7. Spawning through incubation period thermal parameters for Arctic Grayling (ARGR) and Athabasca Rainbow Trout (ARTR) in reclaimed channel areas.

Site	Spawning Commencement[1]		Predicted Emergence		Maximum Temp During Incubation[4]	
	ARGR[2]	ARTR[3]	ARGR[2]	ARTR[3]	ARGR[2]	ARTR[3]
43W	May 9	May 16	June 3	July 4	13.81	20.75
25E-L	May 9	May 17	June 3	July 6	13.47	18.96
LO-1	May 7	May 14	June 6	July 14	11.25	19.01
25E-I	May 8	May 11	June 4	July 10	12.24	17.61
25S-O	May 10	May 16	June 4	July 4	12.39	18.58
34-I	May 13	May 18	June 4	July 3	15.29	18.49
25E-O	May 9	May 16	June 2	July 3	13.98	18.22
Embarras Lakes[5]	na	May 11	na	July 2	na	19.27

[1]Based on achievement of daily average temperature exceeding 2.0°C for ARGR (Hubert et al 1985) and achievement of 6°C daily maximum temperature for ARTR (Sterling 1986).
[2]Based on accumulation on 180 degree days (Hubert et al 1985)
[3]Based on accumulation of 590 degree days (Sterling 1986)
[4]Maximum temperature based on measurements taken every 1 hour.
[5]Site where successful ARTR emergence occurred in 2014. Data from site located downstream of Lower Embarras Lake which is a reclaimed end-pit lake on the Coal Valley Mine (Pisces 2015 in prep).

Although no local end-pit lakes with Arctic Grayling populations currently exist, spawning temperatures would appear near optimal for this species based on information provided in Table 6.
Athabasca Rainbow Trout have been stocked in end-pit lakes on the Coal Valley Mine and monitoring of these populations is ongoing (Sonnenberg and Stemo (2013, 2014a), Pisces in prep). Data collected in 2014 (Pisces in prep) indicates maximum temperatures at all but one site in the Southblock area were lower than those observed in the Embarras Lakes (Table 7). Successful reproduction of Athabasca Rainbow Trout was documented in the outlet of the lower Embarras Lake in 2014 and observed fish densities were extremely high during fall fisheries sampling which indicates high habitat suitability for this species.

Discussion and Implications

Based on temperature monitoring in 2013-14 it is apparent that thermal regimes within the study area are largely suitable for salmonid species (Table 8). Bull Trout are the most temperature sensitive species in the area and were uncommon during baseline assessments (Pisces 2012). Even under pre-mining conditions, temperature regimes in portions of the Erith River drainage are borderline or too warm for year round Bull Trout use; mapping indicates thermal habitat is somewhat fragmented during some years (Figure 2). Temperatures are otherwise suitable for other salmonid species in the area though habitat limitations are known to exist (Sonnenberg and Boorman 2014).

Table 8. Year to year maximum temperature comparisons of all systems. Listed by drainage and by coolest to warmest maximum summer temperature in 2014.

Site	Site ID	Maximum Summer Temp 2014 (^{0}C)	Maximum Summer Temp 2013 (^{0}C)	Variation in 2014 from 2013 (^{0}C)
Erith River Drainage[1]				
Lund Creek	LU-7	11.1	11.61	-0.51
Lund Creek	LU-4	13.62	11.69	1.93
Bacon Creek	BA-2	14.15	14.19	-0.04
Erith River Tributary 1	ERT1	17.46	15.99	1.47
Halpenny Creek	HA-2	16.18	14.63	1.55
Halpenny Creek	HA-5	16.01	15.18	0.83
Bacon Creek	BA-1	17.37	16.15	1.22
Erith River	ER-4	18.22	15.77	2.45
Erith River	ER-1	15.72	18.56	-2.84
Lund Creek	LU-3	20.63	16.94	3.69
Erith River	ER-3	18.25	16.89	1.36
Lendrum Creek	LE-2	19.32	18.51	0.81
Lendrum Creek	LE-1	21.82	18.96	2.86
Erith River	ER-7	Logger damaged	13.98	na
Southblock Lakes[2]				
Lower Lovett	LO-1	14.51	Logger Exposed	na
Upper Lovett River	LO-2	19.48	18.25	1.23
Pit 25E Lake Inlet	25E-I	18.37	19.63	-1.26
Lower 25E Creek	25E-L	21.2	20.29	0.91
Pit 43W Pond Outlet	43W	23.62	21.41	2.21
Pit 25E Lake Outlet	25E-O	22.42	21.03	1.39
Pit 34 Lake Outlet	34-O	23.57	22.54	1.03
Pit 25S Lake Outlet	25S-O	21.84	22.1	-0.26
Pit 34 Inlet	34-I	23.57	Logger Exposed	na

[1]From Sonnenberg and Boorman 2014b.
[2]From Sonnenberg and Stemo 2014b.

Temperatures in the Southblock end-pit lake area are warmer than those observed within the Robb Trend study area. End Pit Lakes are known to result in warming of downstream lotic habitats although salmonid communities are often still present (Sonnenberg and Stemo (2013, 2014a), R. Sonnenberg 2011). The thermal regime of the Southblock area would be considered suitable for all local salmonid fish species aside from Bull Trout. Although the end-pit lakes associated with these systems do provide a cold water thermal refuge at depth, it is unlikely any successful Bull Trout reproduction would occur based on temperature readings in 2013-14. The deeper portions of the end-pit lakes would help ensure survival of other salmonid species which may be able to utilize the inlet and outlet channels at times when lotic temperatures are approaching those deemed unsuitable for resident fish species.

Natural factors are likely contributing to warming of some systems within the study area. The higher than expected temperature values recorded in the Lovett River upstream of the majority of the Southblock Lakes discharge may have resulted from recent beaver activity in the immediate area. Beaverdams would be capable of warming stream temperatures in the same way end-pit lakes do. Water temperatures in the Lovett River were found to be lower at the downstream end of the study section indicating that either cold water inputs or cooling effects are present.

Although the Southblock end-pit lakes are not located within the natural range of the Athabasca Rainbow Trout, they are located in relatively close proximity to the Robb Trend lease area. This area is mostly located within the McLeod River sub-basin where the species is endemic. Table 7 indicates relatively similar temperature regimes occur between these areas which allow the Southblock Lakes to be useful in understanding the temperature regime which will be present following mining in the Robb Trend area. Monitoring completed in 2014 indicates most end-pit lake systems in the Southblock Area would be capable of supporting the thermal requirements of all life stages for the Athabasca Rainbow Trout. This provides further evidence that end-pit lake systems are capable of providing suitable habitat for this species in the local area.

Bull Trout thermal requirements would have been met by conditions in the lower reaches of the Lovett River during the study period. Other habitat limitations aside from temperature would be significant in this area and the findings from this monitoring program do not confirm all species could successfully utilize the habitat. Past monitoring has demonstrated some enhancement works would be necessary in certain end-pit lake systems in order to ensure fish have an adequate chance of colonizing the created habitats (Sonnenberg and Stemo 2014b).

Closure

I trust that the foregoing meets your requirements at this time. Please do not hesitate to contact me if you have any questions.

<original signed by>

Joe Sonnenberg B.Sc.
Fisheries Biologist
Author

<original signed by>

Ricki-Lynn Boorman, P.Biol.
Senior Fisheries Biologist
Review

REFERENCES

Alberta Sustainable Resource Development and Alberta Conservation Association. 2009. Status of the Bull Trout in Alberta: Update 2009. Alberta Sustainable Resource Development. Wildlife Status Report No. 39 (Update 2009). Edmonton, AB. 48 pp.

Brinkman, F. Stephen. H.J. Crockett, K.B. Rogers. 2013.Upper Thermal Tolerance of Mountain Whitefish Eggs and Fry. Transactions of the American Fisheries Society. Vol 142, Issue 3, pp824-831.

Brown CJP. 1952. Spawning habit and early development of the mountain whitefish, Prosopium williamsoni, in Montana. Copeia 1952:109-113.

Hatfield. 2011. An evaluation of water quality in existing end-pit lakes in the Coal Valley Mine Area. Prepared by Hatfield Consultants for Coal Valley Resources Inc. 46 pp+ App

Hatfield. 2014. Bathymetric map of Pit 34 Lake. Prepared by Hatfield Consultants for Coal Valley Resources Inc.

Hubert,W.A.,R. S.Helzner,L. A.Lee,andP. C.Nelson.1985.Habitat suitability index models and instream flow suitability curves: Arctic grayling riverine populations. U.S. Fish Wild1. Servo Bio1. Rep. 82(10.110). 34 pp.

Pisces. 2012. Robb Trend Project Aquatic Resources Environmental Impact Assessment. Report of Pisces Environmental Consulting Services Ltd. To Coal Valley Resources Inc. Edson, AB. 93 pp +App

Raleigh,R.F. 1982.Habitat suitability index models: Brook trout. U.S. Dept. Int., Fish Wildl. Serv FWS/OBS-82/10.24. 42 pp.

Raleigh, R.F., T. Hickman, R.C. Solomon, and P.C. Nelson. 1984. Habitat suitability information: Rainbow Trout. US Fish Wildl. Serv. FWS/OBS-82/10.60. 64pp

Sonnenberg J. and R.L Boorman. 2014. Habitat suitability index modeling the Erith River, Bacon Creek, and Erith River Tributary 1 (ERT1) near Robb, Alberta. Report of Pisces Environmental Consulting Services Ltd. To Coal Valley Resources Inc. Edson, AB. 21 pp +App

Sonnenberg, J and R.L Boorman. 2014b. 2013 Interim Results for Temperature Investigations Conducted Within the Erith River Drainage of the Coal Valley Mine's Robb Trend Lease. Letter Report of Pisces Environmental Consulting Services Ltd. to Coal Valley Resources Inc. Edson, AB. April 23, 2014. 3 pp+

Sonnenberg, J. and E. Stemo. 2013. Aquatic Monitoring Program for End Pit Lakes in the Headwaters of the Embarras River, 2011-12. Report of Pisces Environmental Consulting Services Ltd. To Coal Valley Resources Inc. Edson, AB. 36 pp +App

Sonnenberg, J. and E. Stemo. 2014a. Aquatic Monitoring Program for End Pit Lakes in the Headwaters of the Embarras River, 2012-13. Report of Pisces Environmental Consulting Services Ltd. To Coal Valley Resources Inc. Edson, AB. 37 pp +App

Sonnenberg, J and E. Stemo. 2014b. Preliminary results for investigations conducted on existing end-pit lakes in the South Block Area of the Coal Valley Mine. Letter Report of Pisces Environmental Consulting Services Ltd. to Coal Valley Resources Inc. Edson, AB. 8 pp+App

Sonnenberg, R. 2011. Development of Aquatic Communities in High-Altitude Mine Pit Lake Systems of West-Central Alberta. A Thesis Submitted to the School of Graduate Studies of the University of Lethbridge in Partial Fulfillment of the Requirements for the Degree Master of Science. 175 pp + App

Sterling, G.L. 1986. An evaluation of spawning habitat and fry escapement of rainbow trout(Salmo gairdneri RICHARDSON) before logging in the Tri-Creeks watershed of west-central Alberta. Alberta Energy and Natural Resources, Fish and WildlifeDivision. Tri-Creeks Watershed Study Report. No. 8. 74 pp.

Personnel communications

Sterling, G. June 2013. Fisheries Biologist Foothills Area. Edson, Alberta.

Report #14

Pisces Environmental Consulting Services Ltd.
•Unit 118, 239 Spruce Street• Red Deer County • Alberta • T4E 1B4•
• Phone 403-347-5418 • Fax 403-347-0681•
•www.piscesenvironmental.com•

February 19, 2015

Westmoreland Coal Company
Coal Valley Mine
Box 5000 Stn Main
Edson, AB
T7E 1W1

ATTN: Megan Hill

RE: 2014 post-construction monitoring of the permanent diversion channel on upper Mercoal Creek for the MP2 development.

Introduction

The Mercoal Phase 2 (MP2) project, part of ongoing mining operations at the Coal Valley Mine, required the permanent diversion (known as diversion D-E) of a portion of Mercoal Creek to facilitate mining. As required by Fisheries and Oceans Canada (DFO), a habitat compensation plan that included enhancement of the constructed channel with a goal of maximizing its productive capacity was developed for the project. In order to meet the requirements of the DFO Section 35(2) Fisheries Act Authorization (# ED-04-3170) issued for the project, the mine committed to conducting fish and fish habitat monitoring within the constructed channel. Key components of the monitoring program included:

- Sampling 1, 3, and 5 years following construction of the channel.
- Habitat surveys 1 and 5 years following construction of the channel.

This document presents Year 5 (post construction) monitoring results obtained by Pisces Environmental Consulting Services Ltd. (Pisces).

Background

Baseline investigations of Mercoal Creek found that fish densities were very low in the vicinity of the diversion and that Rainbow Trout (Oncorhynchus mykiss) were the only species to occupy this part of the creek (Boorman 2003). Habitat inventory during baseline investigations found that the majority of habitat (>75 %) affected by the diversion consisted of Class 3 habitat (<0.5 m depth, Boorman 2003). Pool habitat comprised about 2 % of the affected habitat and there was no Class 1 habitat (>1.0 m depth) in the impacted area (Boorman 2003). Modeling of the habitat suitability of Mercoal Creek for Rainbow Trout (Raleigh et al. 1984) found that both the percent pools and the pool class rating variables were limiting factors (Stemo 2005). As a result, habitat compensation efforts included the construction of pools on every meander and the placement of large woody debris within the constructed pools (Stemo 2005).

Monitoring Results

The 2014 monitoring program included sampling of the compensation area as well as the natural channel adjacent to the compensation area. In addition, channel stability, general habitat conditions, and instream sedimentation was also assessed. The investigations were completed on July 30, 2014. Photos delineating habitat conditions at the time of assessment are attached.

Habitat Conditions

The channel was mostly stable and well vegetated at the time of the 2014 assessment; approximately 1 % of the study area was designated as unstable. Habitat consisted of flats (F1, F2, and F3), runs (R3), and riffles (RF) while cover within the study area was provided by aquatic vegetation (AV), overhanging vegetation (OV), woody debris (WD), overhanging bank (OB), and boulder garden (BG) (Table 1). A full 2014 habitat inventory including specific locations of unstable habitat areas is attached.

The habitat inventory completed in 2010 found that the diversion channel provided an additional 750 m^2 of habitat compared to the pre-disturbance condition while findings in 2014 showed the channel provided an additional 950 m^2 of habitat (Table 1). In 2014, habitat conditions were judged to be very similar to what was present in 2010 and 2012 with over 700 m^2 of Class 1 habitat (> 1 m average depth) and 600 m^2 of Class 2 habitat (0.5 - 1.0m average depth) being present in the study area (Table 1).

Table 1. Summary of habitat alteration/loss associated with the diversion D-E of Mercoal Creek based upon the Habitat Classification System (O'Neil and Hildebrand 1986).

Habitat Type	Natural Channel		Diversion Channel 2010 Net Loss/Gain (m^2)			Diversion Channel 2014		Net Loss/Gain (m^2)
	Area (m^2)	% of Total Available Habitat	Area (m^2)	% of Total Available Habitat	Net Loss/Gain (m^2)	Area (m^2)	% of Total Available Habitat	
R3	1122.9	72.40	614.9	26.70	-508.0	408.8	16.30	-714.1
R2	332.0	21.40	0.0	0.00	-332.0	0.0	0.00	-332.0
F3 & P3	87.1	5.60	411.5	17.90	+324.4	766.0	30.70	+678.9
F1 & P1	0.0	0.00	714.0	3.10	+714.0	709.0	28.30	+709.0
F2 & P2	8.0	0.50	411.5	17.90	+403.5	600.5	24.00	+592.5
RF	1.0	0.04	150.7	6.50	+149.7	17.1	0.70	+16.1
LJ	1.4	0.06	0.0	0.00	-1.4	0.0	0.00	-1.4
TOTAL	1552.4	100.00	2302.6	100.00	+750.2	2501.4	100.00	+949.0

The July 30, 2014 assessment included measurement of water quality parameters within the compensation channel (Table 2). No water quality factors were judged to be limiting for fish at the time of assessment though flows were considered to be low. Low discharge was also noted during the 2012 assessment of Mercoal Creek.

Table 2. Mercoal Creek water quality measurements 2014.

Parameter	Measured Value
Turbidity (NTU)	4.5
Dissolved Oxygen (mg/l)	8.8
pH	7.3
Temperature (°C)	19.9 @ 13:30 hrs
Discharge (m^3/s)	0.015

Fish Sampling

The 2014 fish sampling program consisted of electrofishing and angling surveys:

- 720 metres of the diversion channel was electrofished for 1,581 seconds of on-time. No fish were captured or observed during this survey.
- Deep portions of 4 pools were angled due to the limited effectiveness of electrofishing within deeper water. No fish were captured or observed during 1 hour of total angling effort.
- Electrofishing of the natural channel downstream of the diversion was not feasible due to excessive bank cover in the form of overhanging vegetation in 2014. A fish passability assessment of Mercoal Creek was instead initiated downstream of the study area and several barriers to fish migration (beaver dams) were observed. The most significant barriers which are located a short distance upstream of Highway 40 were noted to be in poor condition but were still judged to be barriers during summer 2014.

Summary

Consistent with the Habitat Compensation Plan (Stemo 2005), the constructed diversion channel still had substantially more Class 1 pools in 2014 as compared to the pre-disturbance condition. Based on Habitat Suitability Modelling (Raleigh et al. 1984), compensation efforts have resulted in an increase in the overall habitat quality within this portion of Mercoal Creek.

Fish utilization of the diversion channel was not confirmed in 2010, 2012, or 2014, however fish were also absent in the natural channel downstream of the diversion in 2010 and 2012 which suggests fish densities in the headwaters of Mercoal Creek remain low (as was found during baseline studies (Boorman 2003)). Additional field investigations in 2014 revealed barriers to fish migration in the form of beaver dams are present a short distance upstream of Highway 40. As such, until one of the identified beaver dams in particular fails (condition was rated as poor in 2014) fish distribution into the headwaters of Mercoal Creek will be unlikely.

Recommendations

Though the Mercoal Creek diversion is operating as designed, it is recommended some minor remedial efforts be undertaken. A few areas of instability were identified during the assessment (attached photos); if possible, these areas should be vegetated and stabilized. Additionally, sediment control debris (silt curtain) is present within the diversion channel and should be removed. Habitat features are otherwise intact and meeting compensatory objectives.

Closure

We trust the above report meets with your requirements at this time. If you have any questions regarding the foregoing, please contact our office at your convenience.

<original signed by>

Joe Sonnenberg, BSc.
Fisheries Biologist
Author

Attch.

References

Boorman, J. 2003. Baseline fisheries resource assessment of waterbodies on and adjacent to the proposed Mercoal East mine extension. Report of Pisces Environmental Consulting Services Ltd. to Luscar Ltd. Coal Valley Mine. Edson, AB. 35pp. + App.

O'Neil, J. and L. Hildebrand (1986). Fishery resources upstream of the Oldman River Dam. Edmonton, Alberta, Canada, R. L. & L. Environmental Services Ltd.: 131 p + App.

Raleigh, R.F., T. Hickman, R.C. Solomon, and P.C. Nelson. 1984. Habitat suitability information: Rainbow Trout. U.S. Department of the Interior Fish and Wildlife Service. FWS/OBS-82/10.60. 64 pp.

Stemo, E. 2005. Coal Valley Mine Mercoal Phase 2 Extension Fish Habitat Compensation. Report of Pisces Environmental Consulting Services Ltd. to Luscar Ltd. Coal Valley Mine. Edson, AB. 10pp. + App.
.

Photo 1. Looking downstream at natural channel downstream of diversion.

Photo 2. Looking upstream from downstream end of diversion channel.

Photo 3. Erosion along lower end of Mercoal diversion channel (from Right Upstream Bank).

Photo 4. Looking upstream at representative stretch of the Mercoal Diversion.

Photo 5. Class 1 habitat within diversion channel with cover enhancements.

Photo 6. Upstream end of Mercoal diversion channel.

Habitat Inventory																	
Date:		30-Jul-14															
Stream Name:		Mercoal Creek															
Project:		WMCC Mercoal Diversion Monitoring															
UTM reference:		495715E 5888827N															
Habitat units numbered from downstream to upstream																	
Habitat Unit		Physical Dimensions			Cover (m^2)					Substrate Composition (% area)					Unstable Bank (m)	Riparian Veg	Comments
#	Type	Length (m)	Width (m)	Area (m^2)	WD	OB	OV	AV	BL	FN	GR	CB	BL	BR			
1	F3	13	2.5	32.5		0.50	1.00	0.10		100						Gr/Sh	Sediment fabric in channel.
2	F3	16	8.0	128			2.00	51.20		100						Gr/Exp	
3	F3	28	1.0	28	0.10		3.00	0.10		98		2				Gr	
4	R3	40	0.8	32	0.10		1.50			40	30	25	5		3	Gr	
5	R3	56	1.0	56	0.10		2.50	0.10		30	40	25	5			Gr	
6	R3	44	1.0	44	0.10		2.00	0.10		50	10	30	10			Gr	
7	F3	13	3.5	45.5	0.50		0.10	0.50		100						Gr	
8	R3	35	0.9	31.5	0.10		3.00	0.10		80	10	10				Gr	
9	R3	13	0.6	7.8	0.10					100						Gr/Exp	
10	R3	45	1.0	45			3.00			60	30	10			10	Gr	
11	RF	7	1.5	10.5			0.10				70	30				Gr	
12	R3	34	0.8	27.2			0.20			20	50	20	10		5	Gr	
13	RF	11	0.6	6.6			0.50				80	20				Gr	
14	R3	10	0.5	5			0.10			10	70	20				Gr	
15	R3	33	1.1	36.3			1.00	1.00		80	10	10				Gr	
16	F2	20	14.0	280	0.50			56.00	2.5	80			20			Gr	
17	R3	5	0.6	3			0.10				10	80	10			Gr	
18	F3	31	2.0	62	0.50		5.00	18.60		100						Gr	
19	F1	9	6.0	54	3.00			1.00		90			10			Gr	
20	F3	30	2.2	66			3.00	4.00	0.5	90			10			Gr	
21	R3	15	0.4	6			1.50				80	20				Gr	
22	F2	8	4.5	36	0.1		1.00		0.1	70	10	20				Gr	
23	R3	17	0.9	15.3	0.1		0.50			20	40	40				Gr	

Mercoal diversion habitat inventory cntd.

24	F2	11	3.5	38.5	0.2		1.00			80			20			Gr	
25	F3	21	1	21	0.5		2.00			60	20	20				Gr	
26	F1	16	9	144	4.5		1.00			90		5	5			Gr	
27	R3	28	0.5	14	0.1		0.10			5	70	25				Gr	
28	F1	15	7	105	1		1.00			90		10				Gr	
29	F3	21	2.5	52.5	0.2		0.50		0.2	80		10	10			Gr	
30	R3	24	1	24			1.00			20	40	40				Gr	
31	F1	29	14	406	6		3.00	0.10		90			10			Gr	
32	R3	24	0.4	9.6			1			10	40	40	10			Gr	
33	F3	7	1.5	10.5			0.1			90		10				Gr	
34	R3	25	0.5	12.5			0.5			10	30	60				Gr	
35	F2	10	5	50	0.2		0.5	0.1		90		10				Gr	
36	F3	16	3	48	1		0.5			90		5	5			Gr	
37	R3	18	0.7	12.6	1					20	40	40				Gr	
38	F2	19	8	152			1	0.5		100						Gr	
39	F3	28	2	56	0.1		1			100						Gr	
40	F2	11	4	44	0.5		0.5			95			5			Gr	
41	F3	36	1	36			3			100						Gr	
42	F3	11	6	66	0.5					100						Gr	
43	R3	27	1	27			2			50	20	30				Gr	
44	F3	19	6	114	3		1	2		100						Gr	

Pisces Environmental Consulting Services Ltd.
•Unit 118, 239 Spruce Street• Red Deer County • Alberta • T4E 1B4•
• Phone 403-347-5418 • Fax 403-347-0681•
•www.piscesenvironmental.com•

February 19, 2015

Westmoreland Coal Company
Coal Valley Mine
Bag Service 5000
Edson, AB
T7E 1W1

ATTN: Ross Van Bostelen

RE: Robb Trend Coal Mine Expansion Project
CEAA Information Request - Aquatic Ecology

The Canadian Environmental Assessment Agency (CEAA) has reviewed the Environmental Impact Assessment (EIA) provided to Fisheries and Oceans Canada (DFO) during the screening process for the proposed Robb Trend Coal Mine Project (the Project). CEAA has requested supplemental information to ensure all information is available for the review process. This document provides updated information on current site investigations and assessment on impacts to aquatic resources, as well as summarizes recent developments with Aboriginal groups regarding fish habitat impacts and mitigation measures (SIR #176).

Westmoreland Coal Company (WCC) retained Pisces Environmental Consulting Services Ltd. (Pisces) to conduct aquatic monitoring programs in and around the proposed Robb Trend Coal Mine lease area. A summary of current and ongoing site investigations and assessment on impacts to aquatic resources is provided in Table 1.

Table 1. WCC's recent and ongoing aquatic monitoring programs.

Program	Objectives	Key Findings	*Status
Embarras Lakes (Pits 122 & 142) Aquatic Monitoring	-Identify optimal reclamation strategies for successful establishment of native fish species -Monitor self-sustaining Athabasca Rainbow Trout populations in the end pit lakes and the channels between the lakes -Monitor fish populations in the Embarras River (downstream of the lakes) -Monitor physical and chemical limnological characteristics in the end pit lakes -Monitor benthic macroinvertebrate populations in the end pit lakes and channels -Monitor zooplankton and phytoplankton communities in the end pit lakes -Monitor macrophyte communities in the end pit lakes -Monitor selenium concentrations in Athabasca Rainbow Trout eggs	-Biological parameters comparable to local natural waterbody (Fairfax Lake) -Majority of water quality parameters (including selenium), are within CCME guidelines for protection of aquatic life -Successful overwintering, growth, and reproduction of Athabasca Rainbow Trout -Significant increase in fish densities and production versus baseline conditions, and among the highest fish densities in the region - Fish exclusion barrier is effectively precluding the movement of Brook Trout into the Embarras Lake system -Preliminary results have shown selenium concentrations in Athabasca Rainbow Trout eggs (collected from the Embarras Lakes) are low and no negative effects on reproduction have been documented -Provided recommendations for fish habitat enhancements within reclaimed channels	-Initiated 2011, ongoing program -Reporting (April 2013, August 2013, April 2014), Scheduled report (Spring 2015)
Erith River Corridor Fish & Fish Habitat	-Review existing fish and fish habitat data for the proposed watercourse crossings along the Erith Corridor haulroad -Collect supplemental fish and fish habitat data -Determine potential impacts and mitigation measures	-Found that 7/8 watercourses assessed were fish bearing -Determined potential impacts and mitigation measures, taking additional information into consideration	-Field Work (Summer 2013) -Internal report (January 2014)
Erith River Fish Migration Study	-Determine fish community and migratory patterns in the Erith River downstream of the Robb Trend lease by means of installation and operation of a two-way fish trap	-Confirmed migration of key species (Athabasca Rainbow Trout, Bull Trout, and Arctic Grayling) downstream of lease area -Information may be applied to fish passability discussions as well as habitat compensation planning	-Field Work (Summer 2013) -Reporting (March 2014)
Erith River Drainage Habitat Suitability Index (HSI) Inventory	-Determine habitat suitability of the Erith River and select high sensitivity tributaries (ERT1, Bacon Creek) specifically for Athabasca Rainbow Trout	-Determined HSI scores for select waterbodies -Identified habitat limitations which could be addressed with compensation strategies	-Field Work (Summer 2013) -Internal report (May 2014)
Erith River Habitat Compensation/ Enhancement Reconnaissance	-Identify limiting factors and suitable areas for possible habitat compensation works within the Erith River drainage adjacent to the mine lease	-Identified suitable areas for compensation works immediately adjacent to the Robb Trend Mine Lease	-Field Work (Summer 2013), no report prepared-information obtained used to support habitat compensation plans
Erith River Drainage Temperature Monitoring	-Monitor baseline water temperatures in the mine lease area	-Water temperatures generally cooler compared to reclaimed mining areas	-Initiated 2013 -Reporting (January 2015)
Robb Trend Additional Fish Habitat Investigations/ Inventories	-Collect additional fish habitat inventories on streams that will potentially be impacted by reduced flows downstream of mining (Hay Creek, Lund Creek)	-Collected habitat inventory information within potentially impacted stream sections	-Field Work (Summer 2013), no report prepared-information obtained used to update habitat impacts
South Block Lakes Investigations	-Monitor water temperature profiles in the reclaimed South Block area of the Coal Valley Mine -Identification of optimal reclamation strategies for successful establishment of native fish species -Obtain information regarding fish use of inlet/outlet streams adjacent to end pit lakes	-Identified fish communities in reclaimed channels, Brook Trout prevalent -Data collected indicates several systems would be suitable for establishment of native Arctic Grayling -Provided recommendations for further channel enhancements in the reclaimed channels	-Field Work (Summer 2013) -Reporting (February 2014, January 2015)
Benthic Invertebrate Biomonitoring Programs: Embarras River, McLeod River and Pembina River Drainage Basins	-Establish the range of natural variability (based on select measurement endpoints) of the benthic invertebrate communities in watercourses in the vicinity of the Coal Valley Mine -Compare data from test reaches (potentially impacted) with reaches designated as reference (un-impacted) to determine how the communities compare to natural variability	-Monitored select reference sites located in the proposed Robb Trend mining areas to compare to impacted reaches in the Coal Valley Mine	-Field Work (Fall 2012, Fall 2013), ongoing program -Reporting (April 2013, April 2014)
Mercoal Creek Post-Construction Monitoring	-Conduct fish and fish habitat post-construction monitoring in reconstructed channel, as required by DFO habitat compensation plan	-Compensation efforts have resulted in an increase in the overall habitat quality -No fish captured or observed. Natural barriers (beaver dams) were identified downstream -Provided recommendations for channel improvements	-Field Work (Summer 2010, 2012, 2014) -Reporting (April 2011, March 2013, February 2015)
Mercoal Creek Tributary #3 (MET-3)	-Assess current conditions to facilitate development of a fish habitat enhancement plan, as required by DFO habitat compensation plan -Provide recommendations for channel re-establishment and enhancement	-Provided recommendations for channel re-establishment and enhancement	-Field Work (Spring and Summer 2013) -Reporting (May & August 2013), Scheduled report (Spring 2015)

*Current as of February 19, 2015

1.0 CURRENT AQUATIC MONITORING FINDINGS

Recent aquatic monitoring completed within the Robb Trend lease area identified areas suitable for enhancement as part of potential compensation programs. Habitat components such as pools, substrate, and cover were identified as limiting in some areas where enhancement may be possible. Additionally, fish community monitoring of the Erith River downstream of the mine lease confirmed the presence of Athabasca Rainbow Trout, Bull Trout, and Arctic Grayling which were selected as Valued Ecosystem Components (VECs) for the Project. As mine plans progress and monitoring continues, this information may be applied to fish passability discussions as well as habitat compensation planning.

The ongoing research at the Coal Valley Mine (CVM) intends to provide continuous improvement of reclamation strategies in reconstructed channels as well as end pit lakes designed with connectivity. Adjustments to the Project mine plans indicate channel reconstruction will be more prevalent than in initial reclamation plans, for the purpose of maximizing fish habitat productive capacity. Ensuring that constructed channels are designed to include typical habitat types such as pools, riffles and runs with adequate sinuosity will aid in decreasing potential sedimentation and improve overall design. The Project footprint has been reduced significantly and ongoing monitoring aims to refine reclamation strategies as well as build upon compensation objectives.

Monitoring of past reclamation and compensation areas on the CVM provide important guidance to future works. Over the last two decades, WCC has successfully constructed stream channels (see Appendix A in Pisces 2013 report titled 'CVRI Robb Trend Project Summary of Fish Habitat Impacts, Mitigation and Habitat Compensation Strategies') and end pit lakes (Hatfield 2011, Hatfield 2014) in the CVM area. Information gathered can be used to refine reclamation objectives and strategies. Outcomes of ongoing aquatic monitoring programs include:

<u>Temperature Monitoring/Channel Design</u>

- Water temperatures are generally increased downstream of end pit lake systems as well as within some reclaimed channels. Though detrimental temperatures have not yet been identified, compensation planning will need to take downstream water temperatures into consideration. This can be achieved by limiting direct sun exposure (maximizing stream shading with riparian revegetation), and limiting the quantity of littoral areas near lake outlets. Optimally, deep water habitat located immediately adjacent to lake outlets helps reduce daytime temperature fluctuations and peaks.
- Water temperatures of end pit lake inlet and outlet channels have been shown to be suitable for Athabasca Rainbow Trout spawning. Past monitoring also suggests Arctic Grayling could be supported within end pit lake systems with proper habitat modifications (this species has not yet colonized or been introduced into any such habitat). Habitat conditions including substrate composition, habitat complexity, and cover components need to be addressed during reclamation planning to ensure long term success of native fish species.

End Pit Lakes

- End pit lake resident Athabasca Rainbow Trout successfully utilize constructed inlet and outlet channels for spawning and rearing. As this strategy is a significant component of end use reclamation planning for the Project, proof of concept was very important. Ongoing monitoring is assessing the success of Athabasca Rainbow Trout in the Embarras Lake system. Future monitoring and reporting will identify any limiting factors and make recommendations for future end pit lake system planning.
- Majority of water quality parameters (including selenium) within the Embarras Lakes, are within CCME guidelines for the protection of aquatic life. Minor exceedences of iron, aluminum, and manganese have been recorded.
- Biological parameters have been found to be comparable to local natural waterbody (Fairfax Lake). Macrophytes, phytoplankton, zooplankton are establishing in the reclaimed lakes. Colonization of native aquatic vegetation which enhances habitat complexity and lake naturalization has been successful.

Fisheries Resources

- Athabasca Rainbow Trout densities in the upper Embarras River have increased substantially following end pit lake reclamation.
- The fish exclusion barrier is effectively precluding the movement of non-native Brook Trout into the Embarras Lake system.
- Preliminary results have shown selenium concentrations in Athabasca Rainbow Trout eggs (collected from the Embarras Lakes) are low and no negative effects on reproduction have been documented.
- Monitoring documented relatively high average HSI values within the Erith River, ERT1, and Bacon Creek while also indicating some habitat features may be limiting the productive capacity of the habitat.
- Recent genetic analyses conducted by Alberta Environment and Sustainable Resource Development (ESRD) found that the Athabasca Rainbow Trout in the Embarras Lakes system exhibit limited hybridization/introgression and is therefore considered a conservation population.
- ESRD preliminary results have found that Athabasca Rainbow Trout eggs collected from the Embarras Lakes system exhibited “very high” hatch and survival rates and normal deformity frequencies (J. Calvert pers. comm.)

2.0 FUTURE AQUATIC MONITORING AND RECOMMENDATIONS

WCC has committed to the following aquatic monitoring programs:

- Continued Embarras Lakes (Pits 122 & 142) aquatic monitoring
- Fish habitat enhancements within reconstructed channels in the Embarras Lake system as well as within Mercoal Creek Tributary #3 (MET-3)
- Benthic invertebrate biomonitoring in the Embarras, McLeod and Pembina River Basins

Further aquatic monitoring in past reclamation areas, current mining areas, and the proposed Project area will provide important guidance to future works. Monitoring will be key to confirming "no net loss" to aquatic resources. The following is a list of recommended aquatic monitoring programs:

- Robb Trend Temperature Monitoring Program
    - continue monitoring baseline water temperatures in the mine lease area to identify areas of limiting thermal habitats and potential spawning conditions
    - collect temperature monitoring during mining, making adjustments to reclaimed/reconstructed channels with this information in mind (cover, substrate, location/design of lake outlets). Aim to maintain stream temperatures within Athabasca Rainbow Trout tolerances following mining by adjusting outlets and maximizing shade and fish habitat cover.
- Existing Reclaimed Lakes/Reclaimed Channels Monitoring
    - continue monitoring water temperature profiles in the South Block area to identify suitability for native fish species (i.e. Athabasca Rainbow Trout, Arctic Grayling, Bull Trout)
    - continue monitoring fish utilization of inlet/outlet channels (data collected in 2013-14 showed salmonids are still dominant in reclaimed landscape and habitat has high potential for use)
    - collaborate with ESRD to expand data set which supports channel reconstruction/enhancement as a reclamation tool
    - the existing inlet and outlet channels would benefit from implementation of habitat enhancements (see Pisces South Block reports). If habitat enhancement works are conducted, it is recommended a Qualified Aquatic Environment Specialist (QAES) be involved to provide advice/monitoring.
    - compare findings to the Embarras Lakes monitoring program and integrate findings into future reclamation areas to enhance overall design and functionality of end pit lake systems
- Chance Creek Monitoring Program
    - continue Brook Trout suppression and Rainbow Trout relocation (in congruence with area fisheries management objectives)
    - provide Qualified Aquatic Environment Specialist (QAES) advice/monitoring during channel reconstruction/habitat enhancements
    - establish single pass electrofishing section (500 m max) downstream of exclusion weir to monitor impacts/commence collection of baseline information prior to reclamation activities
    - establish temperature monitoring site upstream and downstream of mining activities to identify extent of thermal habitat impacts and suitability for native fish species
    - establish spawning survey section downstream of mining activities and fish exclusion barrier
    - establish benthic invertebrate monitoring upstream and downstream of mining activities post-mining

3.0 ABORIGINAL CONSULTATION (SIR#176)

Discussions, communication and consultation with aboriginal groups to ascertain Traditional Land Use (‘TLU’) and Traditional Ecological Knowledge (‘TEK’) for the Project continue. These discussions are focused on the gathering of information to establish use of fisheries resources for subsistence or traditional use in the aquatics Local Study Area (LSA) and Regional Study Area (RSA). Some of the initial concerns that have been provided during consultation involving the aquatic resources include:

- Access restrictions during mining
- Environmental impacts/destruction
- Water quality
- Impacts on local waterbodies
- Impacts on local fish species
- Development of a suitable fish habitat compensation plan
- Consumption of fish in the local area

WCC acknowledges that the Project will occupy Crown land otherwise available to exercise traditional uses for a period of time during mine development, operation and reclamation. Access to aquatic resources will be impacted by development, operation and reclamation activities. Upon Project completion and reclamation, lands will be returned to the provincial government and access will no longer be restricted. WCC recognizes that the return of lands to the Crown for public and traditional use historically has not occurred in the most effective manner. WCC is developing a strategy, to be presented to the Alberta Energy Regulator (‘AER’) to improve the timely release of reclaimed lands and improve access to previously mined areas.

WCC is working with DFO, and other stakeholders and regulators, in creating a conceptual compensation plan that will ensure “no net loss” of fish and fish habitat. WCC has presented a response relating to environmental impacts and mine plan changes have taken these concerns into consideration. An increase in mine buffer areas and reduction of impacts to high quality watercourses has been included in revised mine plans.

WCC-CVM has recently completed an update to their onsite surface water management strategy and the updated management plan will be applied to the Project. The surface water management plan targets continuous improvement throughout active monitoring, sampling and inspection throughout the life of the Project to ensure a healthy aquatic environment. Monitoring programs provide real time data that allows, WCC-CVM to identify, avoid and minimize any potentially adverse impacts on water quality in the region.

4.0 SUMMARY

Aquatic monitoring programs located in past reclaimed areas, current mining areas, and the proposed Project area provide essential information to continuously improve reclamation efforts at the CVM. Monitoring thus far has shown that Athabasca Rainbow Trout are successfully utilizing constructed channels and end pit lakes for spawning, rearing, and overwintering. As this strategy is a significant component of end use reclamation planning for the Project, proof of concept was critical. In addition, fish densities in the upper Embarras River have increased substantially following the end pit lake reclamation in this area. Water temperature monitoring of end pit lake inlet and outlet channels suggests Arctic Grayling could also be supported within end pit lake systems with proper habitat modifications (substrate composition, habitat complexity, and cover components). Ongoing aquatic monitoring will document fish and fish habitat development, identify potential limiting factors, provide recommendations to improve reclaimed aquatic areas, with the overall goal of maximizing habitat suitability in reclamation efforts.

5.0 REFERENCE LIST

Hatfield Consultants. 2011. An Evaluation Of Water Quality In Existing End-Pit Lakes In The Coal Valley Mine Area Final Report. 42 pp. + App.

Hatfield Consultants. 2014. Macrophyte and Bathymetry Surveys in End-Pit Lakes in the Coal Valley Mine Area. 35 pp. + App.

J. Calvert, ESRD, personal communication. February 10 & 12, 2015.

Pisces Environmental Consulting Services Ltd. 2011. Post- construction monitoring of the permanent diversion channel on upper Mercoal Creek for the MP2 development. 6 pp.

Pisces Environmental Consulting Services Ltd. 2013. Aquatic Monitoring Program for End Pit Lakes in the Headwaters of the Embarras River, 2011-2012. 36 pp. + App.

Pisces Environmental Consulting Services Ltd. 2013. Recommendations for Channel Enhancements in the Embarras Lakes End Pit Lake System. 22 pp.

Pisces Environmental Consulting Services Ltd. 2013. 2012 post-construction monitoring of the permanent diversion channel on upper Mercoal Creek for the MP2 development. 5 pp.

Pisces Environmental Consulting Services Ltd. 2013. Mercoal Tributary 3 (MET-3) channel re-establishment and fisheries enhancement site visit. 5 pp.

Pisces Environmental Consulting Services Ltd. 2013. Recommendations for Mercoal Tributary 3 (MET-3) channel re-establishment and habitat enhancement. 9 pp.

Pisces Environmental Consulting Services Ltd. 2013. CVRI Robb Trend Project Summary of Fish Habitat Impacts, Mitigation and Habitat Compensation Strategies. 43 pp. + App.

Pisces Environmental Consulting Services Ltd. 2013. 2012 Revised Benthic Invertebrate Biomonitoring Program for the Coal Valley Mine: The Pembina River and McLeod River Drainage Basins. 25 pp. + App.

Pisces Environmental Consulting Services Ltd. 2014. Preliminary Results for Fish Sampling Conducted in the Embarras Lakes System. 6 pp.

Pisces Environmental Consulting Services Ltd. 2014. Assessment of the Fisheries Resources and Habitat for the Proposed Robb Main/Erith River Corridor Haulroad (Internal Report). 33 pp. + App.

Pisces Environmental Consulting Services Ltd. 2014. Erith River Fish Trap Reporting Data from July 3, 2013 to October 2, 2013 Located downstream of the Bacon and Halpenny Creek Confluences in SE 30-48-19 W5M. 3 pp.

Pisces Environmental Consulting Services Ltd. 2014. Habitat Suitability Index Modeling of the Erith River, Bacon Creek, and Erith River Tributary (ERT1) near Robb, Alberta (Internal Report). 21 pp. + App.

Pisces Environmental Consulting Services Ltd. 2014. Preliminary Results for Investigations Conducted on Existing End Pit Lakes in the South Block Area of the Coal Valley Mine. 9 pp.

Pisces Environmental Consulting Services Ltd. 2014. 2013 Revised Benthic Invertebrate Biomonitoring Program for the Coal Valley Mine: The Embarras River Drainage Basin. 32 pp. + App.

Pisces Environmental Consulting Services Ltd. 2015. 2014 Interim Results for Temperature Investigations Conducted Within the Erith River Drainage Within Coal Valley Mine's Robb Trend Lease and Within the Reclaimed Southblock Area. 11 pp.

Pisces Environmental Consulting Services Ltd. 2015. 2014 post-construction monitoring of the permanent diversion channel on upper Mercoal Creek for the MP2 development. 9 pp.