Celgar Pulpmill Environmental Effects Monitoring (EEM) Cycle Four Design Document

Final

June 2005

Prepared for:

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ACKNOWLEDGEMENTS

The Local Monitoring Committee (LMC) for Zellstoff Celgar Ltd. (Celgar) consists of representatives from the federal and provincial governments, environmental managers from Celgar and Hatfield Consultants Ltd. (Hatfield). LMC meetings and teleconferences provided a valuable forum for reviewing results of previous cycles, the draft *Updated Technical Guidance* for the pulp and paper industry, and the draft Cycle Four design document. Hatfield would like to acknowledge members of the LMC for their assistance:

- Ms. Janice Boyd, Environment Canada;
- Ms. Julia Beatty, B.C. Ministry of Water, Land and Air Protection;
- Ms. Robyn Roome, B.C. Ministry of Water, Land and Air Protection; and
- Ms. Fiona Mackay, Zellstoff Celgar Ltd.

1.0 INTRODUCTION

The Environmental Effects Monitoring (EEM) program was developed to assess the adequacy of effluent regulations under the federal *Fisheries Act*. Specifically, EEM addresses possible effects of pulp and paper mill effluents on fish, fish habitat, and use of fisheries resources, and examines the sublethal toxicity of process effluents. The program has been designed to achieve national uniformity in monitoring of effects, while taking into consideration site-specific factors.

The EEM program was implemented in 1992; Cycle One was conducted between 1993 and 1996. Following a general review of Cycle One, program requirements for Cycle Two were revised in *Aquatic Environmental Effects Monitoring Requirements EEM/1997/1*, and specifically in *Annex 1 to EEM/1997/1: Pulp and Paper Aquatic Environmental Effects Monitoring Requirements* (Environment Canada 1997). *Pulp and Paper Technical Guidance for Aquatic Environmental Effects Monitoring EEM/1998/1* (Environment Canada 1998) further described the program for Cycle Two (1997 to 2000). These documents also were in effect for Cycle Three (2000 to 2004).

On May 4, 2004, the *Regulations Amending the Pulp and Paper Effluent Regulations* (RAPPER; Government of Canada 2004) were approved. The amendments deal mainly with monitoring and reporting requirements, and focus on streamlining and improving the original *Pulp and Paper Effluent Regulations* (PPER). In addition to the amended regulations, the draft *Updated Pulp and Paper Technical Guidance for Aquatic Environmental Effects Monitoring* was released in May 2004 (Environment Canada 2004). These documents were used to design and implement Cycle Four.

This document describes the study design for the federal EEM Cycle Four program for Zellstoff Celgar Ltd. The requirements of the provincial monitoring program are also outlined. First, a site characterization is presented, consisting of a mill update and a summary of historical data including previous EEM cycles. Then, the requirements and design of the EEM program is described for each component (i.e., fish population survey, effects on the use of fisheries resources, invertebrate community survey, chemical tracers, and sublethal toxicological testing of process effluent). Next, the requirements and design for the provincial program is described. A tentative schedule for the execution of field surveys, laboratory analyses, and report submission is included. Standard Operating Procedures (SOPs) and qualifications of Hatfield personnel and sub-consultants are also presented.

The following sections are included in this document:

- Section 2 – Site Characterization and Summary of Previous Studies;
- Section 3 – Design for EEM Program;
- Section 4 – Design for Provincial Program;
- Section 5 – Summary and Schedule; and
- Section 6 – References.

2.0 SITE CHARACTERIZATION AND SUMMARY OF PREVIOUS STUDIES

Historical data and site information have been previously reported in detail in the following reports for Celgar:

- Pre-design report (Hatfield 1994a) – mill site history and operations, effluent quality, plume delineation survey, habitat and resource inventories, and receiving environment data.

- Cycle One interpretive report (Hatfield 1997) – site characterization and mill update, fish population survey, benthic invertebrate community survey, supporting environmental variables, and sublethal toxicity testing of effluent.

- Cycle Two interpretive report (Hatfield 2000) – site characterization and mill update, fish population survey, benthic invertebrate community survey, supporting environmental variables, and sublethal toxicity testing of effluent.

- Cycle Three interpretive report (Hatfield 2004a) – site characterization and mill update, fish population survey, benthic invertebrate community survey, supporting environmental variables, and sublethal toxicity testing of effluent.

The study design for each cycle summarized previous findings and updated information, such as mill effluent quality (Hatfield 1994b, 1999, 2002). This section of the Cycle Four study design also provides updates for site characterization and mill operations, brief summaries of monitoring programs regarding the fish population, fish tissues and/or the benthic invertebrate communities, and a summary of effects endpoints for use in determining appropriate surveys for Cycle Four.

2.1 SITE CHARACTERIZATION

This section provides information on:

- the mill, effluent quality, effluent mixing, sublethal toxicity test results and spills to the environment;

- any anthropogenic or natural factors not related to the effluent under study that may reasonably be expected to contribute to any observed effect; and

- reference and exposure area descriptions and habitat characterization.

2.1.1 Mill and Effluent Summary

2.1.1.1 Process Description and Update

The Zellstoff Celgar Ltd. mill is a bleached Kraft pulpmill located north of the confluence of the Columbia and Kootenay rivers at Castlegar, British Columbia, Canada (Figure 2.1). The mill was purchased from Celgar Pulp Company by Zellstoff in February of 2005. The original mill, built in 1961, had a production capacity of 454 ADt/d of bleached softwood Kraft pulp. Operation expanded in 1993 with construction of a new mill, and presently has a target production capacity of 1,200 ADt/d. Daily pulp production (annual averages) between 2000 and 2003 ranged from 1,141 to 1,196 ADt/d (Figure 2.2). Annual effluent flow since 1993 ranged from 109,000 to 126,650 m^3/d.

New components of the mill included a lime kiln, recausticizing plant, ClO_2 generator, effluent treatment system, pulp machine, evaporators, recovery boiler, and Kamyr fibre line. In April 1993, chlorine dioxide (ClO_2) replaced the use of elemental chlorine in the bleaching process (100% ClO_2 substitution). Approximately 39.5 t/d of ClO_2 is currently produced for bleaching; the bleaching sequence is $D_0E_{OP}D_ND$ (D = chlorine dioxide, E = caustic extraction, O = oxygen, P = peroxide, N = sodium hydroxide). A more detailed description of the bleaching process is presented in Hatfield Consultants Ltd. (1994a).

Several smaller projects were initiated and completed during 2000 to 2003 that related to effluent treatment and quality; these included:

- partial dredging of No. 1 spill pond in 2000 and completion in 2003; and
- repairs to the clarifiers and to the liner in the aeration basin; the aeration basin repairs amounted to a $3 million rebuild.

Celgar processes seven softwood species – hemlock, cedar, spruce, balsam, fir, larch, and pine – in the form of various pulping blends.

Figure 2.1 Location of the Zellstoff Celgar Ltd. mill on the Columbia River, British Columbia

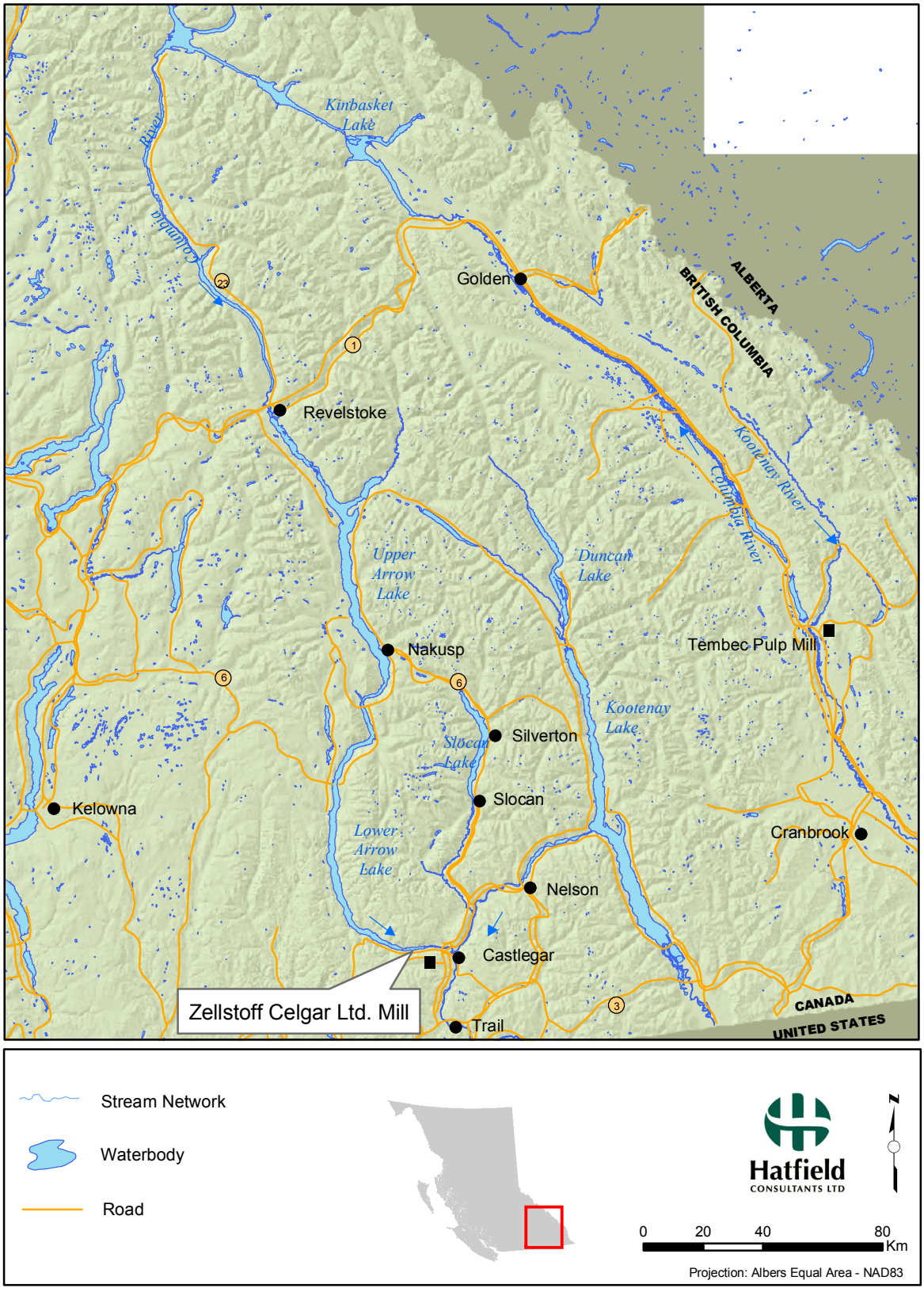
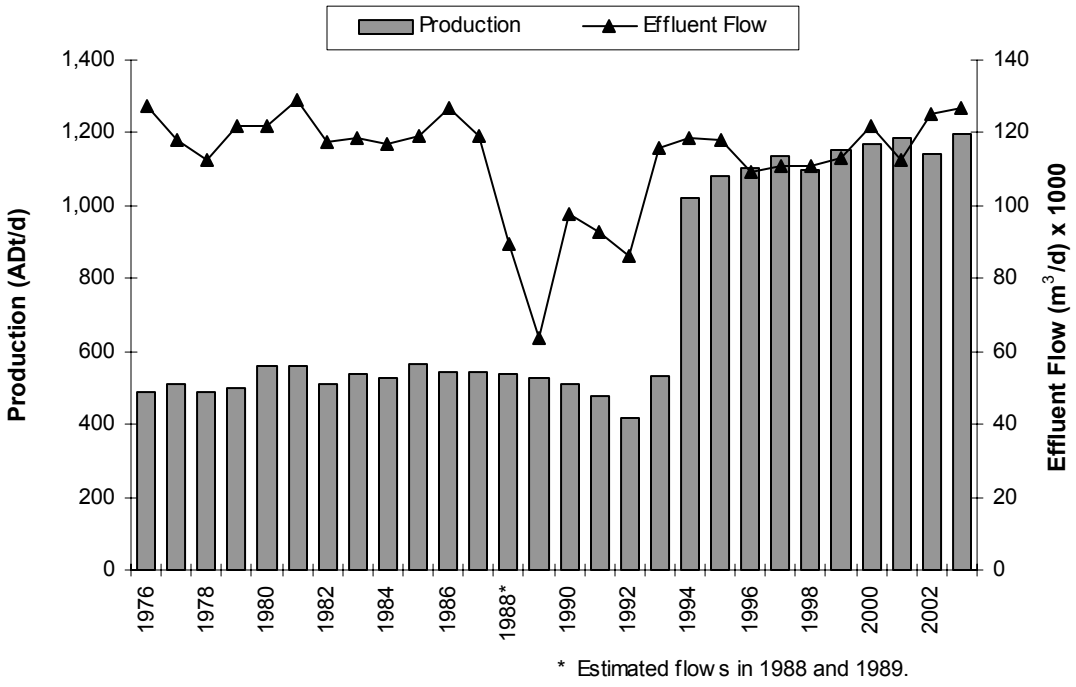


Figure 2.2 Annual average pulp production and effluent flow, Zellstoff Celgar Ltd. mill, 1976 to 2003.



2.1.1.2 Effluent Mixing

The mill's effluent is discharged into the Columbia River approximately 3 km downstream of the Hugh Keenleyside Dam. The submerged diffuser is comprised of six ports and extends 100 m from the south shore along the river bed. The depth of the river at the ports ranges from 15 to 24 m, depending on river flows. Columbia River discharge from the Hugh Keenleyside Dam ranged from 221 to 2,470 m^3/s in 1993; the lowest flow allowed by the Columbia River Treaty is 142 m^3/s. Given an average effluent discharge of 115,000 m^3/d (1.33 m^3/s), complete dilution at lowest flow resulted in an effluent concentration of 0.9%. However, complete mixing does not occur immediately downstream of the diffuser. For Cycle One, the zone of 1% effluent concentration or greater was estimated to extend a maximum of 6 km downstream of the diffuser for Cycle One to accommodate the mixing zone and low flow/low dilution periods.

Sodium was used as an effluent tracer for Celgar during Cycle One; data collected in August 1994 indicated effluent concentrations ranged from 0.54 to 1.03% effluent (n=6) in the near-field area (from the diffuser to Robson). Sodium was also used as an effluent tracer for the fish survey during Cycle Two; levels indicated that within the near-field area effluent concentrations ranged from 0.22 to 1.07%. Sodium concentrations during the Cycle Three benthic invertebrate study indicated effluent concentrations of 0 (far side of river) to 0.28% effluent in the near-field area. Hatfield recommends the use of the diffuser 6 km downstream as the 1% effluent concentration zone (near-field/exposure area) for Cycle Four.

2.1.2 Effluent Quality

2.1.2.1 Effluent Chemistry and Acute Toxicity Testing

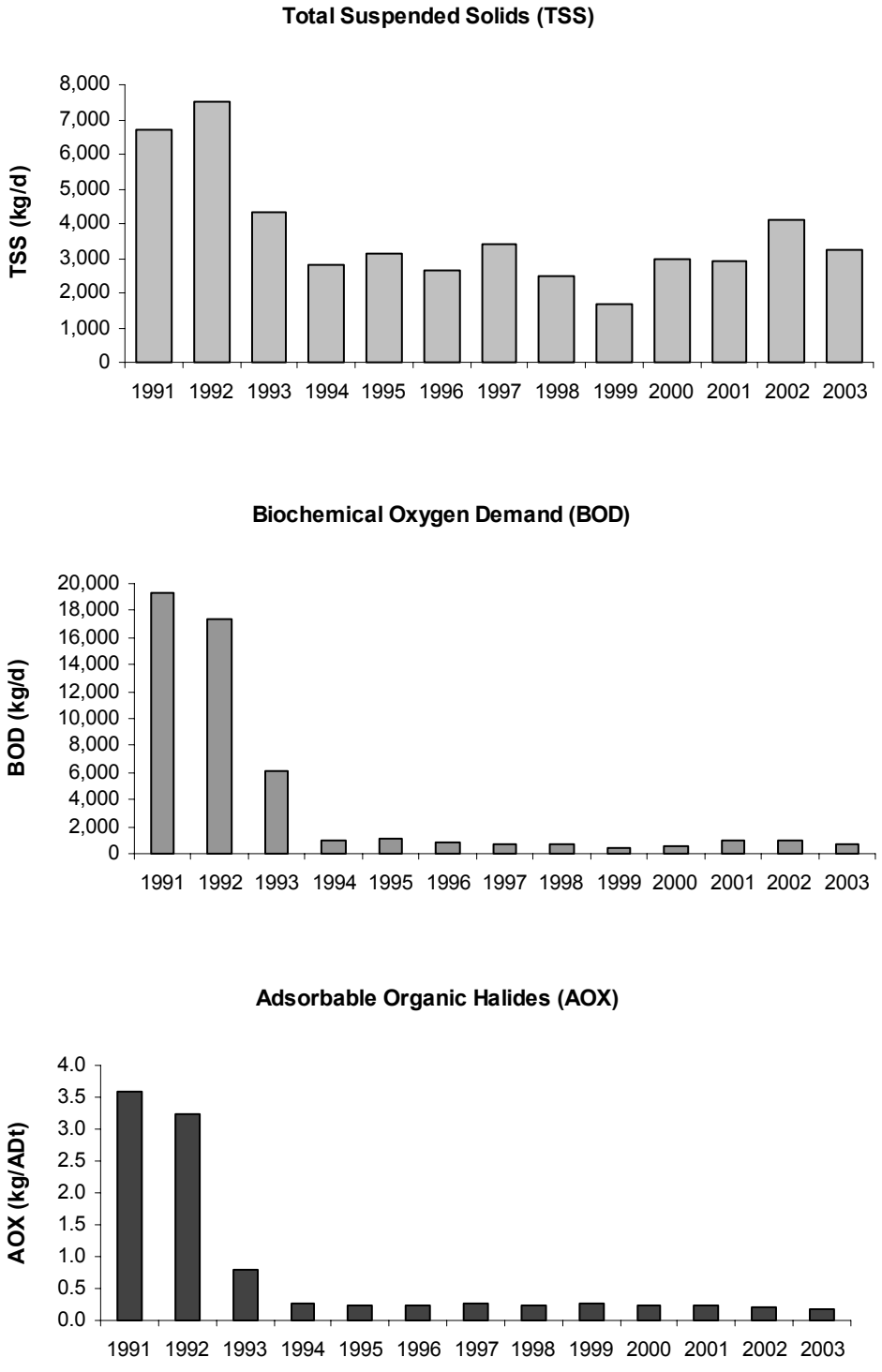
Effluent quality variables are routinely measured as required by provincial permits and federal regulations; annual average levels are presented in Table 2.1 for 2000 to 2003 for the Zellstoff Celgar Ltd. mill.

Effluent flow and production have increased slightly since 1994 when the mill was modernized (Figure 2.2); total suspended solids (TSS), absorbable organic halogens (AOX), and biochemical oxygen demand (BOD) values have decreased considerably relative to those observed from the pre-expansion period (Figure 2.3). BOD and AOX levels have remained relatively stable, although an increase in TSS was observed in 2002. Annual averages for 2003 were 3,147 kg/d TSS, 635 kg/d BOD, and 0.176 kg/ADt AOX. Dioxins and furans have been analyzed once or twice a year; 2,3,7,8-TCDD and 2,3,7,8-TCDF have not been detected (<2.0 pg/L) since 1994.

Table 2.1 Annual average values for process effluent quality variables, Zellstoff Celgar Ltd. mill, 2000 to 2003.

Variable	2000	2001	2002	2003
Total production (ADmt/d)	1,172	1,186	1,141	1,196
Effluent flow (m^3/d)	121,705	112,751	125,344	126,650
PH	7.5	7.5	7.5	7.5
Temperature (°C)	33.0	30.6	30.8	32.1
Conductivity (µS/cm)	1,638	1,693	1,615	1,553
TSS (kg/d)	2,970	2,941	4,133	3,235
BOD (kg/d)	540	964	1,038	671
AOX (kg/ADt)	0.24	0.225	0.208	0.176
Rainbow trout 96-hr LC50 (% effluent) – number of tests	>100 12 of 12	>100 20 of 20	>100 18 of 18	>100 16 of 18
Daphnia magna 48-hr LC50 (% effluent) – number of tests	>100 58 of 58	>100 75 of 75	>100 68 of 68	>100 58 of 66

Figure 2.3 Annual averages of TSS, BOD and AOX, Zellstoff Celgar Ltd. mill, 1991 to 2003.



Celgar undertakes regularly scheduled acute toxicity testing using rainbow trout and the cladoceran *Daphnia magna*. Acute toxicity of final effluent has not been observed since May 1993 (i.e., all LC50 results have been >100%; Table 2.1), except during a soap-spill event in September 2003, as explained in Section 2.1.3. The mill was in full compliance with Pulp and Paper Effluent Regulations throughout 2000 to 2003 aside from during that event.

2.1.2.2 Sublethal Toxicity of Effluent

EEM requires that effluent be tested to assess possible chronic toxicity effects in the receiving environment. The following tests were conducted to assess sublethal responses in aquatic biota to Celgar's effluent.

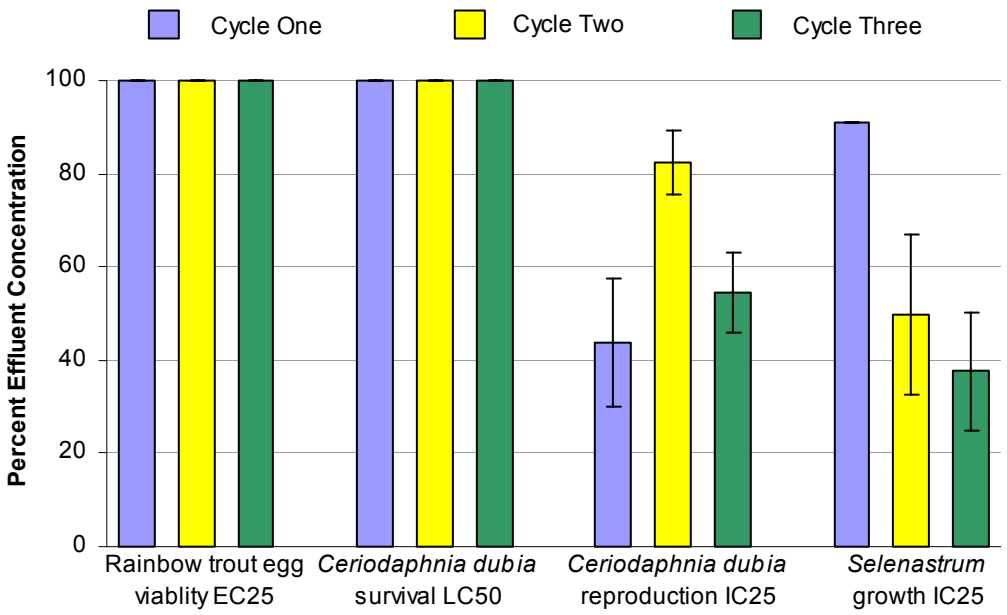
For the EEM Cycle One program, sublethal testing of effluent was undertaken four times for each test between October 1994 and December 1995. Tests included rainbow trout (*Oncorhynchus mykiss*) early life stage embryo test, survival and reproduction of an invertebrate (*Ceriodaphnia dubia*), and growth inhibition of an alga (*Selenastrum capricornutum*). Test endpoints for rainbow trout embryos (EC25 >100% effluent), *C. dubia* survival (LC50 >100% effluent), and *Selenastrum* growth inhibition tests (IC25s >90.9% effluent) exhibited no toxicity. A slight growth enhancement effect was observed at low concentrations of effluent in the *Selenastrum* tests. Slight impacts were observed for *C. dubia* reproduction (IC25 endpoints ranged from 19.8 to 78.8% effluent).

Five sublethal toxicity tests were conducted and reported for EEM Cycle Two. No toxicity was exhibited to rainbow trout embryos; EC25 endpoints were >100% v/v effluent. *C. dubia* LC50 endpoints for survival also exhibited no toxicity (>100% v/v effluent); IC25 endpoints for reproduction ranged from 66.8 to >100% v/v effluent. *Selenastrum* tests indicated growth was impacted for two tests (IC25 endpoints were 18.51 and 21.79% v/v effluent); the other three tests were non-toxic (>90.9%). The potential zone of sublethal effect was calculated at approximately 73 m for *C. dubia* reproduction, and 121 m for *Selenastrum* growth based on a 1% effluent concentration zone of 6 km.

Sublethal testing of effluent was reported for eight terms from winter 2000 to summer 2003 for Cycle Three. No toxicity was exhibited to rainbow trout embryos; EC25 endpoints were >100% v/v effluent. *C. dubia* LC50 endpoints for survival also exhibited no toxicity (>100% v/v effluent); IC25 endpoints for reproduction ranged from 28.4 to >100% v/v effluent. *Selenastrum* tests indicated growth was impacted for five tests (IC25 endpoints were 4.9 to 58.8% v/v effluent); the other three tests were non-toxic (>90.9%). An enrichment effect was observed with *Selenastrum* at various effluent concentrations depending upon the test. The potential zone of sublethal effect was calculated at approximately 110 m for *C. dubia* reproduction and 159 m for *Selenastrum* growth based on a 1% effluent concentration zone of 6 km.

Geometric means for each endpoint (± one standard error) were calculated for each cycle (Figure 2.4). Geometric means for rainbow trout and *C. dubia* survival were 100%. Means for *C. dubia* reproduction and *Selenastrum* growth endpoints have been greater than 30% effluent, although the mean decreased for both endpoints during Cycle Three relative to Cycle Two.

Figure 2.4 Averages (± standard error) for sublethal toxicity test endpoints for Celgar's effluent, Cycles One through Three.



2.1.3 Spills to the Receiving Environment

The mill reported the following spills or variations in effluent treatment and quality during Cycle Three:

- On February 26, 2000, a caustic spill (NaOH) to the effluent system caused pH to be out of compliance for two days (maximum of 9.8). No toxicity was associated with this spill.
- For four months in 2001 to 2002, effluent treatment was significantly altered, although not toxic, while the liner in the aeration basin was repaired; a variance order was provided so that the mill could operate during those months.
- Minor spills to the environment occurred during 2002; these included a diesel fuel leak at the boom boat shack and an overflow of treated effluent from the foam tank.

- On September 13, 2003, approximately 1,600 m^3 of soap carried over into the combined condensate system at Celgar. The soap inventory inverted in the weak black liquor storage tanks after low specific gravity weak black liquor was pumped from the digester area. The condensates overflowed to the process sewer and hence to the effluent treatment system. Effluent treatment problems became apparent on September 14, 2003, when high suspended solids were measured at the secondary clarifier launder ring. On September 18, 2003, acute toxicity of final effluent to *Daphnia magna* was observed. Concurrent chemistry testing revealed high resin and fatty acid concentrations. Bacterial examination showed dispersed growth conditions indicative of a toxic shock to the treatment system. The treated effluent returned to non-toxic condition on September 24, 2003. A subsequent impact study was conducted and no effect in the receiving environment was predicted from this soap spill.

2.2 STUDY AREAS

2.2.1 Habitat Classification

The Cycle One pre-design reference document described physical and biological characteristics of near-field, far-field and reference areas of the Columbia River in the vicinity of Celgar (Hatfield Consultants Ltd. 1994a). Descriptions of sampling stations were updated in the Cycle One interpretive report (Hatfield Consultants Ltd. 1997); river habitat, hydrology, and sediment characterization were presented. Cycle One fish collection areas were described in relation to catch composition and effort, and are discussed below. Similar descriptions were included in interpretive reports for Cycles Two and Three for benthic invertebrate stations and fish areas (Hatfield Consultants Ltd. 2000, 2004a).

2.2.2 Other Factors in Study Areas

Hugh Keenleyside Dam is located 3 km upstream of the mill discharge point. The dam is operated by BC Hydro primarily as a reservoir for downstream water storage and for fish habitat. In 2002, the Arrow Lakes Generating Station, located 400 m downstream of the Hugh Keenleyside Dam, began generating power. The generating station has not influenced flows and water levels in addition to what already is regulated by Hugh Keenleyside Dam.

The Arrow Lakes Reservoir, located upstream of the dam, is currently being fertilized as part of the Upper Arrow Lake Fertilization Program (Columbia Power Corporation (2004). Nutrients are added to the lakes to compensate for nutrient deficiencies caused by dams in the region, potentially enriching the downstream environment.

Downstream of the mill, another source of nutrients, the treated municipal sewage, is discharged in the vicinity of Castlegar; the primary outfall is located approximately 6 km downstream of the mill discharge point.

The Kootenay River confluence is located near the city of Castlegar, approximately 7 km downstream of the mill discharge. Water from this river has the potential to effect water quality in the Columbia River in the far-field area. Conditions in this portion of the Kootenay River (between the confluence and Brilliant Dam) have not been monitored for EEM programs.

No known natural changes occurred in the study area during Cycle Three.

2.2.3 Resource Inventory

A detailed resource inventory of the Columbia River region was presented in the Cycle One pre-design document (Hatfield Consultants Ltd. 1994a). In recent surveys, 23 species of fish were identified from the Canadian portion of the Columbia River downstream of Hugh Keenleyside Dam. Populations of the predominant sportfish and non-sportfish species generally appear to be stable and exhibit densities considered typical for these species. Walleye, a species recently introduced to the Columbia River watershed, has increased rapidly in numbers since it was first noted in Canadian portions of the river in the early 1980s. It has been suggested that a recent decline in burbot numbers may be linked to the increase in walleye abundance in the area. Principal sportfish species include rainbow trout, walleye, white sturgeon and mountain whitefish. Species considered rare which are found in the Columbia River include white sturgeon, mottled sculpin and Umatilla dace.

Based on biology, ecology, distribution and abundance, largescale sucker and mountain whitefish appeared to be the best candidate sentinel species in the study area for Cycle One.

For Cycle One in October 1994, fish were collected from the Columbia River near Castlegar and from Upper Arrow Lake (Hatfield Consultants Ltd. 1997). A reference area downstream of the Revelstoke Dam resulted in poor catch success; therefore, the reference area was moved to Upper Arrow Lake. Mountain whitefish were collected in sufficient numbers from the reference area; largescale or longnose sucker were not collected. In the near-field area for Celgar, mountain whitefish and longnose sucker were collected to satisfy Cycle One requirements; in addition, walleye and largescale suckers were also commonly captured.

The fish survey for Cycle Two focused on mountain whitefish and examined sucker species available in the near-field relative to the Slocan River near Passmore, the reference area for field sampling in July 1998 (Hatfield Consultants Ltd. 2000). Twenty-seven male and female mountain whitefish were captured in the near-field area; 30 males and females were captured in the Slocan River. Largescale suckers were captured in the near-field area (15 males, 20 females); however, largescale suckers appeared to be hybridized with bridgelip suckers in the Slocan River (8 male and 7 female largescale suckers were captured).

The Cycle Three fish survey successfully captured mountain whitefish in the reference and near-field areas (Hatfield Consultants Ltd. 2004a). Sculpin were the next most abundant species collected during Cycle Three, and were readily available upstream and downstream of Celgar. Sculpin were also captured on the Slocan River near Passmore. However, it may be difficult to identify the species of sculpin given hybridization of coexisting species in the lower Columbia River (McPhail and Carveth 1993). Sculpin found during the Cycle Three program were likely torrent sculpin (*Cottus rhotheus*).

2.3 SUMMARY OF BIOLOGICAL MONITORING

The Cycle One pre-design report summarized receiving environment data for benthic community structure and supporting environmental variables at Celgar (Hatfield Consultants Ltd. 1994a). A brief summary of historical surveys and results of Cycles One, Two and Three (Hatfield Consultants Ltd. 1997, 2000, 2004a) conducted along the Columbia River is presented below.

2.3.1 Receiving Water Quality

Prior to 1990, water quality of the Columbia River was altered by effluent from the pulpmill. Colour, dissolved oxygen, biochemical oxygen demand (BOD), tannins/lignins, dissolved sodium and resin acids increased noticeably immediately downstream of the discharge. Conductivity, chloride, total phosphorus and phenol concentrations increased slightly. These changes were more evident at low river discharges when temperature, turbidity, and suspended solid levels also were influenced by effluent. Under most flow conditions, temperature, pH, turbidity, suspended solids, alkalinity and total Kjeldahl nitrogen did not change appreciably downstream of the Celgar diffuser relative to upstream values.

In 1991, water quality objectives were defined for the Columbia River from Hugh Keenleyside Dam to Birchbank by BC Environment. Since then, most water quality objectives have been met for colour, turbidity, total suspended solids, effluent toxicity, chlorinated phenols and resin acids. Dissolved oxygen, pH, and chlorinated resin acid objectives were met most of the time. Dissolved oxygen is often high relative to objectives; high dissolved gas levels are associated with dam outflow rather than pulpmill activities.

During Cycle One, water chemistry was analyzed coincident with invertebrate and adult fish surveys in reference, near-field and far-field areas during October 1994 (Hatfield Consultants Ltd. 1997). Dissolved oxygen levels were lower (9.6 mg/L) relative to water quality objectives (10 mg/L) downstream of Hugh Keenleyside Dam at reference stations and in near- and far-field areas. Higher levels of total suspended solids and tannins/lignins were observed at near-field stations relative to reference and far-field stations. No organic enrichment was observed in relation to pulpmill effluent. Sodium was an effective tracer of effluent in the receiving environment, as noted in Section 2.1.1.2.

Cycle Two water quality analyses did not indicate increased concentrations of nutrients or total organic carbon in the near-field area relative to the reference area. However, significantly higher temperature, conductivity, hardness and ammonia measurements were observed in the far-field area relative to near-field and reference; nitrate-nitrite was significantly lower in the far-field area. The far-field area started downstream of the sewage treatment plant outfall east (downstream) of Robson.

Water quality measurements and samples were taken at each benthic invertebrate station during Cycle Three (Hatfield Consultants 2004a). Sodium and conductivity were used as effluent tracers; both tracers increased downstream of the discharge, but were not significantly different in the near-field area relative to the reference area; sodium concentrations were similar to those reported in Cycle Two. Hardness and total nitrogen were significantly higher in the near-field relative to the reference area; however, significant differences for water quality variables reflected small changes in values from one area to the next and were not considered ecologically important.

2.3.2 Sediment Quality

Substrate in the near-shore vicinity of the Celgar mill has been covered with layers of fibre, flyash, logs and bark debris, especially along the southern half of the river, for a distance of approximately 500 m (Hatfield Consultants Ltd. 1994a). Since 1975, the fibre mat has been decreasing in volume, primarily due to fibre and flyash recovery systems installed at the mill. Fibre mat sediments have exhibited higher levels of resin/fatty acids and dioxins and furans relative to other river sediments.

Depositional sediments collected near Celgar and elsewhere in the Columbia River were composed primarily of sand with some silt and minor quantities of gravel and clay. Total organic carbon, chlorinated phenolics, and dioxin and furan concentrations generally were higher in the near-field area of Celgar and decreased with increasing distance from the diffuser.

During Cycle One, depositional sediments from four areas (Revelstoke, Hugh Keenleyside Dam, near-field and far-field) were analyzed for metals, resin/fatty acids, nutrients, chlorinated phenolics, and dioxins and furans (Hatfield Consultants Ltd. 1997). Concentrations of chlorinated resin/fatty acids, chlorinated phenolics, and dioxins/furans were generally elevated at Celgar relative to reference and far-field stations. Dioxin/furan toxicity equivalents (TEQ) levels exceeded BC water quality objectives (0.7 pg/g TEQ) at the near-field station (3.4 pg/g TEQ).

Cycle One sediment toxicity tests using *Chironomus tentans* and *Hyalella azteca* failed to demonstrate any statistically significant differences in survival between reference, near-field and far-field samples. *C. tentans* and *H. azteca* growth was not inhibited or enhanced in exposed sediments relative to reference sediments.

Sediments from fibre mat stations (October 1994) exhibited higher levels of total organic carbon, resin/fatty acids, chlorinated phenolics and dioxins and furans relative to the near-field EEM station (Hatfield Consultants Ltd. 1997). Sediment toxicity tests from two fibre mat stations indicated no toxicity to C. tentans; however, reduced survival was observed in one sample for H. azteca (Gunter and Crane 1995).

The Cycle Two benthic invertebrate survey sampled erosional substrates that consisted predominantly of gravel, cobble and/or boulders (Hatfield Consultants Ltd. 2000). No physical or chemical analyses were conducted on these coarse sediments. Field observations indicated that four of five far-field stations exhibited considerable algal growth on rocks, evidence of nutrient enrichment in the Columbia River downstream of Castlegar and the sewage treatment plant discharge.

A fibre mat survey in October 1998 analyzed sediment quality at one reference station and six impacted stations (Hatfield Consultants Ltd. 2000). Higher concentrations of resin acids, chlorinated phenolics and dioxins and furans were exhibited in sediments collected within 160 m of the diffuser relative to reference levels; however, concentrations observed in the 1998 fibre mat samples were lower relative to 1994 and earlier levels. Sediment toxicity tests indicated greater toxicity to survival (but not growth) of *Chironomus tentans* and *Hyalella azteca* in the two fibre mat sediments relative to laboratory controls. Benthic invertebrate density and taxonomic richness were significantly lower at the two fibre mat stations relative to the upstream reference station.

Dioxin and furan monitoring of sediments was undertaken at four stations within the Cycle Two study area at the request of BC WLAP to compare to BC water quality objectives. Sediment from the near-field station 100 m downstream of the diffuser (outside of the fibre mat) exhibited higher total organic carbon, resin and fatty acids, chlorinated phenolics and dioxins and furans relative to reference and far-field stations. Dioxin/furan objectives levels were met at all BC Environment sampling stations when the objective was normalized for total organic content, as stated in the objective (0.7 pg TEQ/g of sediment TOC). [Note: One fibre mat sample exhibited dioxin/furan concentrations greater than the objective.]

For Cycle Three, sediment was collected from depositional substrates and analyzed for supporting environmental variables (Hatfield Consultants Ltd. 2004a). Sediments were primarily comprised of sand at all stations. The total organic carbon percentage (TOC%) was slightly higher on average in the near-field area relative to reference and far-field areas; however, this difference was not significant. Total chlorinated phenolic concentrations were significantly higher in the near-field; four of seven stations exhibited total detectable concentrations ranging from 0.007 to 0.027 mg/kg dry weight. Chlorinated phenolics were not detected in any reference area sediments nor in four of the five far-field sediments. The first far-field station, located downstream of the municipal sewage treatment plant, exhibited total chlorinated phenolic compounds of 0.005 mg/kg dry weight.

Dioxins and furans were analyzed in sediments from all three areas. Reference sediments exhibited an average of 0.18 pg/g TEQ; near-field stations located in the fibre mat area exhibited concentrations ranging from 1.1 to 7.1 pg/g TEQ; far-field stations exhibited concentrations of 0.3 to 0.4 pg/g TEQ. The three near-field fibre mat stations exceeded BC water quality objectives.

Sediment toxicity tests were conducted with sediment collected from 6 stations used for the EEM program (Hatfield Consultants 2004a). Results were not conclusive given some control failures; however, overall results demonstrated that sediments collected in the near-field/fibre mat area did not indicate toxicity. Rather, one reference station and one far-field station exhibited reductions in growth or survival.

2.3.3 Planktonic Communities

Communities of phytoplankton and macrophytes in the vicinity of the mill appeared to be influenced primarily by physical habitat features (i.e., river velocity, tributary inputs), rather than by mill effluent (Hatfield Consultants Ltd. 1994a). In July 1992, periphyton chlorophyll *a* and biomass were lowest at Celgar; this may have reflected an inhibition impact by pulpmill effluent.

Periphyton collected during Cycle One exhibited very little difference between reference and exposed stations for chlorophyll a and taxonomic composition (Hatfield Consultants Ltd. 1997). No enhanced growth or toxic effect was observed downstream of the pulpmill. Chlorophyll a concentrations for periphyton were well below BC water quality objectives for the lower Columbia River at all stations.

2.3.4 Benthic Invertebrate Communities

2.3.4.1 Prior to Environmental Effects Monitoring Programs

Benthic macroinvertebrate communities in the Columbia River near Castlegar between 1980 and 1992 were comprised primarily of facultative organisms (e.g., chironomids, molluscs, worms, etc.) that are found in both clean and/or moderately polluted waters (Hatfield Consultants Ltd. 1994a). These organisms also prefer finer-grained sediments, such as sand and silt, and lower water velocities. In early studies, stations within 5 km downstream of Celgar contained large proportions of pollution tolerant fauna, especially at the station nearest the mill. In 1988, a shift to higher proportions of facultative organisms was observed downstream of Celgar. Population densities appear to be increasing over time, possibly due to slight organic enrichment.

2.3.4.2 Cycle One

Two habitat types, erosional and depositional, were surveyed during October 1994 for Cycle One (Hatfield Consultants Ltd. 1997). Both habitats were sampled using a modified Hess sampler with 333 µm mesh. Four subsamples were collected from each station; stations included 2 reference, one near-field and one far-field for each habitat type.

In general, higher density and taxonomic richness were exhibited downstream of Hugh Keenleyside Dam rather that at Revelstoke. Both Revelstoke stations and the Hugh Keenleyside Dam erosional station appeared to be impacted by dam discharge volumes and fluctuations. Near-field benthic communities were the most diverse, with the highest number of organisms, a high number of taxa, the most even distribution of species, and least domination by one or two species. The majority of organisms from depositional stations were facultative taxa (e.g., worms and small crustaceans). Multivariate analyses did not correlate benthic data with pulpmill effluent constituents; rather, environmental factors (e.g., dam operation, particle size) likely influenced some differences in benthic communities.

2.3.4.3 Cycle Two

The Cycle Two benthic invertebrate survey was conducted during September 1999 in three erosional areas of the Columbia River: reference area upstream of the mill and downstream of Hugh Keenleyside Dam, near-field area between the diffuser and Robson, and far-field area from Castlegar to Birchbank. A Hess sampler with 200 μm mesh was used to collect four samples from each station; five stations were located within each area. Three samples from each station were analyzed at 500 μm; samples from seven historical stations were also analyzed for organisms between 240 and 500 μm. The fourth sample was archived.

Benthic invertebrate communities in all areas were healthy and diverse (Hatfield Consultants Ltd. 2000). Significant differences were observed for density among areas using ANOVA; the near-field area exhibited the lowest density relative to the other two areas. Two reference stations (and one far-field station) were highly dominated by *Hydra* spp.; this species is not an indicator of pristine, clean waters as they can thrive at high levels of nutrient enrichment. Number of taxa was not significantly different among areas.

All near-field and far-field station means fell within two standard deviations of reference means for density and taxonomic richness, except one near-field station (CGBN1). This station was located on a constructed boat ramp immediately downstream of the mill (note: the only other option in the area was on large rip rap boulders); this substrate was more compacted and embedded relative to natural substrates, thereby limiting habitat for benthic invertebrate colonization.

For the Cycle Four design, additional indices were calculated based on Cycle Two data for comparison of effects; these included evenness and Bray-Curtis indices. Calculations were based on the *Updated Technical Guidance* (Environment Canada 2004). Results of these calculations are presented in Table 2.2, along with density and taxa richness data. In addition, ANOVA tests were conducted comparing the reference area to the near-field area for a control/impact design. Density was significantly different ($p=0.091$); taxa richness, evenness and the Bray-Curtis index were not significant ($p=0.34$, 0.64 and 0.58, respectively). No near-field means were greater than two standard deviations from the respective reference mean.

Table 2.2 Density and taxonomic richness of benthic invertebrates (three subsamples per station), erosional habitat, Celgar EEM Cycle Two, September 1999.

Station	Mean Density >500 µm (N/m^2)	Taxonomic Richness >500 µm	Evenness[1]	Bray-Curtis Index[1]
Reference Area				
CGBR1	8,423	48	0.581	0.329
CGBR2	24,217	27	0.042	0.815
CGBR3	6,223	76	0.293	0.499
CGBR4	10,227	67	0.172	0.587
CGBR5	40,207	48	0.037	0.810
Average ± SD[2]	*17,859 ± 14,340*	*53 ± 19*	*0.225 ± 0.225*	*0.608 ± 0.208*
Near-field Area				
CGBN1	2,283	49	0.381	0.702
CGBN2	6,283	57	0.226	0.646
CGBN3	5,683	74	0.477	0.543
CGBN4	6,570	68	0.191	0.727
CGBN5	6,383	67	0.140	0.712
Average ± SD	*5,441 ± 1,796*	*63 ± 10*	*0.283 ± 0.141*	*0.666 ± 0.075*
Far-field Area				
CGBF1	24,683	63	0.024	0.786
CGBF2	40,957	66	0.281	0.828
CGBF3	29,727	79	0.194	0.829
CGBF4	38,480	62	0.541	0.831
CGBF5	17,697	51	0.094	0.695
Average ± SD	*30,309 ± 9,633*	*64 ± 10*	*0.227 ± 0.201*	*0.794 ± 0.058*

[1] Evenness and Bray-Curtis indices were calculated as per *Updated Technical Guidance* (Environment Canada 2004).

[2] SD = standard deviation.

2.3.4.4 Cycle Three

The Cycle Three benthic invertebrate survey at Celgar included 3 areas with 5 stations in reference and far-field areas and 7 stations in the near-field area (control/impact design). Three Ponar grabs per station were collected in depositional habitat for a total of 51 samples. Data from this survey are presented in Table 2.3 (Hatfield Consultants Ltd. 2004a).

Table 2.3 Density, taxa richness and indices from the depositional benthic invertebrate survey, Celgar EEM Cycle Three, August/September 2002. (Collected with a 23-cm Ponar grab, n=3, sieved at 500 µm.)

Station	Mean Density (N/m^2)	Total Taxa Richness	Evenness	Bray-Curtis Index
Reference Area				
CGBD1	24,101	39	0.148	0.599
CGBD2	7,825	36	0.223	0.328
CGBD3	40,192	51	0.149	0.540
CGBD4	12,613	50	0.276	0.125
CGBD5	72,618	63	0.252	0.692
Average ± SD[1]	*31,470 ± 26,164*	*48 ± 11*	*0.210 ± 0.059*	*0.457 ± 0.229*
Near-field Area				
CGBD6	22,605	29	0.185	0.825
CGBD7	20,030	27	0.221	0.820
CGBD8	31,702	57	0.234	0.438
CGBD9	18,252	36	0.272	0.632
CGBD10	111,301	62	0.396	0.802
CGBD11	72,328.2	59	0.160	0.759
CGBD12	73,941.9	45	0.145	0.835
Average ± SD	*50,023 ± 36,104*	*45 ± 15*	*0.230 ± 0.085*	*0.730 ± 0.147*
Far-field Area				
CGBD13	128,532	62	0.103	0.835
CGBD16	95,843	66	0.183	0.794
CGBD17	120,964	74	0.097	0.839
CGBD14	114,226	62	0.059	0.850
CGBD15	38,848	52	0.098	0.696
Average ± SD	*99,683 ± 36,098*	*63 ± 8*	*0.108 ± 0.046*	*0.803 ± 0.063*

[1] SD = standard deviation.

Statistical analyses were conducted using 3-area comparisons; results were as follows:

- Density was significantly higher in the far-field area relative to reference and near-field areas.
- Taxa richness was significantly higher in the far-field area relative to the near-field area.
- Evenness was significantly lower in the far-field area relative to the near-field and reference areas.
- When comparisons are made between reference and near-field areas only, no differences were observed for density, richness or evenness.
- A significant dissimilarity was observed between the reference area mean and near-field and far-field areas based on the Bray-Curtis index.

The far-field area may be confounded by a municipal sewage discharge and the confluence of the Kootenay River at Castlegar; however, water quality variables indicated only slight differences among reference, near-field and far-field areas. No water quality or benthic community samples have been collected from the Kootenay River for EEM.

An analysis of endpoints comparing the near-field area to the reference area indicates that there are no differences between these areas, with the exception of the Bray-Curtis index. This suggests that effects on benthic invertebrate communities may not be directly related to Celgar's pulpmill discharge.

2.3.5 Fish Surveys

2.3.5.1 Cycle One

Two sentinel species were studied during the adult fish survey for EEM Cycle One; these species were mountain whitefish (*Prosopium williamsoni*) and longnose sucker (*Catostomus catostomus*). Mature mountain whitefish (with gonadosomatic index greater than 1%) were not collected in sufficient numbers from reference (22 males, 19 females) and near-field (11 males, 12 females) areas; longnose suckers were only collected in the near-field area at Celgar.

Mountain whitefish were larger at age and exhibited higher condition factor and fecundity (females) at Celgar relative to reference fish (Upper Arrow Lake). Relative gonad size in females was approximately the same between the two areas; male mountain whitefish from Celgar exhibited larger gonads relative to reference fish. Relative liver size was generally larger in females relative to males, and larger at Celgar relative to reference fish. External abnormalities of skin and gills were higher in near-field fish; however, internal parasites and liver abnormalities were slightly higher in reference fish.

Longnose sucker collected in the near-field for Cycle One exhibited moderate external abnormalities of skin and opercula; some liver and kidney abnormalities were observed internally.

2.3.5.2 Cycle Two

The two sentinel species targeted for Cycle Two were mountain whitefish and largescale suckers (*Catostomus macrocheilus*). However, the reference area on the Slocan River did not provide sufficient largescale suckers to serve as a sentinel

species. Near-field mountain whitefish of both sexes were older, larger at age, and heavier at any length relative to reference fish. Condition factor was approximately 20% greater for mountain whitefish in the near-field area relative to the reference area. Differences in liver weight relative to length were not significant; only female mountain whitefish liver weight relative to whole weight was significantly smaller for a near-field fish relative to reference fish.

Most of female mountain whitefish exhibited differentiated gonads and were considered "mature" fish (22 in near-field, 26 in reference). Male mountain whitefish could not be distinguished as "mature" or "immature". Gonad weight, relative to length, of female mountain whitefish with differentiated ova was approximately 20% greater in near-field fish relative to reference fish; this difference was not significant. The difference in fecundity relative to whole weight between areas was small (<10%) and not significant; the difference in fecundity versus length was large (>20%) and highly significant. A few external abnormalities were observed in near-field and reference mountain whitefish; these included mild shortening of opercles, light fin erosion, "Pinocchio" nose, and a cloudy eye. External abnormalities observed in near-field largescale suckers included bubbles under the skin of fins and on the head; fish from both areas exhibited skin blemishes and frayed gills. Gas bubble disease is related to operation of the Hugh Keenleyside Dam.

There was little or no evidence of negative reproductive effects; rather, some evidence of positive effects or enhancement of fish condition was observed that could be the result of enhanced invertebrate prey abundance and biomass as a consequence of nutrient addition by pulpmill effluent. Habitat differences between the two areas may also relate to differences in fish life history variables. The near-field area at Celgar on the Columbia River is deeper and more lake-like, while the Slocan River is smaller and faster flowing.

2.3.5.3 Other Surveys in the 1990s

The Department of Fisheries and Oceans conducted a five-year monitoring program of mountain whitefish from the Columbia River near Castlegar between 1992 and 1996 (Nener *et al.* 1995; Antcliffe *et al*. 1997a,b). In July 1996, mountain whitefish sampled from the Columbia River at Genelle (downstream of the pulpmill) and at Beaver Creek (downstream of Trail smelter) exhibited no evidence of reduced condition factor, growth (size-at-age), relative gonad size (GSI), or relative liver size (LSI) compared with similarly-aged fish from the reference area on the Slocan River. Condition factor generally increased from 1992 to 1996, while GSI and LSI remained constant at all sites.

Fish health was assessed using a Cumulative Disease Severity (CDS) approach (Antcliffe *et al.* 1997b). As in 1992 and 1994, CDS in 1996 was significantly higher for fish sampled from the two reaches of the Columbia River relative to Slocan River fish. In 1996, these differences were due to heavy helminth parasitism in Columbia River fish, specifically the *Sanguinicola*-type blood fluke. When helminths were excluded from the analysis of 1996 data, adjusted CDS was similar among all sampling locations. The high incidence of helminths in 1996 may be related to natural parasite cycles, differences in water quality between river systems, or reduced immune system functioning.

2.3.5.4 Cycle Three

An adult fish survey was conducted in September 2002. Fish were collected from two areas: Columbia River near Celgar (near-field area); and the Slocan River near Passmore (reference area). Boat electrofishing was conducted during the day and after dark to collect fish. Results of the Cycle Three survey are:

- Mountain whitefish were readily available in both the near-field and reference areas. Largescale sucker were present in low numbers in the near-field area, and not captured in the reference area.
- Whitefish adults were significantly younger and larger (i.e., size-at-age) in the near-field area relative to the reference area.
- Condition for male and female whitefish in the near-field area was significantly greater relative to the reference area (+20.5% for females, +15.3% for males).
- Gonads were significantly larger in the near-field area for males (+20.8%); however, no difference was observed for females. Near-field female whitefish of similar body size exhibited significantly higher fecundity (number of eggs/female) relative to reference fish.
- Relative liver size (relative to body weight) was significantly higher in near-field female whitefish (+18.9%); slopes were not equal for male relative liver size, so no effect could be determined.

The biological response pattern was indicative of a relative increase in resources in the near-field area compared to the reference area; this was similar to the sentinel fish species response observed in Cycle Two.

2.3.6 Biological Tissues

Fish, particularly mountain whitefish, have been collected since 1988 for organochlorine monitoring (Hatfield Consultants Ltd. 1994a). Generally, dioxin (2,3,7,8-TCDD) has not been detected in control fish, but has been detected downstream of Celgar. Furan (2,3,7,8-TCDF) has been found in low concentrations in muscle tissue at control stations; levels downstream of the pulpmill were considerably higher. TCDD TEQs ranged from 17 to 77 pg/g in fish from Celgar to Waneta in 1991, and did not meet the 15.0 pg/g health consumption advisory level for muscle tissues. BC water quality objectives of 1 pg/g in fish muscle tissue were set in 1992 (Butcher 1992).

Dioxin and furan monitoring during 1994 (Cycle One) exhibited the following TEQ levels in mountain whitefish muscle tissues: reference, non-detect to 0.35 pg/g; near-field, 1.5 to 5.4 pg/g; far-field, 0.79 to 7.9 pg/g; all samples were composites of 6 fish (Hatfield Consultants Ltd. 1997).

Mountain whitefish collected from Genelle in 1996 by DFO exhibited TEQ concentrations >1 pg/g in muscle tissue of fish that were nine years (8.19 pg/g) and 13 years (38.35 pg/g) of age (Antcliffe *et al.* 1997b). All other values ranged from 0.250 to 1.022 pg/g in fish aged two to six years. TEQ concentrations in reference mountain whitefish from the Slocan River ranged from trace to 0.246 pg/g.

Ten mountain whitefish were collected from the near-field area in July 1998 for dioxin and furan analyses as required by BC Environment; muscle tissue only (no skin or bones) was used. Results from the five oldest fish (aged 7 to 10 years) indicated that TEQs ranged from 0.28 to 0.60 pg/g. These levels were all below the BC water quality objective of 1 pg/g TEQ.

Dioxin and furan concentrations in muscle tissue from mountain whitefish in the near-field area collected in September 2002 remained below federal and provincial guidelines (TEQs ranged from 0.48 to 0.68 pg/g).

Fish tainting studies have not been required for EEM programs at Celgar.

2.4 SUMMARY OF EFFECTS

A summary of effects observed on fish health in Cycles Two and Three is presented in Table 2.4; $p<0.05$ was used for assessing statistical significance. For both cycles, mountain whitefish were collected in sufficient numbers for the adult fish survey from the near-field and the Slocan River reference areas. A second sentinel species has not been successfully identified for Celgar.

Table 2.4 Summary of effects on fish health observed in Cycles Two and Three for mountain whitefish, Celgar EEM program.

	Effect Endpoint	Species/ Sex	Effect? (p-value)	Direction	Magnitude[1] (% diff)	Sufficient Power for Comparison?
Cycle Two	Age	Female	**Yes (p=0.015)**	NF > Ref	30	na
		Male	No (p=0.12)	-	15	na
	Size-at-age (body weight)	Female	No[2]	-	na	na
		Male	**Yes (p<0.001)**	NF > Ref	123	na
	Condition (length by body weight)	Female	**Yes (p<0.001)**	NF > Ref	**17**	Yes
		Male	**Yes (p<0.001)**	NF > Ref	**24**	Yes
	Relative gonad weight (by body weight)	Female[3]	No (p=0.49)	-	-6	No (P=0.40)
		Male	**Yes (p=0.002)**	NF > Ref	**286**	Yes
	Relative liver weight (by body weight)	Female	**Yes (p=0.006)**	NF < Ref	-20	Yes
		Male	No (p=0.12)	-	-14	No (P=0.58)

Table 2.4 Cont'd.

	Effect Endpoint	Species/ Sex	Effect? (p-value)	Direction	Magnitude[1] (% diff)	Sufficient Power for Comparison?
Cycle Three	Age	Female	**Yes (p<0.001)**	NF < Ref	-61.2	na
		Male	**Yes (p<0.001)**	NF < Ref	-62.5	na
	Size-at-age (body weight)	Female	**Yes (p<0.001)**	NF > REF	77.0	na
		Male	**Yes (p<0.001)**	NF > REF	123.9	na
	Condition (length by body weight)	Female	**Yes (p<0.001)**	NF > Ref	**20.5**	Yes
		Male	**Yes (p<0.001)**	NF > Ref	**15.3**	Yes
	Relative gonad weight (by body weight)	Female	No (p=0.28)	-	-7.1	Yes (P=0.97)
		Male	No (p=0.06)	NF > Ref	20.8	Yes (P=0.85)
	Relative liver weight (by body weight)	Female	**Yes (p<0.001)**	NF > Ref	18.9	Yes
		Male	No[2]	-	na	na

[1] Magnitude calculation based on ANCOVA adjusted least square means, near-field relative to reference.

[2] Slopes were unequal.

[3] Spawning females only – those with differentiated ova.

na = not applicable.

A summary of effects observed on fish tissue regarding dioxin and furan concentrations has indicated that TCDD TEQs have been below Health Canada consumption guidelines in all fish tested since 1992. A dioxin monitoring program has not been required for Celgar's EEM program for Cycles Two and Three. However, dioxin and furan analyses have been conducted to assess BC water quality objectives; these criteria were met in fish collected in 1998 and 2002.

No reports of tainting have been received for the Columbia River in the vicinity of Celgar; therefore, no tainting surveys have been included in Celgar's EEM program.

Table 2.5 summarizes the results of statistical analyses for effects endpoints (density and richness) for benthic invertebrate surveys for Cycles Two and Three. These were re-analysed comparing only reference and near-field areas for the determination of effects, with $p<0.05$ for significance and $P\geq0.80$.

Table 2.5 Summary of effects on benthic invertebrate community structure observed in Cycles Two and Three – near-field versus reference only; Celgar EEM program.

Cycle	Effect Endpoint	Effect? (*p* value)	Direction and Magnitude	Sufficient Power for NF and Ref Comparison?
Two	Density (log_{10})	**Yes (p=0.037)**	NF< Ref, -69%, <2 SD	Yes
	Richness	No (p=0.34)	16%	Yes (P=0.9)
Three	Density	No (p=0.35)	59%	Yes (P=0.93)
	Richness	No (p=0.73)	-6.3%	Yes (P=0.93)

Density was significantly lower in the near-field relative to the reference area in Cycle Two, but was below the critical effect size (2 SD of reference area mean). No significant differences in density or richness were observed in Cycle Three.

3.0 DESIGN FOR EEM CYCLE FOUR

3.1 EFFECTS DETERMINATIONS

The EEM program uses a tiered decision framework for the fish and benthic invertebrate surveys to answer the following questions:

- Is there an effect?
- Has the effect been confirmed for two consecutive cycles?
- Are the extent and magnitude of the effect known?
- Is the cause of the effect known (i.e., is it mill related)?

In Sections 3.1.1 and 3.1.2, results from Celgar's EEM Cycles Two and Three Programs are evaluated using this framework to determine what approach should be used for Cycle Four investigations.

3.1.1 Fish Survey

Pulp and paper mills are required to conduct a fish survey if the effluent concentration is greater than 1% within 250 m of the point of discharge. Fish surveys for the EEM program include a fish population survey and tissue analyses to determine if effluent is having an effect on fish and fisheries resources (Environment Canada 2004). The fish population survey provides an assessment of whether differences exist in whole organism metrics between fish from exposed and reference areas. Metrics, including age, size-at-age, condition, relative liver weight, and relative gonad weight, are compared between reference and exposed sites to assess potential effects on fish health. The fish tissue survey assesses 1) effects on palatability of fish tissue through tainting, and 2) dioxin and furan accumulation.

3.1.1.1 Fish Population Survey

The fish survey decision tree for Celgar is depicted in Figure 3.1. The figure has been highlighted with decisions for Celgar's Cycle Four design. The first question in the decision tree asks if there was an effect (i.e., a significant difference between a whole-organism metric in fish from near-field and reference areas) on fish in previous cycles. Effects have been observed on mountain whitefish age, size-at-age, condition, relative gonad weight, and relative liver weight for the last two cycles (Table 3.1). Generally, differences in these metrics observed between near-field and reference areas were suggestive of enrichment (i.e., fish in the near-field are bigger than fish in the reference area). The next question in the decision tree asks whether these endpoints exceeded the critical effect sizes: a 10% difference in condition and a 25% difference in relative liver and gonad weights between fish in near-field and reference areas. Condition in

male and female fish has exceeded the critical effects size (15 to 24% difference) for Cycles Two and Three. Relative gonad size in male fish exceeded the critical effect size for one cycle (286% difference). Given that consistent effects have been observed for at least one effects endpoint for both sexes across cycles, the fish survey should move into the "magnitude and extent" phase of the EEM program.

Table 3.1 Summary of effects observed in mountain whitefish in Cycles Two and Three.

Effects Endpoint	Sex	Critical Effect Size	Percent Difference between Near-field and Reference Area (NF vs. Ref)	
			Cycle Two	Cycle Three
Condition	Males	10%	**+24%**	**+15%**
	Females	10%	**+17%**	**+21%**
Relative Gonad Size	Males	25%	**+286%**	+20.8
	Females	25%	NS	NS
Relative Liver Size	Males	25%	NS	NS
	Females	25%	-20%	+19%

Bolded value represents an effect that exceeded the critical effect size.

NS = no effect was observed (i.e., metric was not statistically different between near-field and reference area fish)

To assess the magnitude and geographical extent of fish effects, typically fish would be sampled beyond the 1% near-field zone to identify where conditions return to reference conditions. However, the investigation of the magnitude and extent of effects on fish in the far-field area for Celgar is confounded by multiple factors:

- Influence of large tributaries (e.g., Kootenay River) on water quality in far-field area;
- Influence of non-point source and point source (e.g., STP) discharges on water quality in far-field area;
- Influence of dam-related effects on fish in near-field and far-field area; and
- Differences in habitat characteristics and food resources in the reference area (Slocan River) relative to near-field and far-field areas on the Columbia River.

Because these confounding factors limit the meaningfulness and interpretability of the data that would be generated by a magnitude and extent study, it is recommended that the program move into the Investigation of Cause (IOC) phase to establish whether the effects on fish observed in the near-field area are due to mill-related effects, other sources (e.g., nutrient enrichment of Arrow Lake), or reflect habitat differences between reference and exposure areas.

The proposed IOC study is described in Section 3.2.

3.1.1.2 Fish Tissue Analyses

Tainting

Tainting evaluations are recommended when previous tainting studies or recent complaints (within the last three years) demonstrate there is an issue.

BC Environment and Celgar have not received reports of fish tainting in the past three years. Therefore, a tainting study is not required for Cycle Four.

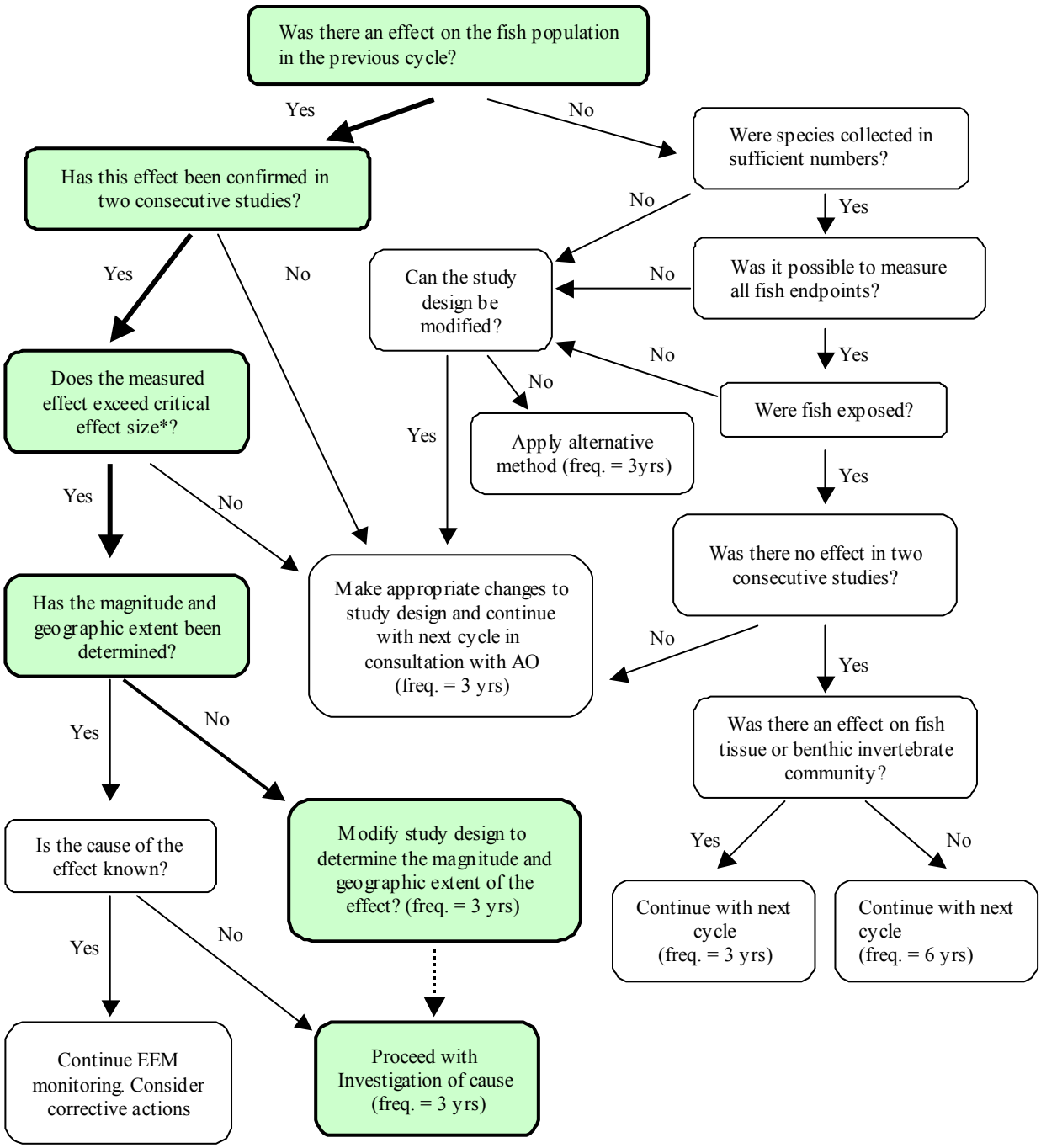
Dioxin and Furan Tissue Analyses

Tissue analyses for chlorinated dioxins and furans are required if:

- Effluent contained measurable concentrations of 2,3,7,8–TCDD (15 ppq) or 2,3,7,8-TCDF (50 ppq) since the submission of the most recent EEM report; or
- Dioxin and furan concentrations exceeded 15 pg/g in muscle or 30 pg/g in liver in fish from the exposure area in the previous EEM survey.

Concentrations of dioxins and furans in mountain whitefish collected during Cycle Three monitoring and WLAP Objectives Monitoring were below these guidelines (Hatfield 2004; Roome, *pers. comm.*, 2005). Therefore, dioxin and furan monitoring in fish tissues will not be conducted for Cycle Four.

Figure 3.1 Fish survey decision tree for Cycle Four, Celgar mill.



* The recommended effect sizes (difference from reference) for the fish survey are: relative gonad size: ±25%, relative liver size: ±25%, condition: ±10%.

⋯⋯▶ proposed approach for Cycle Four.

3.1.2 Benthic Invertebrate Survey

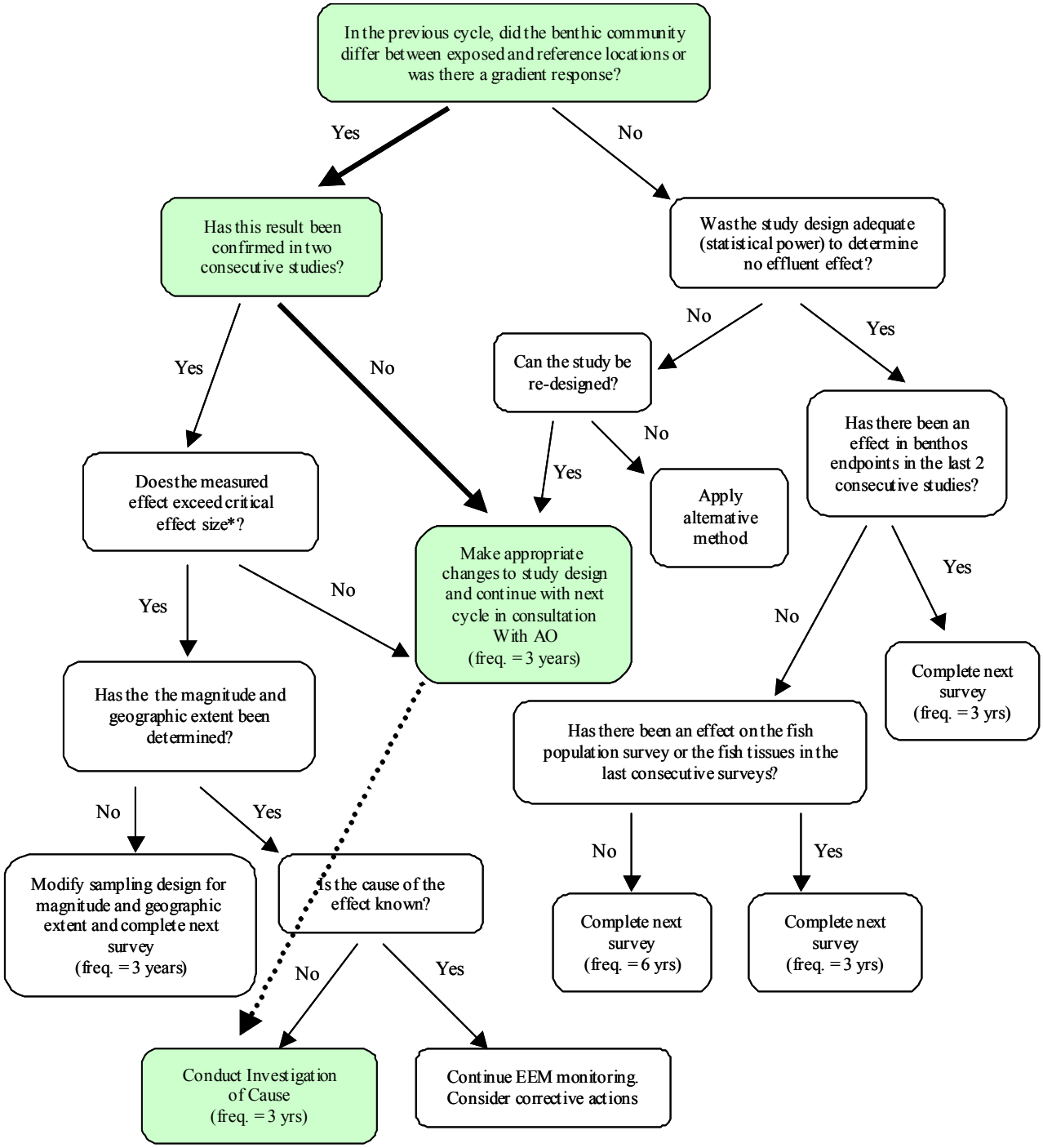
Invertebrate community assessments are used to delineate the extent of habitat degradation due to organic enrichment or other forms of physical and chemical contamination by pulp and paper mill effluent.

3.1.2.1 Invertebrate Survey Decision Tree

Figure 3.2 presents the invertebrate survey decision tree from the *Updated Technical Guidance* (Environment Canada 2004). The first question on the benthic survey decision tree asks whether benthic communities differed between exposure and reference areas (or if there was a gradient response). In Cycle Two, the erosional survey indicated a significantly lower density in the near-field relative to the reference area. In Cycle Three, density and richness did not differ significantly between reference and exposure depositional areas. The decision tree suggests that we modify the design and conduct another cycle of monitoring.

Hatfield recommends conducting another depositional survey to investigate potential effects on invertebrates. We recommend refining and expanding the design used for Cycle Three to minimize variability within reference and near-field areas to better assess whether there are effects on benthos; this design will be a component of the Investigation of Cause study (described in the following section) and will be used to compare community structure between areas.

Figure 3.2 Benthic Invertebrate decision tree for Cycle Four, Celgar mill.



* The effect sizes for the benthic invertebrate community are: 2 standard deviations ± reference area mean for density and richness.

▶ proposed approach for Cycle Four.

3.2 INVESTIGATION OF CAUSE STUDY

An Investigation of Cause (IOC) study investigating nutrient sources and uptake by benthic invertebrates and fish is proposed to determine whether:

- Enrichment effects observed in mountain whitefish in previous cycles are attributable to the mill effluent, upstream sources (i.e., Arrow Lake nutrient enrichment), confounding downstream sources (i.e., STP), or are related to habitat differences between reference and exposure areas; and

- Whether enrichment effects are evident in benthic invertebrate communities within the fibremat and non-fibremat areas of the near field.

The proposed IOC study will investigate nutrient enrichment in the near-field area through an isotope tracer study, which is supported by an expanded benthic invertebrate survey. The isotope tracer study will compare nutrient signatures in effluent to those observed in nutrient sources (i.e., sediments, benthic water) and biota (benthic invertebrates and small-bodied fish) in the receiving environment. The expanded benthic invertebrate survey will assess whether enrichment effects exist in the near-field area as a whole, and within fibremat and non-fibremat subareas.

3.2.1 Selection of Reference and Exposure Areas

The reference area for the IOC study will be located downstream of the Hugh Keenleyside Dam and upstream of the mill discharge along the Columbia River (Figure 3.3). Isotope tracer (all samples excluding fish) and benthic invertebrate samples will be collected from 5 stations located downstream of the dam; fish will be collected from riffle habitats within the reference area.

The near-field area will be located along the Columbia River from the mill discharge to just below the Castlegar Sewage Treatment Plant (STP). Isotope tracer (all sample excluding fish) and benthic invertebrate samples will be collected from twelve stations: five stations inside the historical fibre mat, five stations outside of the fibre mat, and one station located above and below the Castlegar STP discharge; fish will be collected from riffle habitats within the near-field area but away from the confounding influence of the STP.

3.2.2 Isotope Tracer Study

3.2.2.1 Background

There is evidence that stable isotope analysis may identify distinct nutrient signatures in biosolids of effluent that can be linked to nutrient signatures in physical media (i.e., historical fibre mats, sediments, and suspended sediments and biota in the receiving environment. Incorporation or uptake of effluent

signatures into aquatic food webs has been documented at multiple trophic levels. For example, Velinsky *et al.* (2003) measured stable isotopes of carbon and nitrogen in pulpmill effluent and suspended sediments in a stream located upstream of a mill (Velinsky *et al.* 2003). Results indicated that effluent solids were enriched in ^{13}C and depleted in ^{15}N relative to suspended material in stream water. Signatures of effluent and suspended sediments from upstream areas were then compared to those observed in filter-feeding invertebrates. The carbon isotopic composition of filter feeders was most similar to effluent solids just below the discharge. Farther downstream, macroinvertebrate carbon values were comparable to those observed in suspended sediments upstream of the facility. The isotopic enrichment of nitrogen between the effluent solids and macroinvertebrates was well within the expected shift in isotope ratios observed in related studies. This study illustrated that pulpmill effluent solids are a source of C and N to downstream organisms and can be used successfully to trace the movement of nutrients through aquatic food webs.

Various studies have indicated that carbon, nitrogen, and/or sulphur isotopic signatures can be used to investigate nutrient sources and uptake in the food web. Thus, we propose that stable isotopes be used to determine the source of nutrients in the near-field area.

3.2.2.2 Study Overview

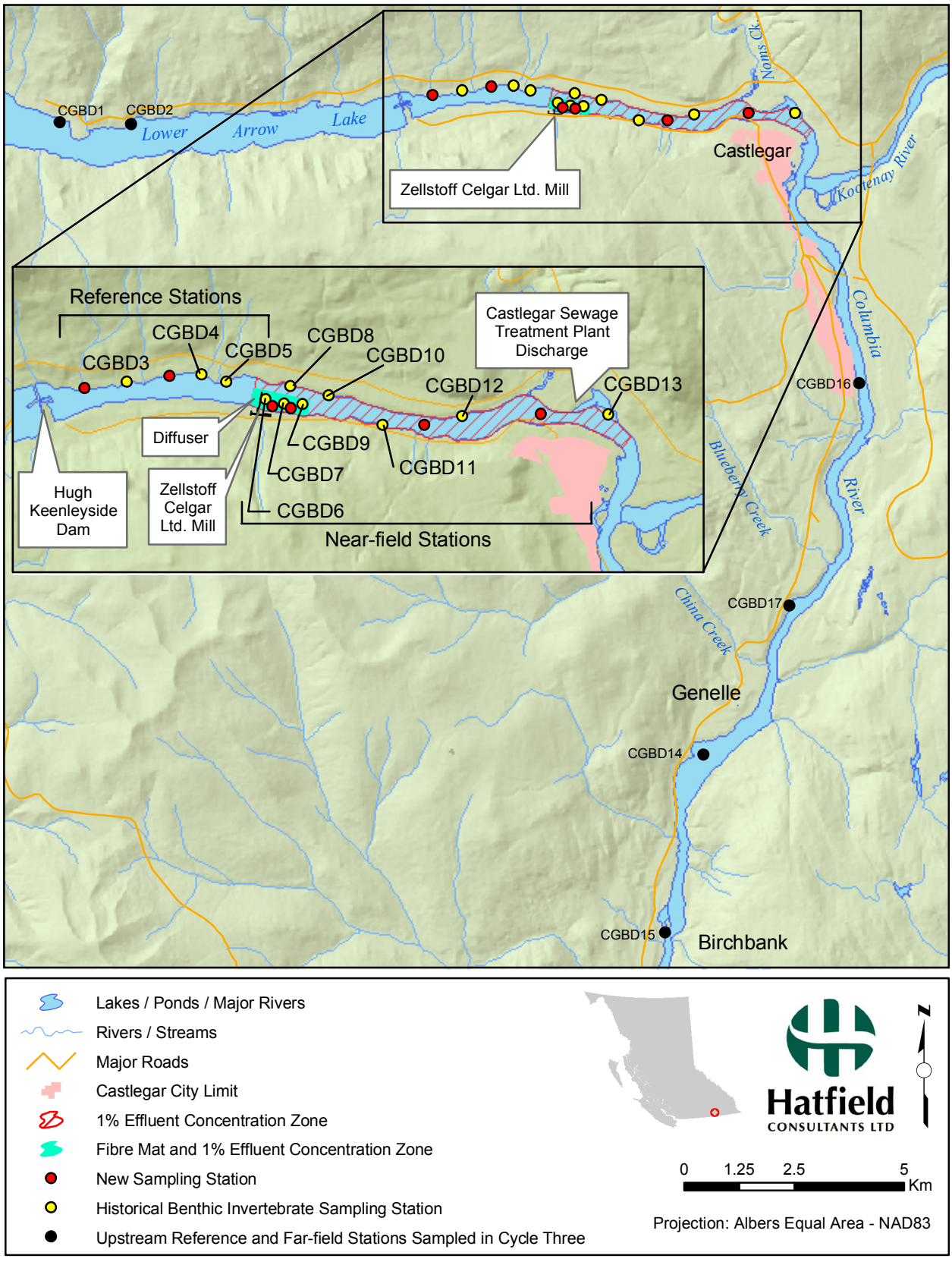
The objective of the isotope tracer study is to investigate the potential source(s) of the nutrient enrichment response pattern observed in near-field mountain whitefish. The tracer study includes two phases, which are described below:

- Phase 1 – separation of nutrient sources; and
- Phase 2 – evaluation of nutrients in benthic communities and small-bodied fish.

In the second phase of the analyses, ratios of carbon, nitrogen, and sulfur in effluent and other nutrient sources in the receiving environment (fibre mat/sediment and benthic water samples) will be compared to determine baseline signatures and whether nutrients present in water and sediments are a result of current operations, represent historical deposits, or are from a confounding source.

In the second phase of the analyses, ratios of carbon, nitrogen, and sulfur in benthic invertebrates and small-bodied fish will be compared between reference and exposure areas and to nutrient signatures of effluent, sediment, and water to determine if the observed enrichment in fish is mill-related.

Figure 3.3 Proposed benthic invertebrate, sediment, and benthic water sampling stations for Investigation of Cause Study, Celgar EEM Cycle Four, August/September 2005.



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Phase One – Separation of Nutrient Sources

Stable isotopes of carbon, nitrogen and sulfur will be used to compare nutrient signatures of fibremat, sediments, and benthic water to effluent and between reference and exposure areas. The goal of this phase is to identify if there is a distinction between current mill effluent biosolid signatures, fibre mat, sediment, and benthic water (i.e., water sediment interface) in the vicinity of the mill.

a) Sample Collection

Samples of fibre mat/sediment deposits, and benthic water samples will be collected in August/September 2005 during the Cycle Four field program (Table 3.2). Sediment/fibre mat and benthic water samples for isotope analyses will be collected by Hatfield personnel. Whole treated effluent (2-L samples) will be collected by mill personnel three times prior to, during, and following the August/September field program (e.g., every 20 days).

Table 3.2 Samples to be collected for stable isotope (carbon, nitrogen and sulphur) analyses, Celgar EEM Cycle Four Investigation of Cause.

Location	Phase One	Phase Two
Effluent discharge	3 effluent biosolids samples	na
Near-field Area	1 fibre mat /sediment sample x 12 stations	1 composite sample/representative benthic invertebrate x 3 representative benthic invertebrates X 12 stations
	1 benthic water sample x 12 stations	5-10 small-bodied fish
Reference Area	1 sediment sample x 5 stations	1 composite sample/representative benthic invertebrate x 3 representative benthic invertebrates X 12 stations
	1 benthic water sample x 5 stations	5-10 small bodied fish

na = not applicable

Hatfield staff will prepare effluent, river water, fibre mat/sediment samples for carbon, nitrogen and sulphur stable isotope analyses and ship them to the appropriate laboratory. A small sediment sample will be collected from the surface of each benthos grab from each station for isotope analyses (sample preparation described below).

b) Sample Preparation and Analysis

Effluent and water samples will be frozen then shipped to ALS (Vancouver, BC) for filtering. Samples will be filtered using 0.7 µm pre-combusted glass fibre filters, then the filter will be placed in a labelled vial and frozen. A small volume

of surface sediment/fibre mat (1 cm x 0.5 cm x 1 cm) will be placed in a vial and frozen immediately after sampling. Filters and sediment samples will be shipped frozen to the appropriate laboratory (i.e., Stable Isotope Nature Laboratory, University of New Brunswick) for stable isotope analysis.

Phase Two – Nutrients in the Food Web

The objective of Phase Two is to determine which nutrient sources are being used by fish and benthic invertebrates (which represent a food resource for fish). Three representative invertebrate species will be selected that are important dietary items for mountain whitefish residing in the vicinity of the mill (Hatfield 2000; Antcliffe *et al.* 1997a;b) to provide direct assessment of nutrient uptake in benthos and an indirect assessment of nutrient uptake in fish; actual species of invertebrates selected will be based on availability at time of sampling, but may include select species of:

- cladocerans (*Alona costata*);
- midges (e.g., *Procladius* species);
- ostracods (Cyclopoida);
- oligochates (e.g., *Nais*); and
- bivalves (e.g., Sphaeriidae).

Small-bodied fish, likely sculpins, will also be collected from near-field and reference areas to directly assess nutrient uptake in fish.

a) Sample Collection

Benthic invertebrates will be collected from depositional habitats using a 23cm Ponar grab. One grab will be collected at each station. Contents of the grab will be carefully transferred to a tub, then sieved on the boat or on shore through a box sieve with 200 µm mesh size. Particles and organisms larger than the mesh size retained in the box sieve will be washed into a sample collection bottle. Samples will be preserved with ethanol and subsequently shipped to the consulting taxonomist for sorting.

A small number (5-10 fish) of small-bodied fish (e.g., sculpins) will be collected from riffle habitats along the shoreline of reference and near-field areas using seines and/or a backpack electrofishing unit. The species to be collected will be based on availability at the time of the survey.

b) Sample Analysis

Representative invertebrate organisms must be present in sufficient abundance in reference and near-field areas (at least 5 to 10 organisms per station) to provide an adequate sample for stable isotope analysis (minimum of 5 mg wet weight)

(Table 3.2). Preserved samples will be sorted in the laboratory and a separate composite for each representative organism will be prepared for each station and analyzed for carbon, nitrogen, and sulfur isotopes.

Individual fish tissue samples will be analyzed for the same isotopes.

c) Data Analysis

The analysis of isotope signatures will be conducted within the near-field area and between each near-field area and the selected reference stations through bivariate plots. This will allow visual comparison of signatures for two of the three isotopes at a time and illustrate any overlap in signature patterns. ANOVAs will be conducted when appropriate.

3.2.3 Expanded Benthic Invertebrate Survey

For Cycle Four, Hatfield recommends that a control/impact survey be conducted in reference and near-field depositional zones during August/September of 2005.

The reference area will be comprised of 5 stations located downstream of the dam; in Cycle Three, two stations were located upstream of the dam and three stations were located downstream of the dam. Locating all reference stations downstream of the dam will minimize variability between reference sites, providing a greater likelihood for detecting potential differences between reference and near-field areas.

The near-field area will be comprised of twelve stations: five stations inside the historical fibre mat, five stations outside of the fibre mat, and one station located above and below the Castlegar Sewage Treatment Plant (STP) discharge. Increasing the number of stations inside and outside of fibre mat will allow comparisons to be made within the near-field area (i.e., fibre mat vs. non-fibre mat), as well as relative to the reference area; these comparisons were not possible in Cycle Three due to a limited number of stations. The inclusion of the stations located upstream and downstream of the STP provides useful information for the isotope tracer study regarding the influence of the STP (described in the previous section). Where possible, historical sampling locations will be used to allow for temporal comparisons.

Sample Collection

All stations will be located in depositional habitat; invertebrates will be collected with a 23-cm Ponar grab from a boat. Figure 3.3 approximates these locations; actual station locations will be determined in the field and reported in the interpretive report.

Contents of the grab will be carefully transferred to a tub, then transported to the shoreline where it will be sieved through a box sieve with 200 µm mesh size. Particles and organisms larger than the mesh size retained in the box sieve will be washed into a sample collection bottle. Samples will be preserved with buffered formalin and subsequently shipped to the consulting taxonomist (Appendix A2).

Sample Replication

Samples will be collected from five stations in the reference area and twelve stations in the near-field area. Three replicates (i.e., grabs) will be collected at each station (total of 51 samples).

Sample Analysis

Samples will be re-sieved in the laboratory using 500 and 200 µm screens. Identification and data analysis will be conducted on the 500 µm fraction of composite samples from each station. The 200 to 500 µm fraction will be archived in case further study of invertebrate communities is required. Specimens will be identified to family, or possibly to genus, as recommended by the *Updated Technical Guidance* (Environment Canada 2004).

Data Analysis

a) Community Metrics

A variety of metrics will be used to assess benthic invertebrate community structure:

- Density;
- Taxa (family) richness;
- Evenness index; and
- Bray-Curtis index.

These metrics will be calculated as described in the *Updated Technical Guidance* (Environment Canada 2004). The total surface area of sediments collected for benthic invertebrate survey will be adjusted to correct for the surface area of sediment removed from each grab for chemical analyses, to allow for more accurate benthic invertebrate density estimates. Major differences in presence/absence or densities of specific taxonomic groups will also be examined and discussed in relation to effluent exposure and/or habitat characteristics of each station.

b) Statistical Analyses

All analyses of benthic invertebrate data will be completed using SYSTAT v.10 statistical software (SPSS Inc. 2000). Summary statistics, including mean, median, standard deviations, standard error, and minimum and maximum values will be calculated for each key benthic community metric for each station and each area.

Analysis of Variance (ANOVA)

Two-tailed ANOVAs and appropriate *post-hoc* comparisons will be conducted for benthic community metrics and supporting environmental variables to identify differences between reference and near-field areas, and near-field subareas (i.e., inside and outside of the fibre mat). Residuals from each ANOVA will be evaluated for normality and homogeneity of variance qualitatively using residual plots. If data fail to meet the assumptions of the model, ANOVAs will be conducted using $\log_{10}$-transformed variables. If assumptions of the model are not met using the transformed variables, ANOVAs will be conducted using ranked data. All tests will be conducted at a significance level of $\alpha = \beta = 0.10$ (power = 0.90).

Determination of Effects

Results from ANOVAs will be used to determine whether there are effects on benthic invertebrates in exposure areas. An effect is defined as a statistically significant relationship between exposure and reference areas. The magnitude and direction of observed effects will be calculated and compared to ± 2 standard deviations of the mean for the reference area.

Correlations

Spearman's rank correlations will be used to evaluate the relationships between benthic community metrics and supporting environmental variables.

Cluster Analysis

Cluster analysis is a multivariate procedure for detecting natural groupings in data. It is based on the relative abundance of taxa from each station; taxa that are abundant tend to influence the cluster analysis more than rare taxa. The cluster analysis will be conducted on Bray-Curtis dissimilarity coefficients created from abundance data for individual taxa. These Bray-Curtis dissimilarity coefficients differ from those described in the preceding section in that they include pair-wise comparisons of all stations, rather than being restricted to comparisons to the reference median.

Power Analysis

Post hoc power analyses will be used to evaluate the ability to detect a difference of ± 2 standard deviations in benthic invertebrate community structure between reference and exposed stations. For *post-hoc* analyses, alpha will be set equal to 0.1. Power will be calculated using an effect size equivalent to two standard deviations (SDs) from the reference area mean. All analyses will be conducted using G*Power software (Faul and Erdfelder 1992), using methods described in Cohen (1998).

3.2.4 Supporting Environmental Data

Sediment Quality

A number of key variables will be measured in sediments from each station to aid in the interpretation of the IOC study and to meet provincial monitoring requirements (Section 4.0). Samples will be analyzed for the following variables:

- total organic carbon (TOC);
- total nitrogen;
- total phosphorus;
- particle size; and
- dioxins and furans (3 near-field fibre mat stations only [described in Section 4.0]).

Water Quality

Standard *in situ* water quality variables including water temperature, dissolved oxygen, pH, and conductivity will be measured at each station during sample collection. Current velocity (near surface) and observations regarding each location will also be recorded.

Water samples will be collected for analyses from two depths at each station: the subsurface and near bottom. If the depth is <2 m, then one water sample will be collected at mid-depth (at least 15 cm below the surface). A Van Dorn bottle will be used to collect water at depth. Water samples will be analyzed for:

- hardness;
- total phosphorus, orthophosphate, and total dissolved phosphorus;
- total nitrogen, nitrate-nitrite, and ammonia;
- total organic carbon and dissolved organic carbon; and
- sodium (as an effluent tracer).

Final effluent grab samples, collected on each day of fieldwork in the near-field (a minimum of three samples per survey), will be analyzed for all water quality variables. All laboratory analyses will be conducted by ALS Environmental in Vancouver, British Columbia (see Appendix A2).

3.2.5 Chemical Tracers

Mills are required, where practical, to provide confirmation at the time of field sampling that the samples collected are representative of effluent exposed and reference areas. The selection of a tracer will depend on the type of mill involved and the complexity of the receiving environment. Resin acids have been identified as a useful tracer in fish in some cases, but other tracers may be substituted if proven to be effective.

A mill is required to measure resin acids in fish bile, water and effluent if:

- fish can move freely between exposure and reference areas;
- the mill's furnish is at least 50% softwood or recycled fibre; and
- resin acids are present in effluent at a concentration equal or greater than 50 µg/L.

Resin acids were not used as a tracer at Celgar in Cycle Three given the low total resin acid concentrations present in final effluent. Effluent concentrations of resin acids remain low; therefore, the use of bile concentrations of resin acid metabolites as a tracer is not recommended for Cycle Four.

Sodium is a potential effluent tracer for the Celgar mill in the receiving environment to assess general exposure areas. Sodium will be measured in water and effluent to estimate effluent concentrations during the fish survey.

3.2.6 Sublethal Toxicity Testing

The objectives of sublethal toxicity testing in EEM are:

- to contribute to the field program as part of the weight-of-evidence approach;
- to compare process effluent quality between mill types Canada-wide and to measure changes in effluent quality as a result of effluent treatment and process changes; and
- to contribute to the understanding of the relative contributions of the mill in multiple discharge situations.

Sublethal toxicity tests that have been selected for mills west of the Rocky Mountain divide for Cycle Four include:

- fish early life stage development test using rainbow trout (*Oncorhynchus mykiss*);
- invertebrate reproduction and survival test using *Ceriodaphnia dubia*; and
- plant growth inhibition test using the green alga *Selenastrum capricornutum*.

Sublethal toxicity testing will be conducted twice in each calendar year, for a total of six tests for Cycle Four. The suite of three tests will be conducted during each test period. All analyses will be conducted by Vizon SciTec Inc., Vancouver, British Columbia (Appendix A2). Test results will be reported to Environment Canada within 90 days of test completion.

3.2.7 QA/QC

A variety of quality assurance and control (QA/QC) procedures will be used in the field, office, and laboratory to ensure the quality of the data collected and analyzed for the fish survey, in accordance with requirements detailed in the draft version of the *Updated Technical Guidance* (Environment Canada 2004).

General

Data collection and analyses will be conducted in accordance with Hatfield Consultants Ltd. Standard Operating Procedures (SOPs; Hatfield 2004b).

All Hatfield personnel that will work on the project are qualified, experienced biologists with project experience in monitoring pulp and paper mill effluents, including environmental effects monitoring and/or organochlorine monitoring. For further information, see Appendix A3.

Field crew responsibilities will be clearly established prior to beginning field work through the use of Field Work Instructions (FWIs), which contain detailed information regarding sampling locations, inventory of the samples to be collected, an inventory of equipment and methods to be used, and a field safety plan. FWIs are prepared and discussed prior to beginning field sampling to ensure that the field crew is familiar with the workplan and to address any foreseeable issues.

To ensure the safety of our staff, a field safety plan is a mandatory component of the FWI. Prior to initiating fieldwork, potential safety issues associated with field work are identified and local emergency contacts and necessary safety equipment are identified. A copy of this information is provided to the field crew at Hatfield offices. The Hatfield Company Health and Safety Management Plan is available at the company office and when staff are in the field for further guidance (Hatfield Consultants Ltd. 2004c).

Equipment used for sampling will be inspected prior to the field program. Sampling gear and equipment used for field programs are regularly inspected and maintained according to manufacturer's instructions to ensure equipment is operating properly and safely.

Data collected will be recorded on customized datasheets, which are created to increase efficiency in the field and reduce the likelihood of potential errors or omissions. Sample ID labels will be affixed to datasheets and sample containers using a simple duplicate-labelling system that provides each sample with a unique sample ID and ensures samples are not mislabelled. Sample ID labels will be affixed to the container and secured with clear tape to ensure they are waterproof.

Fish Collection

Fish collection permits will be obtained from provincial and federal government agencies as required. Fish will be collected using the most appropriate method. Efforts will be made by the field crew to minimize capture and handling stress.

The primary method of quality assurance in the field involves completion of data sheets to provide a record and hardcopy of relevant observations. Data sheets prepared for use in the field for the Celgar fish survey include:

- Fish Collection Sheet;
- Water and Effluent Collection Sheet; and
- Chain of Custody/Analysis Request Forms.

Benthic Invertebrate and Sediment Collection

A number of procedures are followed in the field to prevent contamination of sediment samples used for chemical analysis. Before sampling, equipment is rinsed or soaked with the appropriate chemicals. For dioxin and furan analyses, equipment is rinsed with environmental grade hexane, then acetone using plastic wash bottles. For metals analyses, equipment is cleaned with detergent then rinsed with deionized, distilled water.

Sampling is conducted sequentially from the least contaminated areas to the most contaminated areas. Only grabs that do not contain large, foreign objects, obtain an adequate penetration depth, and are not overfilled or leaking are used. To avoid sample contamination during sample collection:

- Staff wear disposable polyethylene (dioxin and furan analyses) or non-powdered latex (metals) gloves;
- Sediments are transferred from the grab to a bowl for compositing using a clean, stainless steel spoon. Direct contact between sediments and gloves is avoided;

- Sediments in direct contact with the grab are not used; and
- Between stations, sampling equipment is washed (as described above) and rinsed with ambient site water.

Field duplicates are used to assess the precision of the field sampling and heterogeneity of sediments collected from the same location by collecting another sample. The number of QA/QC samples collected is equal to 5 to 10% of the total number of samples collected (e.g., one set of QA/QC samples for each set of 10 to 20 stations sampled). Station(s) used for collection of QA/QC samples are randomly selected.

Water and Effluent Collection

Samples will be collected, preserved, and stored in accordance with current standard technical guidance and quality assurance and control (QA/QC) practices.

The following procedures will be used in the field to prevent sample contamination:

- Sampling will be conducted sequentially from the least to the most contaminated sites;
- During sample collection, staff will wear powder-free, latex gloves;
- If samples are collected from the boat, samples will be collected upstream of the boat;
- If samples are collected on foot, the individual collecting the sample will wade in downstream from the station and avoid disturbing the substrate;
- Prior to sample collection, the sample bottle and cap will be triple-rinsed with site water;
- During sample collection, bottle lids will be held lid down; and
- During sample collection of composite samples, the sample container will be kept covered.

To assess potential contamination when collecting water samples in the field, three QA/QC samples are used: field blanks, trip blanks, and field duplicates. Field blanks, comprised of a deionized water sample prepared in the field, are used to assess contamination from handling the sample. Trip blanks, comprised of a deionized water sample prepared in advance of sampling, are used to evaluate the efficacy of sample preservation and storage conditions; trip blanks can be requested from the analytical laboratory or prepared prior to shipping sample containers. Field duplicates are collected separately from other samples to assess the precision of the field sampling and heterogeneity of water collected from the same location and depth.

The number of QA/QC samples is equal to 5 to 10% of the total number of samples collected (e.g., one set of QA/QC samples for each set of 10 to 20 samples). Station(s) used for collection of QA/QC samples are randomly selected.

Shipping

Prior to shipment to analytical laboratories, detailed lists of samples are made on chain of custody (COC) forms. These forms are used to notify the laboratory of the number and type of samples that are being shipped and type of analyses requested. In addition, these forms allow samples to be tracked by the project manager from the point of shipment to the laboratory. Information recorded on the COC includes the date, project, sender's name, sample type (e.g., water, sediment), sample ID number, sampling time and location, analyses requested, and preservatives added or required.

All samples are carefully packaged with insulating materials and shipped to analytical laboratories for storage and subsequent analyses. Biota, sediment and water samples are usually shipped either cool (on ice) or frozen (dry ice) in plastic coolers via courier. Preserved biota samples (e.g., benthic invertebrates) are shipped in bins or coolers to the consulting taxonomist. The receiving laboratory checks the COC to ensure all samples are accounted for and in good condition, and confirms the samples received, date, and analyses to be performed.

Benthic Invertebrate Analysis

An experienced invertebrate taxonomist, familiar with benthos from the Columbia River, will undertake invertebrate taxonomy for Celgar EEM Cycle Four. Consulting taxonomists contracted by Hatfield for this work include Applied Technical Services, Victoria, or Biologica Environmental Services, Victoria (Appendix A2). A reference collection has been established for the EEM program at Celgar; it is currently stored by Hatfield Consultants Ltd.

Freshwater benthic invertebrate samples are re-sieved in the laboratory at 500 µm and approximately 200 µm; the 500 µm fraction is analyzed for all samples; the 200 to 500 µm may be analyzed or archived. The *Updated Technical Guidance* (Environment Canada 2004) outlines procedures for re-sorting. EEM requires that a minimum of 10% of the samples be re-sorted with a ≥90% sorting efficiency.

Subsampling of individual benthic samples (minimum subsample size of one quarter recommended) should only be conducted when a large number of organisms are found in individual samples; however, samples should be enumerated in their entirety where possible. A minimum of 300 organisms should be present in a subsample. If subsampling is undertaken, subsampling error is estimated by continuing to sort subsamples until the entire sample is

sorted for a minimum of 10% of all samples that are subsampled. Subsampling accuracy and precision should be <20% error. See the Revised Guidance for Sample Sorting and Subsampling Protocols for EEM Benthic Invertebrate Community Surveys (Environment Canada 2002b) and *Updated Technical Guidance* (Environment Canada 2004) for more information.

Benthic invertebrates may be identified to the lowest taxonomic level readily possible (i.e., genus and species), although family level identification is required for Cycle Four. Different life stages of benthic organisms (i.e., larvae, nymphs, pupae, adults) are identified and enumerated separately on raw data sheets. The taxonomic laboratory reports count data for each field replicate, listing taxa present and abundance. Organisms are identified using standard keys as outlined in *Updated Technical Guidance* (Environment Canada 2004).

Water and Sediment Analysis

Laboratories used to analyze water and sediment samples must be accredited by the Canadian Association for Environmental Analytical Laboratories (CAEL). All laboratory QA/QC samples will be assessed using in-house laboratory protocols to identify potential contamination and determine the precision and accuracy of the analyses. Any deviations from QA/QC criteria will be identified in the laboratory reports.

For water and sediment quality analyses conducted in the laboratory (i.e., ALS Environmental Services, Vancouver), a number of QA/QC samples are used to ensure that sample contamination did not occur during analysis and that results reported are precise and accurate. A method blank, consisting of a deionized water sample prepared at the initiation of the analysis, is used to assess potential contamination during analyses. A sample split into two aliquots (duplicate sample) is used to assess the precision of the analyses. Spiked samples, reference standards, and laboratory controls are used to establish the accuracy of the analyses.

Sublethal Toxicity Testing

The toxicological laboratory uses a number of QA/QC samples to ensure that the results reported are precise and accurate. For each set of tests, a control group and a reference toxicant test are used to assess the accuracy of the toxicity test. In addition, five replicates of each treatment group are used in each test to assess the precision of the results.

All laboratory QA/QC samples are assessed using in-house laboratory protocols to identify potential contamination and determine the precision and accuracy of the analyses. Any deviations from QA/QC criteria are identified in the laboratory reports.

Data Handling and Analyses

Results from field sampling, including information recorded on field datasheets and laboratory results, will be reviewed for potential errors or omissions and to identify any anomalous results. Results will then be entered into Excel spreadsheets (if not already in that form) and checked for transcription errors. Original raw data files will be retained; duplicate files will be used for data analysis and manipulation.

For statistical analyses, a detailed log will be kept that describes the procedures used. As described in Section 3.2.3, all assumptions for statistical models will be checked and data will be checked for outliers.

Reporting

EEM reports will undergo editorial reviews for grammar, spelling, and consistency. The report will be comprehensive and detail methods and results. Any changes to protocols, study designs, or other components will be outlined. An evaluation of QA/QC for the study and raw data will be presented in an appendix.

4.0 DESIGN FOR PROVINCIAL PROGRAM

4.1 INTRODUCTION

Historically, the EEM programs for the Celgar mill have incorporated monitoring requirements of the MWLAP water quality objectives and the Columbia River Integrated Environmental Monitoring Program (CRIEMP). These monitoring requirements have included benthic invertebrate community, water and sediment quality, and fish tissue surveys, and sediment toxicity testing.

Due to improvements in environmental quality in the Columbia River in the vicinity of the mill, related to the elimination of elemental chlorine in pulp processing and corresponding reduction of dioxins and furans in the aquatic environment, provincial monitoring requirements for Cycle Four have been reduced. Dioxins and furans will only be measured in sediments at three sites located in the fibremat in the near-field areas, where concentrations have been elevated above Canadian Council of Ministers of the Environment (CCME) Interim Sediment Quality Guideline (0.85 pg/g) (Roome, pers. comm. 2005); all other stations exhibited dioxin and furan concentrations below this guideline. Dioxin and furans will not be measured in fish tissue because concentrations observed in mountain whitefish in Cycle Three were below CCME guidelines for tissue residues. Sediment toxicity testing has been eliminated from the program due to problems encountered with quality of test results (Roome, *pers. comm.* 2005).

4.2 METHODS

4.2.1 Sample Collection

Sediment chemistry samples will be collected for dioxin and furan analyses from three near-field fibremat stations (CGBD6, CGBD7, and CGBD9) during the EEM Cycle Four program. Sediment samples will be collected using a stainless steel Ponar sediment grab. Three grabs will be collected at each station. The top 10 cm of each grab will be removed, composited, homogenized, and placed in an amber glass jar. The general appearance of the sediments, including grain size, presence of a hydrocarbon or biogenic sheen, and presence of debris, plant material, or biota, will be recorded.

An adhesive label with the sample ID will be placed on each jar and secured with clear tape. Sample IDs and other relevant info (e.g., type of analyses requested, station ID) will be written on the lid of the jar using a waterproof marker. A duplicate sample ID label will be attached to the datasheet. All samples will be stored in a cooler, to avoid exposure to heat and light, and shipped to the AXYS Analytical Services Ltd. (Victoria, BC) for analysis.

4.2.2 Data Analysis

Dioxin and furan concentrations will be screened against CCME guidelines for sediment quality for the protection of freshwater aquatic life.

5.0 SUMMARY AND SCHEDULE

5.1 SUMMARY OF CYCLE FOUR SURVEYS

Table 5.1 summarizes the number and type of samples that will be collected from near-field and reference areas. A summary of sediment, effluent, and water quality variables to be measured during the Cycle Four program is presented in Table 5.2.

Table 5.1 Summary of number of fish benthic invertebrate, sediment/fibre mat, and effluent to be collected from near-field and reference areas, Celgar EEM Cycle Four program.

Area	Investigation of Cause – Isotope Tracer Study Samples					Benthic Invertebrate Control / Impact Study[2]
	Fish[1]	Benthic Invertebrates	Sediment / Fibre Mat[2]	Benthic Water	Effluent	
Columbia River Reference Area (D/S of dam)	5-10	1 sample / station X 5 stations X 3 organisms = 15 samples	Isotope 1 grab / station X 5 stations = 5 samples Chemistry 1 sample/station X 5 stations = 5 samples	Isotope 1 sample / station X 5 stations = 5 samples Chemistry 1 grab / station X 5 stations = 5 samples	Isotope 3 samples Chemistry 3 samples	3 samples/station X 5 stations = 15 samples
Columbia River Near-field Area: *Fibre-mat* *Non-fibremat* *U/S of STP* *D/S of STP*	5-10	1 sample / station X 12 stations X 3 organisms = 36 samples	Isotope 1 grab / station X 12 stations = 12 samples Sediment chemistry 1 sample/station X 12 stations = 12 samples Dioxin and Furans 1 sample/station X 3 stations = 3 samples	Isotope 1 grab / station X 12 stations = 12 samples Chemistry 1 grab / station X 12 stations = 12 samples		3 samples/station X 12 stations = 36 samples
Total Number of Samples	**10-20**	**51**	**34 + 3 D/F**	**34**	**6**	**51**

[1] Number of fish: target number of small-bodied fish of the same species per area.

[2] Benthic community sites match those used in tracer isotope study; therefore, only one set of sediment and water chemistry samples need to be collected from each station.

Table 5.2 Summary of water, effluent and sediment quality variables to be measured during the Celgar EEM Cycle Four program.

Variable	Fish Areas	IOC/Benthic Stations
Water and effluent quality – required variables	X	X
Dissolved oxygen[1]	X	X
Temperature[1]	X	X
pH[1]	X	X
Conductivity[1]	X	X
Hardness	X	X
Total phosphorus	X	X
Total nitrogen	X	X
Total organic carbon	X	-
Current velocity[1]	X	X
Depth[1]		
Water and effluent quality – supporting variables	X	X
Sodium	X	X
Orthophosphate	X	X
Total dissolved phosphorus	X	X
Nitrate+nitrite	X	X
Ammonia	X	X
Dissolved organic carbon		
Sediment Quality		
Particle size	-	X
Total organic carbon	-	X
Dioxins/furans (3 stations only)	-	X

[1] These variables will be measured in water only in the field with a YSI meter or other equipment.

5.2 PROPOSED SCHEDULE FOR CYCLE FOUR

Table 5.3 provides the proposed schedule for Cycle Four activities.

Table 5.3 Schedule of EEM Cycle Four activities for Celgar.

Date	Activity
Winter 2004 to Summer 2006	Six sublethal toxicity tests
September 2004	LMC meeting to discuss draft Cycle Four Design
March 2005	MWLAP submits provincial monitoring requirements for Cycle Four to LMC members
March 2005 – June 2005	Hatfield revises draft design based on input from MWLAP and EC
Mid-late June 2005	Revised Cycle Four design submitted to LMC members
	LMC conference call to discuss draft design
Mid-Late June 2005	Cycle Four Design finalized
August/September 2005	Cycle Four Investigation of Cause field program
2006/2007	Data analysis and report preparation
April 1, 2007	EEM Cycle Four interpretive report submitted to Environment Canada

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