SALMON RIVER WATERSHED ENRICHMENT FOR FISH HABITAT RESTORATION 2010

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For

The Campbell River Salmon Foundation
Campbell River, BC

Administered by

BC Conservation Foundation
Nanaimo, BC

January 2011

EXECUTIVE SUMMARY

On June 30, 2010, inorganic fertilizer was applied to the Salmon River (Kelsey Bay), Grilse Creek, Memekay River and the White River (July 14) to restore nutrients lost through decreased salmon production and to address footprint impacts as a result of BC Hydro diversion operations. While many species benefit from enrichment activities on the Salmon River, winter-run steelhead trout (*Oncorhynchus mykiss*) and coho salmon (*O. kisutch*) are the primary targets. A total of 3,570 kg of slow release fertilizer (Crystal Green, 5-27-0) was distributed over eight sites in the Salmon and Memekay rivers as well as Grilse Creek. Additionally, four sites in the White River/Consort Creek drainage were enriched. Partnership funding from the Campbell River Salmon Foundation, Habitat Conservation Trust Foundation and Living Rivers Georgia Basin/Vancouver Island was used to purchase, apply, and monitor nutrient applications.

Water sampling results indicate that orthophosphate and total phosphorous levels were elevated in treated reaches as compared to representative controls. Nitrogen levels were variable, but generally sufficient to support algal growth. Periphyton collector plates confirmed that chlorophyll *a*, used as a surrogate for algal growth, was elevated in treated reaches. However; juvenile fish growth analysis from data collected in Grilse Creek suggested that no significant difference in mean weight was achieved by fry in treated reaches. This is the first time in thirteen years that the difference in growth has not been significant. High summer flows have been suspected to reduce the effectiveness of previous treatments. In 2010, flows were nearly 50% higher than the 10 year average.

Citation: Pellett, K. 2011. Salmon River nutrient enrichment for fish habitat restoration, 2011. Report prepared by BCCF for BC Ministry of Environment Fisheries Section, Nanaimo, BC; Campbell River Salmon Foundation; and Living Rivers Georgia Basin/Vancouver Island. 34 p.

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ACKNOWLEDGEMENTS

Funding for nutrient enrichment activities was received from the Campbell River Salmon Foundation, Living Rivers Georgia Basin/Vancouver Island, and the Habitat Conservation Trust Foundation. The British Columbia Conservation Foundation (BCCF; Nanaimo, BC) administered this project under the supervision of Pat Stephenson (Regional Coordinator). Fertilizer additions were conducted by BCCF and A-Tlegay Fisheries Society staff while monitoring activities were conducted primarily by BCCF. Funding for fall fry assessments was provided by BC Hydro as an interim measure prior to the approval of the Campbell River WUP.

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1.0 INTRODUCTION

The spring and summer of 2010 was the twenty-second year of inorganic nutrient addition to the Salmon River watershed on Vancouver Island. This habitat restoration project was designed to improve the growth and survival of juvenile salmonids through the addition of slow release fertilizer. Studies suggest that 6-7% of the historical input of marine-derived nutrients from spawning salmon is currently available in Pacific Northwest streams (Gresh *et al.* 2000). In combination with other stream habitat restoration techniques, nutrient addition is recommended as a strategy to replace losses in marine-derived nutrients during periods of poor salmon returns (Larkin and Slaney 1996).

The Salmon River diversion, located on the mainstem 58 km upstream of tidewater, diverts part of upper Salmon River flows via flume to the Campbell River watershed. This diversion contributes to hydroelectric generation at the Ladore and John Hart power stations. Prior to diversion dam construction in 1958, anadromous fish were blocked by a log jam in a canyon located about 12 km downstream of the dam. This obstruction was removed by the BC Fish and Wildlife Branch in 1975 and 1976. Hatchery-reared steelhead fry, progeny of wild Salmon River broodstock, were released into the upper Salmon River and Grilse Creek from 1986 to 1998. Coho fry stocking was also undertaken by local streamkeepers in the late 1990s. Colonization by steelhead and coho in the upper watershed was further encouraged with the construction of a fishway at the BC Hydro diversion dam in 1992. Counts of migrating kelts at the fish screen/trap in 1998 and 1999, supported by snorkel surveys, indicated that steelhead escapement to the upper Salmon River above the diversion dam was well established. Steelhead fry stocking was subsequently discontinued. Enumeration of downstream migrating juveniles has been conducted annually at the Salmon River fish screen (located in the diversion canal) since 1987, and summarized in contract reports beginning in 1989 (Perrin 1989; Carswell 1990 to 1993 inclusive; Hansen 1994; Hansen and Rimmer 1995; and Hansen 1997 to 2003, inclusive).

Winter steelhead stock abundance in the Salmon River has been recently classified within the routine management zone, or above 30% of capacity (Lill 2002). An annual snorkel survey in the second week of March remains the primary stock assessment technique to gauge relative abundance of adult spawners. Closed-site electrofishing at ten standard sites in the watershed is used as a secondary indicator, with summer fry densities inferring spring adult abundance and population status. Mean abundance observed on March index surveys from 1999 to 2005 was 8.5 fish/km. Recently, the density of adults has increased to an average of 17.7 fish/km (2006-2010 data). A total of 150 steelhead was observed over the 11.5 km index section (13.0 fish/km) in spring 2010. The mean density of juvenile steelhead in electrofishing sites has been strongly correlated with snorkel counts. Densities averaged 31.6 fry/100m^2 from 1998 to 2005 and have increased to 56.7 fry/100m^2 from 2006 to 2010.

Development of a slow-release fertilizer has been undertaken by the Fisheries Research and Development Section, Ministry of Environment (MoE), Vancouver, BC as supervised by Dr. Ken Ashley. Field trials to study the instream application of solid inorganic fertilizer in Salmon River tributaries were initiated in 1995 and continued through to 1997 inclusive (Mouldey Ewing *et al.* 1996-98). In 2002, another experimental product, a struvite-coated urea granule, was applied to the upper Salmon River just below the Jessie Creek confluence (Hansen 2003). An organic product made from Alaskan pollock bone meal was developed for initial testing in 2003 and field tested in 2004 and

2005 in the upper Salmon River. In 2003/04 the bone meal was compressed into 'presto-logs' while in 2005/06 it was packaged as a loose matrix of coarse fragments into burlap bags. An inorganic high phosphorous fertilizer called Nutricote T40 was introduced to the program in 2007. Nutrients applied to the Salmon River in 2009 were derived from Crystal Green®, an innovative fertilizer made from recycled waste materials.

Nutricote T40, Pollock bone meal, and Crystal Green were tested at the Pacific Environmental Science Center (PESC) for environmental contaminates and pesticides while bone meal was confirmed pathogen free at the MoE Fish Health Lab in Nanaimo, BC. Results indicated products were suitable for stream applications. A chronology of stream enrichment in the Salmon River watershed from 1988 to 2008 is detailed in Appendix 1.

Funding in 2010 was provided by the Campbell River Salmon Foundation (CRSF) and Living Rivers-Georgia Basin/Vancouver Island (LR-GB/VI). LR-GB/VI program also provided support for stream enrichment projects on the east coast of Vancouver Island (ECVI). Costs related to sites upstream of the Salmon River diversion were covered by LR-GB/VI while costs for sites below the dam including the White River were covered by CRSF.

2.0 GOALS AND OBJECTIVES

This stream enrichment project was designed to enhance the growth and survival of juvenile steelhead (*Oncorhynchus mykiss*) and coho salmon (*O. kisutch)* through increased periphyton accrual and subsequent increases in the aquatic invertebrate food supply. Project design includes the use of Crystal Green, an inorganic slow release fertilizer, rather than liquid drip which must be applied all summer long. A total of twelve nutrient application sites treated approximately 55 km of stream length. Stream flow, water chemistry, periphyton accrual, and fish growth monitoring was intended to ensure fertilizer loading rates were not excessive and to assess the effectiveness of fertilizer additions.

3.0 STUDY AREA

The Salmon River, located on ECVI, flows into Johnston Strait at Kelsey Bay (65 km north of Campbell River). The total mainstem length of the Salmon River is 87.4 km. BC Hydro's diversion dam is located approximately 58 km upstream of the tidewater on the mainstem. Flows are diverted via a 14 km flume to the Campbell River watershed, and contribute to power generation at the Ladore and John Hart power stations. The three largest tributaries to the Salmon River are the White River, Memekay River, and Grilse Creek.

3.1 Site Locations

Fertilizer was applied to twelve sites in the Salmon River watershed in 2010 including White River and Consort Creek (Figure 1). Three sites were located upstream of the BC Hydro diversion dam with two sites situated on Grilse Creek at the upper and lower bridge crossings of the Grilse Creek Main Line (ML). The third site was located on the Salmon River mainstem 1 km upstream of the deactivated Rock Creek ML bridge crossing. Mainstem Salmon River sites below the diversion dam (5) included the Menzies ML Bridge crossing adjacent to the diversion fish screen, Memekay ML bridge crossing and Kay Creek. The last sites were located on the Memekay River at the upper and lower bridge crossings. These locations were accessible by logging roads

maintained by Western Forest Products (WFP). Two sites were located on the White River mainstem and two others on Consort Creek, a tributary of the White.

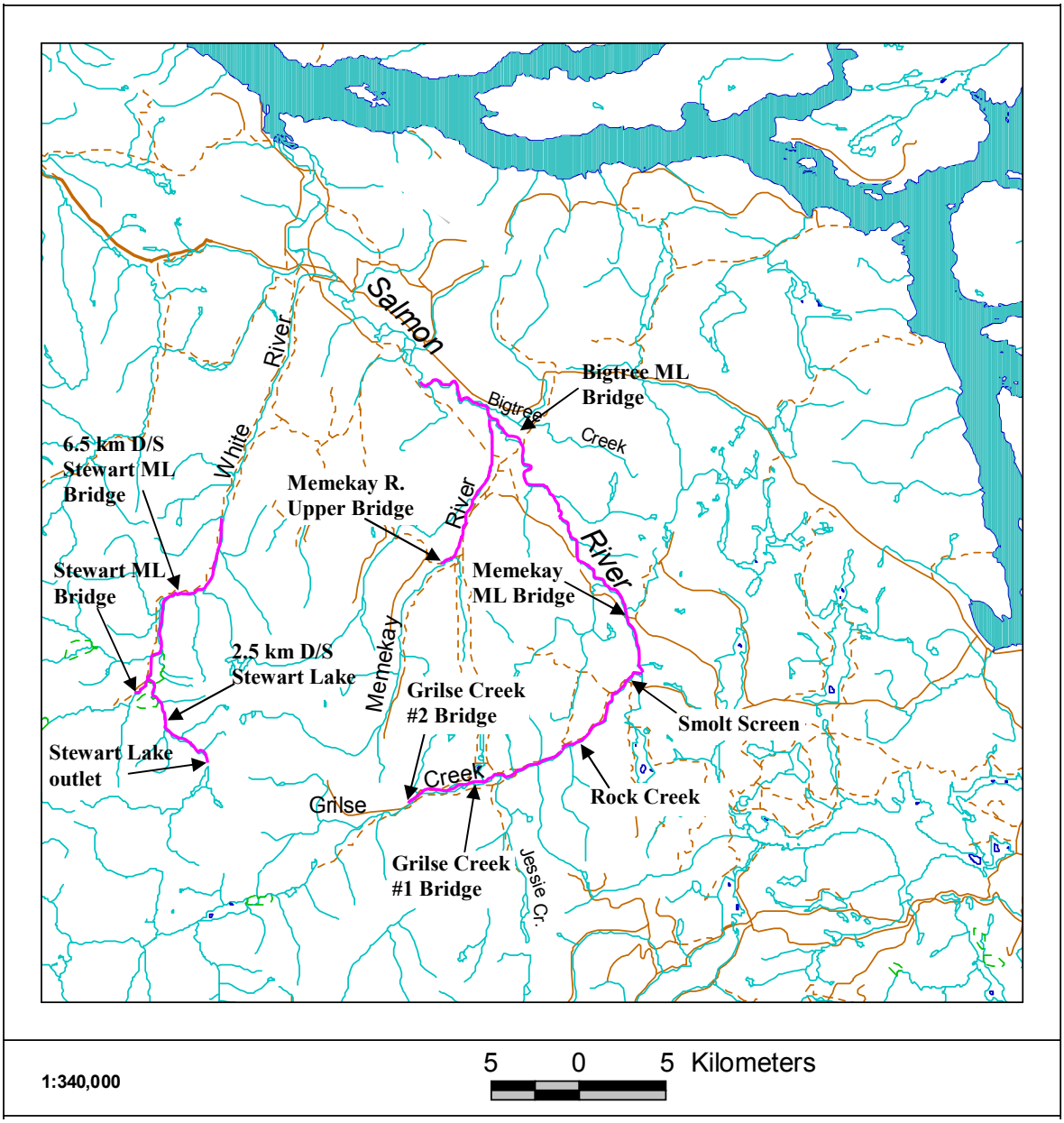


Figure 1. Map of the Salmon River watershed indicating enrichment sites on the mainstem Salmon River, White River, Grilse Creek and the Memekay River in 2010. Highlighted portions indicate stream reaches that were enriched.

4.0 MATERIALS AND METHODS

4.1 Nutrient Loading Rate

The target orthophosphate concentration of 2.5 *µ*g/l P for nutrient enriched streams suggested by McCusker *et al.* (2002) has been adopted for treatments for most Vancouver Island watersheds. Loading rates were calculated to achieve a target concentration of 5 *µ*g/l orthophosphate following procedures outlined for liquid drip applications (Hansen and Wright 2007).

Crystal Green has a 5-27-0 N-P-K ratio as well as 10% Mg content by weight. Water velocity and not temperature was found to control release rate during initial testing. Release rate was estimated at 45 days if subject to high water velocity (>0.5 m/s) and 90 days or more if applied in slower locations.

The loading rate formula was derived based on the following information:

- Crystal Green = 11.9% phosphorous by weight (PESC testing results);
- target concentration of 2.5-5.0 µg/l P (i.e. 2-5 ppb);
- 90 day treatment period, two applications (45 day release)

The equation weas constructed using the average summer flow rate in m^3/s as the primary variable for calculating fertilizer loading rates:

Equation 1. Crystal Green loading rate calculation.

Crystal Green (kg) = (average flow m^3/s) x (45 days) x (5.0 µg/l) / (0.119 µg P) x (1000 l/m^3) / ($1x10^9$ µg/kg) x (86,400 seconds/day)

Simplified:
Kg Crystal Green = 164 kg x average flow (m^3/s)

4.2 Fertilizer Application

Crystal Green was packaged off site into 10 kg burlap bags prior to the start of the project. Burlap allows for bag removal if necessary, but also biodegrades by the end of the treatment when left in stream. Fertilizer application sites in most systems are spaced approximately 3-5 km apart to allow most of the nutrients to be used in primary production between treatment locations. In headwater sites and tributaries with low flow, fertilizer applications were spread out with a fraction of the total loading rate applied every 100 m to 1 km. In the Salmon mainstem, sites were spread further apart. Sites were also selected based on known spawning and rearing areas to provide the maximum benefit to juvenile salmonids.

4.3 Monitoring

Visual Observations

Pertinent data was documented for each site visit, along with photo documentation. Detailed notes on algal growth at each site as well as temperature, flow, and other environmental factors were also documented. Anecdotal comments on fish abundance, safety concerns, road conditions, and recommendations for future treatments were included.

Water Sampling

Water samples were collected three times during the treatment period. Samples were collected in one litre plastic bottles supplied by PESC. The bottles were rinsed three times with stream water in the field before the samples were collected. Bottles were packed with ice in a cooler and shipped by courier to PESC for analysis within 24 hours. Water samples were analyzed for:

- low-level orthophosphate (PO_4);

- low-level nitrate (NO_3) + nitrite (NO_2); and,
- total phosphorus (P).

A subset of samples were also collected and taken to the Applied Environmental Research Laboratory (AERL) at Vancouver Island University (VIU). These samples were analyzed for orthophosphate only at detection levels that far exceeded those at PESC.

Water Sample Sites – Nutrient Application

The sample sites for fertilizer applications are shown in Figure 1 and described as follows:

Grilse Creek:

- Grilse Creek control – 0.8 km upstream of the Grilse Creek ML bridge crossing, accessed along a small ephemeral tributary.
- Grilse Creek bridge – just above the lower bridge on South Fork (SF) ML, accessed from the south side approximately 100 m west along SF-B.

Salmon River mainstem:

- Salmon River control – washout site 500 m upstream of Grilse Creek confluence.
- Rock Creek – 7.0 km upstream of the diversion dam, downstream of the enrichment site.
- Bigtree ML – east side of Bigtree ML Bridge crossing of the Salmon River.
- Salmon River Pallan's – old Pallan's Bridge site, opposite bank from Spur DY-R.
- Full Mix – 100 m d/s of the Salmon River ML Bridge crossing at the smolt screen.

Memekay River:

- Memekay River Control – upstream of the Memekay River # 2 Bridge.
- Memekay River Bridge – downstream of the bridge crossing on Airstrip Road.

White River

- White River control – 50 m upstream of the Stewart ML Bridge crossing.
- Consort control – Consort Creek at Stewart Lake outlet.
- Consort treated – 2.5 km downstream of Steward Lake.
- White River treated – 100 m downstream of Stewart ML Bridge.
- White River treated – Victoria ML Bridge.

Periphyton Sampling

Periphyton blocks were placed in Grilse Creek, Salmon mainstem, and the Memekay River at control and treatment sites in order to quantify algae growth (chlorophyll *a)*. The blocks were placed at the time of fertilizer application and core samples taken three times over the treatment period, coinciding with peak algal growth.

Blocks consist of a sheet of white florist's foam, 1.25 cm thick, attached to black Plexiglas plates with electrical ties (Figure 3). The plates were bolted to concrete blocks and placed in the stream, angled slightly into the direction of flow. Rocks were placed around the block edges for extra stability in high flows. Each block was submerged under at least 18 cm of water to allow for decreasing stream flow. Where possible, sites were selected with similar solar exposure, water depth, and water velocity.

Using a 7 dram plastic vial, two cores of foam (each 2.7 cm in diameter, 5.73 cm^2 in surface area) were punched, one out of each of the two periphyton blocks (Mouldey Ewing *et al.* 1998). Each sample was drained and placed in the vial. The vial was vented with holes through the cap to allow the sample to dry. Vials were placed in a sealed, light-proof container, kept cool with ice, and frozen as soon as possible. At the end of the sampling period, all samples were shipped frozen, in a cooler with ice, to a lab for analysis. The samples were measured for chlorophyll *a* ($\mu g/cm^2$).

Figure 2. Periphyton collector plate secured to stream bed with cobbles.

Water Temperature

Water temperature data was collected opportunistically during monitoring activities. Temperatures were collected using a hand-held digital thermometer (Taylor, model 9847N).

Stream Flow

Stream discharge for the Salmon River was estimated using information from the Water Survey of Canada (WSC) gauge stations at the BC Hydro diversion dam and above the Memekay River confluence (Appendix 2). Stream discharge was also measured using a Swoffer[1] velocity meter following RIC standards.

Juvenile Fish Sampling

Technicians conducted juvenile sampling in September 2010. A total of eight sites were sampled including the Salmon River mainstem, Grilse Creek and the Memekay River, two sites less than previous years (Appendix 3). Sampling was conducted using closed-site electrofishing techniques. At each electrofishing site, approximately 100 m^2 of suitable steelhead fry habitat (typically cobble/gravel riffles, <30 cm in depth, and <25 cm/sec in velocity) was enclosed with small mesh stop nets, and all fish were collected using the standard two-pass removal method (de Leeuw 1981). Lengths were recorded for all fish captured, and 30-50 juveniles per species and age class were weighed using an Ohaus top loading scale (model CS 200) accurate to 0.1 g. Habitat parameters were documented consistent with current Fisheries Branch techniques (methodology by R. Ptolemy, Rivers Biologist, MoE, Victoria), and each site was photographed. Upon removal of the stopnets, a depth/velocity profile across a representative transect within the site was recorded using a Swoffer current velocity meter, model 2100.

[1] Swoffer Current Velocity Meter – Model 2100

Population estimates were derived and depth/velocity profile adjusted using Fisheries Branch habitat suitability index curves. Sites were chosen to assess effectiveness of fertilizer additions (Grilse Creek) and to monitor stock abundance in general. Spot shocking was conducted outside of these sites when less than 30 fish were collected. A simple statistical analysis of steelhead/rainbow trout weights was performed on control and treatment samples to test for significant differences in growth.

5.0 RESULTS

5.1 Fertilizer Application

A total of 1,920 kg of Crystal Green was applied on June 30 at eight sites in the Salmon River watershed (Table 1). An additional 1,650 kg was applied on July 14 to the White River drainage. Fertilizer was bagged, trucked, and placed instream by BCCF and A-Tlegay First Nations fisheries staff. The bags were typically secured in high to moderate flow areas by placing several large cobbles on the top half of the burlap. Bag placement was clustered to allow for easy removal if necessary. Where possible, site locations were removed from high traffic areas to prevent tampering and vandalism. No loading rate adjustments were made in 2010 as flows were slightly above average late in the growing season.

Table 1. Summary of loading rates and nutrient applications in the Salmon River watershed, 2010.

Watershed	Stream	Site	Nutrient Source	Amount (kg)	Application Date	Km of River
Salmon	Memekay	Upper Bridge	Crystal Green	150	30-Jun-10	5.5
Salmon	Memekay	Lower Bridge	Crystal Green	140	30-Jun-10	2.3
Salmon	Grilse	Upper Bridge	Crystal Green	140	30-Jun-10	3.5
Salmon	Grilse	Lower Bridge	Crystal Green	140	30-Jun-10	2
Salmon	Salmon	Rock Creek	Crystal Green	260	30-Jun-10	6
Salmon	Salmon	Smolt Screen	Crystal Green	340	30-Jun-10	6
Salmon	Salmon	Memekay ML Bridge	Crystal Green	350	30-Jun-10	6
Salmon	Salmon	Kay Creek	Crystal Green	400	30-Jun-10	6
Salmon	White	Stewart ML Bridge	Crystal Green	650	14-Jul-10	6.5
Salmon	White	6.5 km D/s Stewart ML	Crystal Green	800	14-Jul-10	5.5
Salmon	Consort	Stewart Lake	Crystal Green	100	14-Jul-10	2
Salmon	Consort	Roadside	Crystal Green	100	14-Jul-10	3.5
TOTAL				**3,570**		**55**

5.2 Monitoring

Notes and Visual Observations

June 30 – Application

Flows were down to approximately 8 m^3/s by June 30, 2010 which was deemed to be suitable for nutrient application. Water temperatures averaged 9.5 ^oC at application sites with minimal algal growth noted in the Memekay River.

1. Bags of Crystal Green applied at the lower Grilse Creek bridge.

2. A-Tlegay and BCCF fisheries staff applying nutrients at the Rock Creek site on the Salmon R.

3. Application of nutrients at the upper Grilse Creek bridge crossing.

4. The A-Tlegay Fisheries Society and BCCF application crew at the Menzies Mainline bridge.

August 6 – Five Weeks

Growth was noticeable at the upper Grilse Creek Bridge as this was the divide between the treated and untreated reaches. Growth at the lower Grilse Bridge was light to moderate while no growth was apparent at the washout site on the Salmon River mainstem (control). Light green growth was noted at the Rock Creek enrichment site.

1. Looking downstream at Grilse Creek from the #2 bridge, excellent brown growth in the tail out.

2. Periphyton collector plate at the lower Grilse Creek bridge.


3. Caddis fly larvae actively grazing on pheriphyton in an enriched reach.


4. Sterile conditions in the control section of the Salmon River.

August 18 – Seven Weeks

Water temperatures across five sites averaged 15.8 °C with a maximum temperature of 19 °C measured at the Bigtree ML bridge. Moderate green and brown growth was found at the site while good brown algal growth was noted at the lower Memekay River. Moderate growth was apparent at the smolt screen while excellent growth was noted at lower Grilse and Rock Creek. Both the Salmon River and Grilse Creek control sites were relatively sterile although light to moderate growth was noted at the Memekay River control.


1. Looking downstream from the upper Grilse Creek bridge, strong growth continues in the tailout.

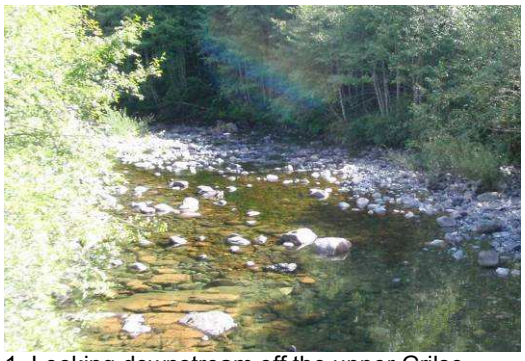

2. Periphyton accrual in Grilse Creek below the lower bridge.


3. Periphyton growth at the lower Memekay bridge.


4. Looking downstream off the Bigtree Mainline bridge.

September 1 – Nine Weeks

On September 1, strong brown growth was still apparent in Grilse Creek and Memekay River. Moderate growth was noted at the Bigtree ML Bridge and moderate to strong growth at the smolt screen. Growth in the tailout of the upper Grilse Creek Bridge changed slightly from predominantly brown to a mix of brown and green algae.



1. Looking downstream off the upper Grilse Creek bridge.

2. Strong periphyton growth along the marins at the lower Memekay River bridge.

3. Moderate periphyton growth at the Bigtree Mainline bridge on the Salmon River.

4. Ideal periphyton accrual on stream substrates downstream of nutrients at the smolt screen in the Salmon River.

Table 2. Water temperature data collected throughout the Salmon River watershed from June to September, 2010.

Date	Stream	Site	Temp (°C)
30-Jun-10	Salmon	Lower Memekay	9.2
30-Jun-10	Salmon	Grilse Control	8.9
30-Jun-10	Salmon	Grilse #1 Bridge	10.1
30-Jun-10	Salmon	Rock Creek	10.0
30-Jun-10	Salmon	Kay Creek	10.5
6-Aug-10	Salmon	Lower Memekay	14.9
6-Aug-10	Salmon	Grilse Control	12.6
6-Aug-10	Salmon	Memekay Control	14.5
6-Aug-10	Salmon	Lower Grilse	16.1
6-Aug-10	Salmon	Smolt Screen	16.1
6-Aug-10	Salmon	Rock Creek	15.4
6-Aug-10	Salmon	Bigtree Bridge	16.9
18-Aug-10	Salmon	Lower Memekay	16.4
18-Aug-10	Salmon	Grilse Control	12.8
18-Aug-10	Salmon	Smolt Screen	16.4
18-Aug-10	Salmon	Rock Creek	14.5
18-Aug-10	Salmon	Bigtree Bridge	19.0

Flow Data

Mean daily stream flow data were obtained for the WSC station located above the Salmon River Diversion (Figure 3, Appendix 2). In 2009, flows were often lower than average (2000-2008) beginning as early as June 5th. This year flows were well above normal throughout the majority of the treatment period and did not drop below the ten year average until August 21. The lowest flow was recorded on September 12 at 1.4 cms followed by 72 cms on September 25 which effectively ended the nutrient treatment after 86 days.

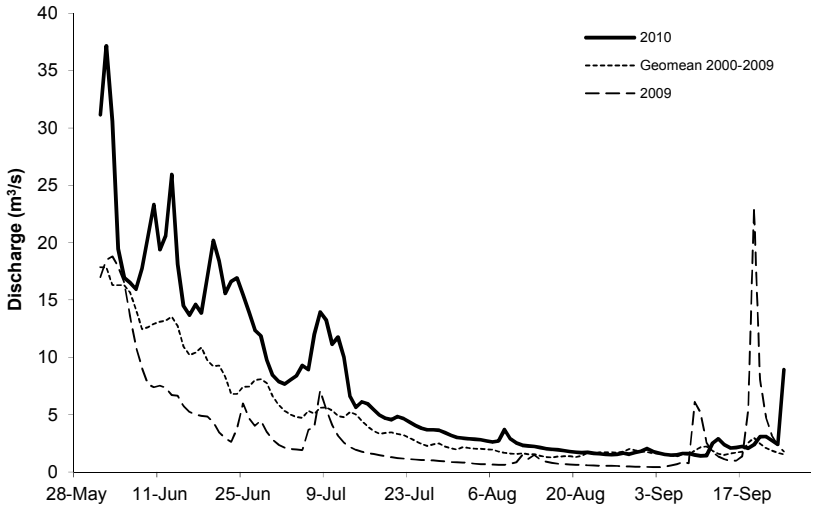


Figure 3. Daily discharge data (WSC station 08HD015, Salmon River above Diversion) for the period June 1-September 24, 2010, compared to 2000-2009 data.

Juvenile Fish Sampling

Juvenile fish sampling conducted in Grilse Creek revealed no significant difference in mean weight between control and treated areas. Fish in the treated reach were found to be marginally larger but the difference was not significant at the 95% confidence level (Figure 4).

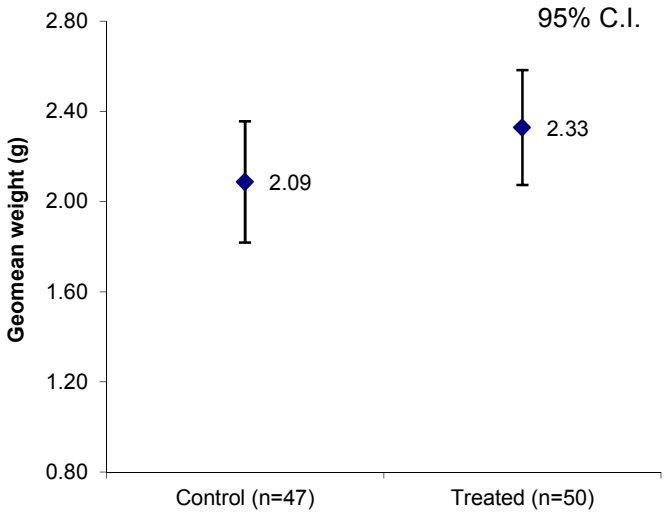


Figure 4. Mean weights of steelhead/rainbow fry sampled in control and treated reaches of Grilse Creek, September 23, 2010.

Improved fish growth in treated versus control sites has been observed in Grilse Creek since data were first collected in 1999. However, 2010 data indicate no difference in mean weight of juvenile steelhead under enriched conditions (Figure 5). This can be compared to an average increase of 114% for the period 1999-2008. The largest response was documented in 2004 when fish in the treated reach of Grilse Creek were found to be 218% larger. Poor results were documented in 1999 and 2007 which were attributed to high water conditions throughout the treatment period. 2010 also had similarly high water conditions as documented in Figure 3.

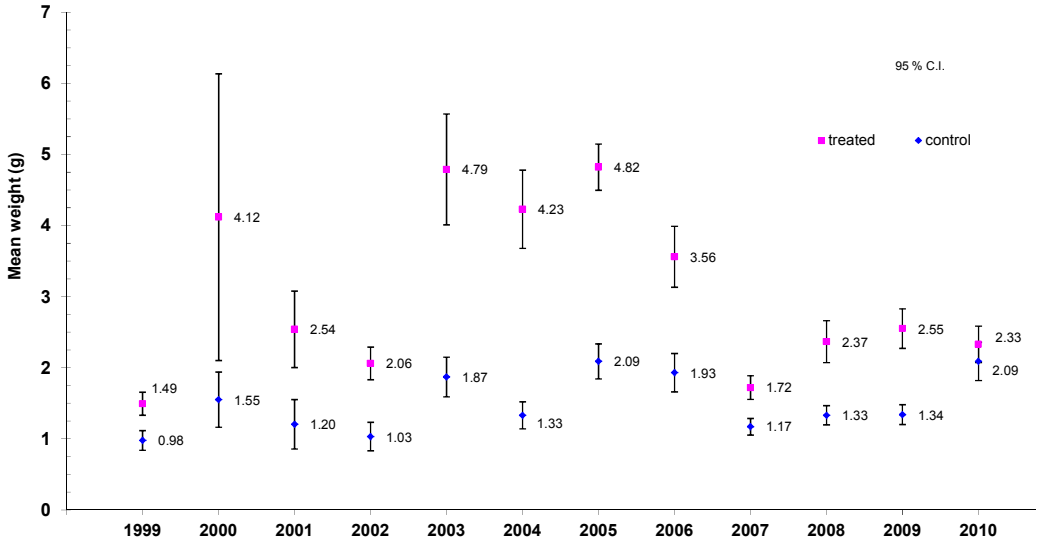


Figure 5. Mean weights of steelhead/rainbow fry captured in the upper two sites in Grilse Creek from 1999 to 2010.

Juvenile steelhead densities sampled in eight sites on the Salmon River confirmed a significant number of adult steelhead returned to the system the previous winter. Sampling occurred September 16 - September 23, consistent with previous years. The geometric mean density of 64 fry per 100 m^2 (fry/unit) is near the precautionary target of 60 fry/unit set by provincial biologists and ranks third of thirteen years for the period 1998-2009 (Table 3, Figure 6). High densities of fry encountered at site one have been documented in the past and are though to be the result of pink salmon which are present at the time of the survey. Densities above and below the diversion dam were nearly identical suggesting a large area of the watershed was well seeded in 2010.

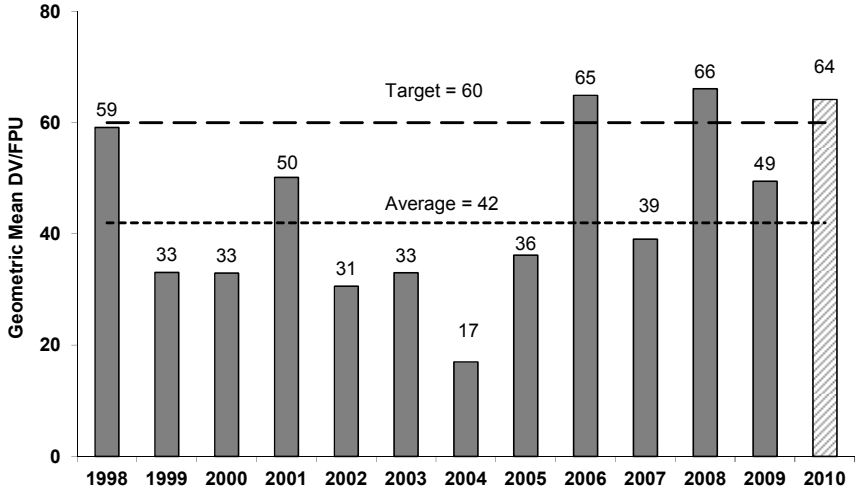


Figure 6. Mean depth/velocity adjusted steelhead/rainbow fry abundance sampled at ten sites in the Salmon River and tributaries, 1998-2010.

Table 3. Electrofishing data summary for ten sites sampled in the Salmon River watershed, 2010

Site #	Site Description Below Diversion	Site Ref. (km)	Date	Mean Weight (grams)	Unadj'd FPU	D/V Adj'd FPU	Predicted FPU	% of Predicted
1	Pallans	23.94		2.04	129.7	239.1	72.2	331.4%
2	WSC Station (Kay Creek)	35.44		3.44	28.1	44.7	42.8	104.4%
3	Memekay Mainline Bridge	52.60		2.73	31.2	70.7	54.0	130.8%
4	Smolt Screen	58.02		NOT SAMPLED				
7	Memekay River (lower bridge)	27.93		3.13	20.7	28.0	47.1	59.5%
	MEAN			**2.78**	**39.2**	**67.8**	**53.0**	**128.1%**
	Above Diversion							
5	Washout, old bridge 5km u/s diversion	67.73		NOT SAMPLED				
6	Washout 500 m u/s of Grilse confluence	69.25		1.47	38.0	84.0	100.1	83.9%
8	Grilse Ck (100 m u/s of lower bridge)	70.77		1.82	48.5	61.4	80.8	75.9%
9	Grilse Ck (300 m d/s of upper bridge)	74.27		2.41	41.0	62.2	61.3	101.5%
10	Grilse Ck (500 m u/s of upper bridge)	75.91		2.06	31.6	41.0	71.4	57.4%
	MEAN			**1.91**	**39.3**	**60.2**	**77.1**	**78.1%**

Periphyton Sampling

Periphyton collectors were placed in the mainstem Salmon River, Memekay River, and Grilse Creek to monitor algal response to fertilizer treatments. Artificial substrata were placed in representative control and treatment locations on June 30, 2010. The sampling program consisted of biweekly core sampling beginning on August 6, five weeks after the placement of collectors.

Core samples were taken on August 6, August 18 and September 1 to capture peak growth. Monitoring during previous treatments revealed moderate increases in growth during the first four weeks followed by peak growth in the later weeks. Growth was strongest in Grilse Creek although the Memekay River showed no late season die off (Figure 7). Early growth was variable although the Memekay River site showed a strong start. Downstream of the enrichment sites in Grilse Creek and Memekay River, algal growth was up to 400% stronger by September 1st with levels that were over 10 fold above control readings in early August.

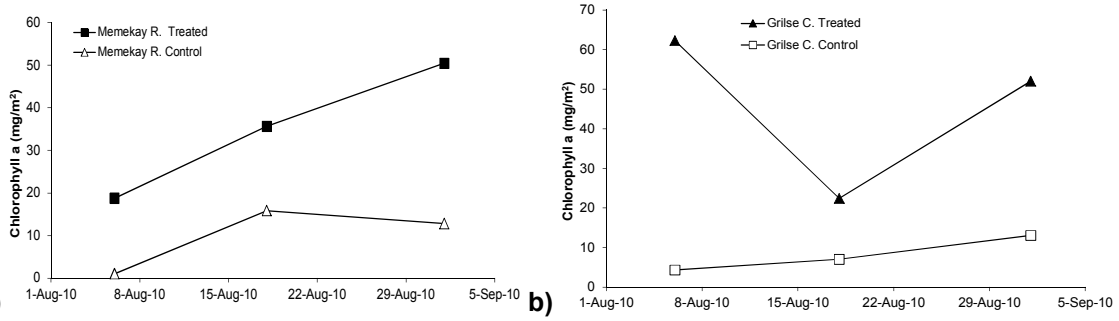


Figure 7. Chlorophyll *a* levels as measured on artificial substrata in the Memekay River (a) and Grilse Creek (b), 2010.

Chlorophyll *a* concentrations in the mainstem Salmon River monitoring sites indicated moderate improvements to algal biomass downstream of enrichment sites. Growth at the control site was minimal through August while sites at the Smolt Screen and Bigtree ML Bridge increased 1 to 5 fold by the end of the season. The largest gains were measured near the end of the season although significant differences were noted oin early August (Figure 8)

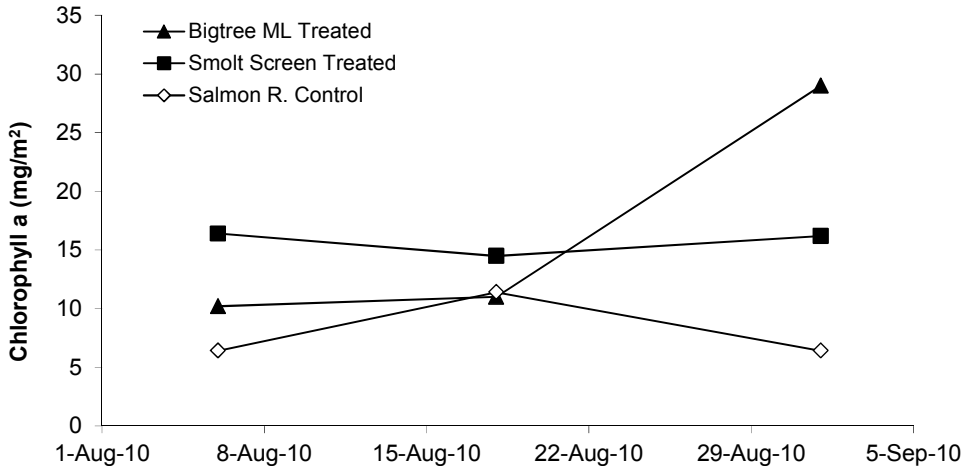


Figure 8. Chlorophyll *a* levels as measured on artificial substrata in the Salmon River at three sites, 2010.

Water Chemistry Sampling

Water chemistry sampling commenced five weeks after fertilizer application on the Salmon River mainstem, Memekay River, and Grilse Creek. The first samples were collected on August 6 and analyzed for orthophosphate only at Vancouver Island University's Applied Environmental Research Laboratory (VIU-AERL, Table 4). Ortho-p concentrations in control sites were all below the theoretical detection limit of 1 ug/l while treated sites ranged between 1.4 and 6.9. A second set of samples collected on August 18 were sent to both PESC and VIU-AERL for analysis. Ortho-P concentrations in control sites were all below 1 ug/l while treated sites ranged from 3.1 to 6.5 (AERL) or 2-6 (PESC) with the exception of the Bigtree ML site which was similar to the controls. Samples collected on September 1, 2010 indicate ortho-p concentrations of 1 ug/l across all sites.

Nitrogen concentrations were generally highest in the Memekay River and Grilse Creek which is consistent with previous years. The lowest values on each sample date were measured at the Bigtree ML Bridge while moderate values (31-41 ug/l) were measured at mainstem sites.

Total phosphorous tracked with ortho-p and suggests less phosphorous was present in samples collected later in the season. Control sites were all below the detection limit of 2 ug/l while peak values of 6-7 were measured in treated reaches of Grilse Creek and Memekay River.

Table 4. Water chemistry data collected in the Salmon River, Memekay River, and Grilse Creek during the summer of 2010.

			Parameters (ug/L or PPB)		
Stream	Sample Location	Sample Date	Nitrate + Nitrite	Orthophosphate	Total Phosphorus
Salmon River	Big Tree ML	6-Aug-10	--	1.4 ± 0.5	--
Memekay River	Memekay Treated Lower	6-Aug-10	--	4.8 ± 0.7	--
Memekay River	Upper Memekay Control	6-Aug-10	--	0.7 ± 0.2	--
Grilse Creek	Grilse Control	6-Aug-10	--	0.7 ± 0.7	--
Grilse Creek	Lower Grilse	6-Aug-10	--	6.9 ± 0.7	--
Salmon River	Washout Control	6-Aug-10	--	0.9 ± 0.2	--
Salmon River	Smolt Screen	6-Aug-10	--	3.9 ± 0.2	--
Salmon River	Rock Creek	6-Aug-10	--	4.6 ± 0.5	--
Salmon River	Big Tree ML	18-Aug-10	19	<1.0 / 0.5 ± 04	<2
Memekay River	Lower Memekay	18-Aug-10	103	6 / 6.5 ± 0.2	7
Grilse Creek	Grilse Lower Bridge	18-Aug-10	75	5 / 6.4 ± 0.2	6
Salmon River	Smolt Screen	18-Aug-10	27	3 / 5.3 ± 0.5	6
Salmon River	Rock Creek	18-Aug-10	35	2 / 3.1 ± 0.2	3
Memekay River	Memekay control	18-Aug-10	90	<1 / 0.3 ± 0.4	<2
Grilse Creek	Grilse Control	18-Aug-10	71	<1 / ND	<2
Salmon River	Washout Control	18-Aug-10	31	<1 / 0.2 ± 0.5	<2
Salmon River	Big Tree ML	1-Sep-10	24	1	<2
Memekay River	Lower Memekay	1-Sep-10	82	1	6
Grilse Creek	Grilse Lower Bridge	1-Sep-10	72	1	2
Salmon River	Smolt Screen	1-Sep-10	41	1	<2
Salmon River	Rock Creek	1-Sep-10	37	1	2
Memekay River	Memekay control	1-Sep-10	89	1	<2
Grilse Creek	Grilse Control	1-Sep-10	72	1	<2
Salmon River	Washout Control	1-Sep-10	40	1	<2

* Note: Orthophosphate concentrations with 95% confidence intervals were analized at Vancouver Island University's Applied Environmental Research Laboratory (VIU - AERL), concentrations in red are below the theoretical detection limit.

**Samples collected on August 18, 2010 were analyzed at PESC and VIU-AERL.

6.0 DISCUSSION AND RECOMMENDATIONS

Nutrients were applied to the Salmon River throughout the summer growing season in prescribed amounts (2-5 ug/l ortho-p) in an attempt to boost primary productivity. Additions occurred slightly later than average (June 30) and ended on September 25 with the first fall rain. A positive algal growth response was documented in tributary and mainstem monitoring locations, consistent with previous years. Juvenile fish growth response was found to be not significant at the 95% confidence level for the first time in thirteen years. Results from previous years indicate that high flows throughout the summer growing season tend to reduce the effectiveness of nutrient treatments. In the summer of 2010, flows were 50% higher than the recent 10 year average. As water chemistry and periphyton results suggest nutrient treatments should have been effective it appears that high flows are likely responsible for the reduced effectiveness. It is unclear what result high flows would have on the growth of 1+ and 2+ steelhead parr.

Increased riffle habitat and algal growth should prove beneficial to parr even if fry are found to have a null response to nutrient treatments.

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APPENDIX 1. Chronology of Salmon River Nutrient Enrichment Treatments, 1988 – 2009.

The Salmon River fertilization project has been initiated and supervised by the Ministry of Environment, Lands and Parks (MELP), Fisheries Section, in Nanaimo (now Ministry of Environment (MoE)). Other agencies and contractors involved are listed below, along with specific details of each year of application. Juvenile sampling by electrofishing was carried out every year in the late summer. MoE records are computer filed at the Nanaimo office and the B.C. Conservation Foundation office in Nanaimo.

Pre-fertilization sampling:

1988 **Agencies:** MELP, NANAIMO. Contractor: Limnotek Research and Development Inc.
Water chemistry samples: ✔ Five sample sets from 2 sites.
Periphyton samples: ✔ Two series of 3 sample sets over 21 days- from 2 sites.
Taxonomy samples: Algae. ✔
References: Perrin (1989).

Fertilization and Sampling

1989 **Agencies:** MELP, NANAIMO. Contractor: Limnotek Research and Development Inc. Funding from the B.C. Habitat Conservation Fund.
Fertilizer Applied: prill (solid) form – 34-0-0 and 12-51-0 blend.
Period of Application: June 2 – August 26, 1989.
Sites: Norris Creek, Grilse Creek (upper bridge site).
Water chemistry samples: 10 sample sets from 3 sample sites.
Periphyton samples: ✔ Two series of 35 and 40 days- from 3 sites.
Taxonomy samples: Algae ✔ Three sample sites.
References: Perrin (1990).

1990 **Agencies:** MELP, NANAIMO. Contractor: Limnotek Research and Development Inc. Funding from the B.C. Habitat Conservation Fund.
Fertilizer Applied: Liquid- 32-0-0 (Norris Creek only) and 10-34-0.
Period of Application: May 12 – July 29, 1990.
Sites: Norris Creek, Grilse Creek (upper), Grilse Creek (lower bridge site).
Water chemistry samples: ✔ Seven sample sets from 5 sites.
Periphyton samples : ✔ One series (7 samples over 51 days) from 4 sites.
Taxonomy samples: ✔ One set from 4 sites; one replicate from 2 sites.
References: Perrin (1991b).

1991 **Agencies:** MELP, NANAIMO. Contractor: Limnotek Research and Development Inc. Funding from the B.C. Habitat Conservation Fund.
Fertilizer Applied: Liquid- 32-0-0 (Norris Creek only) and 10-34-0.
Period of Application: May 18 – July 31, 1991.
Sites: Norris Creek, Grilse Creek (upper) and Grilse Creek (lower bridge site).
Water chemistry samples: ✔ Four sample sets from six sites.
Periphyton samples: ✔ Eight sample sets from five sites (one series over 57 days).
Taxonomy samples: Algae ✔ One sample set from 5 sites.
References: Perrin (1991a).

1992 **Agencies:** MELP, NANAIMO. (Administered by B.C. Conservation Foundation (BCCF). Funding from the Habitat Conservation Fund).
Fertilizer Applied: Liquid- 32-0-0 (Norris Creek only) and 10-34-0.
Period of Application: May 15 – July 28, 1992.
Sites: Norris Creek, Grilse Creek (upper bridge), Grilse Creek (lower bridge).
Water chemistry samples: ✔ Three sample sets from six sites.
Periphyton samples: No.
Taxonomy samples: No.
References: Carswell (1992).

1993 **Agencies:** MELP, NANAIMO. (Admin. by BCCF. Funding from the B.C. Habitat Conservation Fund and fertilizer purchased by the Campbell River Chapter of the Steelhead Society of B.C.).
Fertilizer Applied: Liquid- 32-0-0 (Norris Ck. only) and 10-34-0.
Period of Application: May 25 – August 8, 1993.
Sites: Norris Creek, Grilse Creek (upper bridge), Salmon River- Rock Creek ML bridge crossing, Memekay ML bridge crossing.
Water chemistry samples: ✔
Periphyton samples: ✔
Taxonomy samples: unknown (see Comments).
References: Carswell (1993).

Comments: Water, periphyton and insect sampling were conducted by Daiva Zaldokas, MELP, Vancouver, Fisheries Research and Development Section.

1994 **Agencies:** MELP, NANAIMO. (Admin. by BCCF. Funding from the B.C. Habitat Conservation Fund, liquid fertilizer purchased by the Campbell R. Chapter of the Steelhead Society of B.C.).
Fertilizer Applied: Liquid- 32-0-0 (Norris Creek only) and 10-34-0.
Period of Application: May 19 – August 14, 1994.
Sites: Norris Creek, Grilse Creek (upper bridge), Salmon River- Rock Creek ML bridge crossing, Memekay ML bridge crossing.
Water chemistry samples: Two sample sets from ten sites.
Periphyton samples: No.
Taxonomy samples: No.
References: Hansen (1994).

1995 **Agencies:** MELP, NANAIMO. (Admin. by BCCF. Funding from Habitat Conservation Fund, liquid fertilizer purchased by the Campbell R. Chapter of the Steelhead Society of B.C.).MELP, Vancouver, Fisheries Research and Development Section monitored slow-release briquettes (pucks) in Norris Creek and Grilse Creek.
Fertilizer Applied: Briquettes in Norris Creek and Grilse Creek and liquid 10-34-0 in the mainstem Salmon River.
Period of Application: May 25 – August 25, 1995.
Sites: Norris Creek, Grilse Creek (upper bridge), Salmon River- Rock Creek ML bridge crossing, Memekay ML bridge crossing.

Water chemistry samples: ✔ Two sample sets from five sites on the mainstem Salmon River. Seven sample sets from five sample sites on Norris Creek and Grilse Creek (MELP, Vancouver).
Periphyton samples: ✔ (MELP, Vancouver).
Taxonomy samples: ✔ (MELP, Vancouver).

References: Hansen (1995). Mouldey Ewing, Ashley (1998).

Comments: An in-depth study of the slow-release fertilizer was conducted by the MELP Fisheries Research and Development Section, Vancouver, from 1995 to 1997 inclusive. Three reports are cited in **REFERENCES** (Mouldey Ewing, et al. 1996, 1998, 1998).

1996 **Agencies:** MELP, NANAIMO. (Admin. by BCCF. Funding from the B.C. Habitat Conservation Fund, liquid fertilizer paid for by the Campbell River Chapter of the Steelhead Society of B.C.) .
MELP, Vancouver, Fisheries Research and Development Section, monitored slow-release briquettes in Norris Creek and Grilse Creek.
Fertilizer Applied: Briquettes- Norris Creek and Grilse Creek. Liquid 10-34-0- Salmon River mainstem.
Period of Application: June 1 – September 5.
Sites: Briquettes- Norris Creek, Grilse Creek (upper bridge). Liquid- (Salmon River)- Rock Creek ML bridge crossing, fish screen, and Memekay ML bridge crossing.
Water chemistry samples: ✔ Two sample sets from six sites on the mainstem Salmon River. Nine sample sets of five sites on Norris Creek (2 sites) and Grilse Creek (3 sites).
Periphyton samples: ✔ Nine sample sets from five sites on Norris Creek (2 sites) and Grilse Creek (3 sites).
Taxonomy samples: algae.
Benthic invertebrate biomass measured: ✔
References: Hansen (1999b). Mouldey Ewing and Ashley (1998).

Comments: Fertilizer toxicology testing was conducted by EVS Environmental Consultants (1997) for rainbow trout, chironomids, amphipods and daphnids.

1997 **Agencies:** MELP, NANAIMO. (Admin. by BCCF. Funding by BC Hydro and the Campbell River Chapter of the Steelhead Society of B.C.).
MELP, Vancouver. Fisheries Research and Development Section.
Fertilizer Applied: Briquettes (7-40-0) (Norris Creek and Grilse Creek) and liquid 10-34-0 (mainstem Salmon River).
Period of Application: June 12 – October 6.
Sites: Norris Creek (briquettes), Grilse Creek (upper bridge) (briquettes), Salmon River- Rock Creek ML bridge crossing (liquid), fish screen (liquid), and Memekay ML bridge crossing (liquid).
Water chemistry samples: ✔ Every two weeks (eight sample sets) from nine sample sites throughout 40 km of the river treatment area.
Periphyton samples: ✔ Eight sample sets from nine sample sites.

Taxonomy samples: algae. ✔
Benthic invertebrate biomass measured: ✔
References: Hansen (1999a). Mouldey, Ashley & Wilson (1998).

Comments: In addition to treatment of the upper Salmon River and tributaries, the Memekay River and Cooper Creek were treated with briquettes (7-40-0): 60 kg to Cooper Creek and 599 kg to each of two sites on the Memekay River (total – 1,198 kg). **Water chemistry samples:** ✔ Two sample sets. **Periphyton:** none. **Taxonomy:** none.

1998 **Agencies:** MELP, NANAIMO. (Admin. by BCCF. Funding - BC Hydro).
Fertilizer Applied: Briquettes - 7-40-0 (Norris Creek) and liquid 10-34-0.
Period of Application: June 10 – August 19.
Sites: Norris Creek, Grilse Creek (upper bridge), Salmon River- above Rock Creek ML bridge crossing, fish screen and Memekay ML bridge crossing.
Water chemistry samples: No.
Periphyton samples: No.
Taxonomy samples: No.
References: Hansen (1999c).

Comments: In addition to the mainstem Salmon River and upper Salmon tributaries, the Memekay River and Cooper Creek were also treated. Sixty kilograms of briquettes were added to the upper end of Cooper Creek and liquid 10-34-0 was applied by drip station to the Memekay River just below the ML bridge.

1999 **Agencies:** MELP, NANAIMO. (Admin. by BCCF. Funding BC Hydro).
Fertilizer Applied: liquid 10-34-0.
Period of Application: August 9 – September 28.
Sites: Grilse Creek (upper bridge), Salmon River- above Rock Creek ML bridge crossing, fish screen and Memekay ML bridge crossing.
Water chemistry samples: No.
Periphyton samples: No.
Taxonomy samples: No.
References: Hansen (1999d).

Comments: In addition, a liquid drip station (10-34-0) was maintained on the Memekay River just below the Memekay ML bridge. Due to extremely high flows from a record high snow-pack, discharge in the Salmon River and tributaries was too high in June and July for practical delivery of a fertilizer drip-rate. Fertilization did not start until early August when flows had moderated, and was continued later than in previous years.

2000 **Agencies:** MELP, NANAIMO. (Admin. by BCCF. Funding BC Hydro)
Fertilizer Applied: liquid 10-34-0 and briquettes (new formula).
Period of Application: June 19 – September 12.
Sites: Briquettes- Grilse Creek just upstream of the falls, Liquid- Grilse Creek (upper bridge), Salmon River- above Rock Creek ML bridge crossing, fish screen and Memekay ML bridge crossing.

Water chemistry samples: No.
Periphyton samples: No.
Taxonomy samples: No.
References: Hansen (2001).

Comments: Briquettes were placed in Cooper Creek, 7 km upstream of the confluence with the Memekay River. A liquid drip station (10-34-0) was maintained on the Memekay River just below the Memekay ML bridge.

2001 **Agencies:** MWLAP, NANAIMO. (Admin. by BCCF. Funding by Weyerhaeuser (FRBC) & BC Hydro, Bridge Coastal Restoration Program).
Fertilizer Applied: liquid 10-34-0.
Period of Application: July 5 – August 24.
Sites: Memekay River at the ML bridge crossing, Grilse Creek (upper bridge), Salmon River- upstream of Rock Creek ML bridge crossing (deactivated), fish screen and Memekay ML bridge crossing.
Water chemistry samples: Yes.
Periphyton samples: Yes.
Taxonomy samples: No.
References: Hansen, (2002).

2002 **Agencies:** MWLAP, NANAIMO. (Admin. by BCCF. Funding by BC Hydro, Bridge Coastal Restoration Program).
Fertilizer Applied: liquid 10-34-0.
Period of Application: June 18 – August 19.
Sites: Memekay River at the ML bridge crossing, Grilse Creek (upper bridge), Salmon River upstream of Rock Creek ML bridge crossing (deactivated), fish screen and Memekay ML bridge crossing.
Water chemistry samples: Yes.
Periphyton samples: Yes.
Taxonomy samples: No.
References: Hansen, (2003)

Comments: An experimental, slow-release fertilizer product was applied to the upper Salmon River just below the Jessie Creek confluence on July 29, 2002. The fertilizer was a struvite-coated urea granule (18-6-0) produced by PSP Enterprises of Urbana, Ohio.

2003 **Agencies:** MWLAP, NANAIMO. (Admin. by BCCF. Funding by BC Hydro, Bridge Coastal Restoration Program and Weyerhaeuser Canada Ltd., Renewal Investment Corp.).
Fertilizer Applied: liquid 10-34-0.
Period of Application: June 17 – Sept 6.
Sites: Memekay River at the ML bridge crossing, Grilse Creek (upper bridge), Salmon River upstream of Rock Creek ML bridge crossing (deactivated), Salmon River bridge near the diversion and Memekay ML bridge crossing.

Water chemistry samples: Yes.
Periphyton samples: No.
Taxonomy samples: No.
References: Hansen & Wright, (2003)

Comments: A new product providing organic instream nutrients was tested in Paterson Creek in 2003. The product was made from organic fish meal (Alaskan pollock) pressed into 4 kg logs.

2004 **Agencies:** MWLAP, NANAIMO. (Admin. by BCCF. Funding by BC Hydro, Bridge Coastal Restoration Program.and Weyerhaeuser Canada Ltd.
Fertilizer Applied: liquid 10-34-0.
Period of Application: June 8 – September 17.
Sites: Memekay River at the ML bridge crossing, Grilse Creek (upper bridge), Salmon River upstream of Rock Creek ML bridge crossing (deactivated), fish screen and Memekay ML bridge crossing.
Water chemistry samples: Yes.
Periphyton samples: No.
Taxonomy samples: No.
References: Hansen, (2004)

Comments: An experimental, organic fishmeal product (pollock) was applied to the upper Salmon River just below the Jessie Creek confluence on June 17 and July 22, 2004.

2005 **Agencies:** MWLAP, NANAIMO. (Admin. by BCCF. Funding by BC Hydro, Bridge Coastal Restoration Program) and Weyerhaeuser Canada Ltd.
Fertilizer Applied: liquid 10-34-0.
Period of Application: June 18 – August 19.
Sites: Memekay River at the ML bridge crossing, Grilse Creek (upper bridge), Salmon River upstream of Rock Creek ML bridge crossing (deactivated), fish screen and Memekay ML bridge crossing.
Water chemistry samples: Yes.
Periphyton samples: No.
Taxonomy samples: No.
References: Manley, Hansen & Wright (2006)

Comments: An experimental, organic fishmeal product (pollock) was applied to the upper Salmon River just below the Jessie Creek confluence on June 22, 2005.

2006 **Agencies:** MoE., NANAIMO. (Admin. by BCCF. Funding by BC Hydro, Bridge Coastal Restoration Program) Cascadia Canada Ltd.
Fertilizer Applied: liquid 10-34-0.
Period of Application: June 14 – September 5.
Sites: Memekay River at the ML bridge crossing, Grilse Creek (upper bridge), Salmon River upstream of Rock Creek ML bridge crossing (deactivated), fish screen and Memekay ML bridge crossing.
Water chemistry samples: Yes.
Periphyton samples: Yes

Taxonomy samples: No.
References: Hansen & Wright (2006)

Comments: An experimental, organic fishmeal product (500 kg of pollock) was applied to the upper Salmon River just below the Jessie Creek confluence on June 29, 2006.

2007 **Agencies:** MoE., NANAIMO. (Admin. by BCCF. Funding by BC Hydro, Bridge Coastal Restoration Program) Western Forest Products Ltd., and Georgia Basin Living Rivers
Fertilizer Applied: 16-40-0. (Nutricote T40)
Period of Application: July 4 – September 30.
Sites: Memekay River at the ML bridge crossing, Grilse Creek (upper and lower bridges), Salmon River upstream of Rock Creek ML bridge crossing (deactivated), smolt screen and Memekay ML bridge crossing.
Water chemistry samples: Yes.
Periphyton samples: Yes
Taxonomy samples: No.
References: Pellett (2007)

Comments: Solid Nutricote T40 fertilizer replaced liquid as the source of nutrients for stream enrichment. Product was tested at PESC again in June of 2007 to confirm it is safe for stream applications. No pollock or liquid fertilizer was used this year.

2008 **Agencies:** MoE., NANAIMO. (Admin. by BCCF. Funding by BC Hydro, Bridge Coastal Restoration Program) Western Forest Products Ltd., and Georgia Basin Living Rivers
Fertilizer Applied: 16-40-0. (Nutricote T40)
Period of Application: June 24 (White) and June 26 (Salmon) – September 30.
Sites: Memekay River at the ML bridge crossing, Grilse Creek (upper and lower bridges), Salmon River upstream of Rock Creek ML bridge crossing (deactivated), smolt screen, Memekay ML bridge crossing, Bigtree ML Bridge, White River at Stewart ML, 6.5 km d/s Stewart ML, Consort Creek at Stewart Lake outlet and Consort at 2.5 km d/s of Stewart Lake.
Water chemistry samples: Yes.
Periphyton samples: Yes
Taxonomy samples: No.
References: Pellett (2008)

Comments: Solid Nutricote T40 fertilizer replaced liquid as the source of nutrients for stream enrichment. Product was tested at PESC again in June of 2007 to confirm it is safe for stream applications. Addition of Bigtree ML Bridge site and White River system to FIA project funds.

2009 **Agencies:** MoE., NANAIMO. (Admin. by BCCF. Funding by BC Hydro, Bridge Coastal Restoration Program) Campbell River Salmon Foundation, and Georgia Basin Living Rivers
Fertilizer Applied: 16-40-0. (Nutricote T40), 5-27-0 (Crystal Green)
Period of Application: June 17 (Salmon) and June 24 (White) – September 30.
Sites: Memekay River at the ML bridge crossing, Grilse Creek (upper and lower bridges), Salmon River upstream of Rock Creek ML bridge crossing (deactivated), Menzies ML bridge, Memekay ML bridge crossing, Bigtree ML Bridge, White River at Stewart ML, 6.5 km d/s Stewart ML, Consort Creek at Stewart Lake outlet and Consort at 2.5 km d/s of Stewart Lake.
Water chemistry samples: Yes.
Periphyton samples: Yes
Taxonomy samples: No.
References: Pellett (2010)

Comments: Solid Nutricote T40 fertilizer replaced by Crystal Green as the source of nutrients for stream enrichment on the Salmon, Grilse and Memekay. Product was tested at PESC to confirm it is safe for stream applications. White River drainage treated with remaining Nutricote T40. Campbell River Salmon Foundation provided partnership funding in absence of FIA support for areas below diversion and the White River/Consort Creek.

2010 **Agencies:** MoE., NANAIMO. (Admin. by BCCF. Funding by Campbell River Salmon Foundation and Georgia Basin Living Rivers
Fertilizer Applied: 5-27-0 (Crystal Green)
Period of Application: June 30 (Salmon) and July 14 (White) – September 25.
Sites: Memekay River at the 2 lower bridge crossings, Grilse Creek (upper and lower bridges), Salmon River upstream of Rock Creek ML bridge crossing (deactivated), Menzies ML bridge, Memekay ML bridge crossing, Kay Creek (in lieu of Bigtree ML Bridge), White River at Stewart ML, 6.5 km d/s Stewart ML, Consort Creek at Stewart Lake outlet and Consort at 2.5 km d/s of Stewart Lake.
Water chemistry samples: Yes.
Periphyton samples: Yes
Taxonomy samples: No.
References: Pellett (2011)

Comments: Campbell River Salmon Foundation provided partnership funding in absence of BCRP and FIA support for areas below diversion and the White River/Consort Creek. Georgia Basin Living Rivers – Vancouver Island provided financial support for activities that CRSF funds not able to cover. No significant growth response by steelhead fry in 2010 due possibly to high flows.

APPENDIX 2. Water Survey of Canada, discharge data (preliminary) for the Salmon River from June 1 to September 30, 2010.

Station 08HD015 -Salmon River above Diversion, 2010							
Jun	**m^3/s**	**Jul**	**m^3/s**	**Aug**	**m^3/s**	**Sept**	**m^3/s**
1	31.2	1	7.9	1	2.9	1	2.0
2	37.2	2	7.7	2	2.9	2	1.8
3	30.6	3	8.0	3	2.9	3	1.6
4	19.5	4	8.4	4	2.8	4	1.5
5	16.9	5	9.3	5	2.7	5	1.5
6	16.5	6	8.9	6	2.6	6	1.5
7	15.9	7	12.0	7	2.7	7	1.6
8	17.7	8	13.9	8	3.7	8	1.6
9	20.4	9	13.3	9	2.9	9	1.5
10	23.3	10	11.1	10	2.5	10	1.4
11	19.4	11	11.8	11	2.3	11	1.4
12	20.6	12	10.0	12	2.3	12	2.5
13	25.9	13	6.6	13	2.2	13	2.9
14	18.1	14	5.6	14	2.1	14	2.4
15	14.5	15	6.1	15	2.0	15	2.1
16	13.7	16	5.9	16	2.0	16	2.1
17	14.6	17	5.4	17	1.9	17	2.2
18	13.9	18	5.0	18	1.9	18	2.1
19	17.0	19	4.7	19	1.8	19	2.4
20	20.2	20	4.5	20	1.7	20	3.1
21	18.4	21	4.8	21	1.7	21	3.1
22	15.6	22	4.7	22	1.7	22	2.7
23	16.6	23	4.3	23	1.6	23	2.4
24	16.9	24	4.0	24	1.6	24	8.9
25	15.4	25	3.8	25	1.5	25	72.0
26	13.9	26	3.7	26	1.5	26	49.4
27	12.4	27	3.7	27	1.5	27	15.3
28	11.9	28	3.6	28	1.6	28	12.0
29	9.8	29	3.4	29	1.5	29	8.2
30	8.4	30	3.2	30	1.7	30	5.8
		31	3.0	31	1.8		
Mean	**18.2**	**Mean**	**6.7**	**Mean**	**2.2**	**Mean**	**7.3**
Min	**8.4**	**Min**	**3.0**	**Min**	**1.5**	**Min**	**1.4**
Max	**37.2**	**Max**	**13.9**	**Max**	**3.7**	**Max**	**72.0**

APPENDIX 3. Summary of electrofishing data by site for the period 1998-2010.

1998

Site #	Mean Weight (grams)	Unadj'd FPU	D/V Adj'd FPU	Predicted FPU	% of Predicted
1	2.25	189.8	201.90	65.5	308%
2	4.01	31.76	52.10	36.8	142%
3	3.79	63.45	64.10	38.9	165%
4	3.48	60.42	67.10	42.4	158%
5	3.13	75.06	97.50	47.1	207%
6	2.33	27.87	37.20	63.3	59%
7	4.03	25.9	41.10	36.6	112%
8	3.52	49.2	54.70	41.9	131%
9	2.98	20.96	27.60	49.5	56%
10	3.56	34.47	51.10	41.4	123%
MEAN	**3.31**		**59.11 ***		**146%**

1999

Site #	Mean Weight (grams)	Unadj'd FPU	D/V Adj'd FPU	Predicted FPU	% of Predicted
1	1.44	59.5	104.40	102.4	102%
2	2.79	42.4	64.30	52.8	122%
3	2.81	10.1	12.00	52.5	23%
4	1.04	26.8	29.50	141.8	21%
5	1.50	18.5	19.90	98.3	20%
6	1.09	11.8	17.90	135.3	13%
7	1.46	21.6	24.60	101.0	24%
8	1.60	64.3	69.20	92.2	75%
9	1.52	16.9	19.40	97.0	20%
10	1.00	49.5	56.30	147.5	38%
MEAN	**1.63**		**33.09 ***		**46%**

2000

Site #	Mean Weight (grams)	Unadj'd FPU	D/V Adj'd FPU	Predicted FPU	% of Predicted
1	2.83	72.0	130.36	52.0	250%
2	4.70	21.1	50.11	31.3	160%
3	4.31	35.2	133.29	34.2	390%
4	5.25	13.0	15.45	28.1	55%
5	2.98	31.2	43.25	49.4	88%
6	6.63	9.0	11.69	22.2	53%
7	4.30	15.2	17.39	34.3	51%
8	3.71	23.8	31.15	39.7	78%
9	4.62	11.8	16.27	31.9	51%
10	1.46	23.8	25.25	100.8	25%
MEAN	**4.08**		**32.96 ***		**120%**

2001

Site #	Mean Weight (grams)	Unadj'd FPU	D/V Adj'd FPU	Predicted FPU	% of Predicted
1	3.02	46.1	56.84	48.7	117%
2	4.77	22.2	28.52	30.9	92%
3	4.88	32.2	53.29	30.2	176%
4	3.96	18.8	31.76	37.3	85%
5	2.33	81.6	121.04	63.3	191%
6	2.04	13.0	18.02	72.3	25%
7	3.20	37.0	58.91	46.1	128%
8	3.11	60.2	77.94	47.3	165%
9	2.89	31.7	43.95	51.0	86%
10	1.21	55.8	83.14	122.2	68%
MEAN	**3.14**		**50.14***		**113%**

2002

Site #	Mean Weight (grams)	Unadj'd FPU	D/V Adj'd FPU	Predicted FPU	% of Predicted
1	3.27	32.5	50.56	45.1	112%
2	3.89	22.6	38.54	37.9	102%
3	3.32	61.7	104.68	44.4	236%
4	4.44	7.5	10.31	33.2	31%
5	4.42	2.9	4.38	33.3	13%
6	2.96	11.4	19.71	49.9	40%
7	3.28	33.8	57.43	44.9	128%
8	3.34	34.3	51.14	44.2	116%
9	2.07	21.5	48.06	71.3	67%
10	1.02	22.4	28.17	144.4	20%
MEAN	**3.20**		**30.61***		**86%**

2003

Site #	Mean Weight (grams)	Unadj'd FPU	D/V Adj'd FPU	Predicted FPU	% of Predicted
1	3.37	22.9	34.19	43.79	78%
2	4.87	13.8	18.89	30.29	62%
3	5.01	43.2	58.97	29.42	200%
4	4.71	49.4	96.12	31.31	307%
5	2.53	29.6	48.21	58.28	83%
6	3.35	6.3	9.50	44.07	22%
7	5.27	22.5	28.12	27.97	101%
8	5.69	19.1	24.43	25.93	94%
9	4.78	12.5	18.59	30.86	60%
10	1.87	37.8	71.92	79.00	91%
MEAN	**4.14**		**33.02***		**110%**

2004

Site #	Mean Weight (grams)	Unadj'd FPU	D/V Adj'd FPU	Predicted FPU	% of Predicted
1	1.46	28.7	53.53	101.3	53%
2	3.95	12.9	18.26	37.3	49%
3	4.50	1.0	1.53	32.8	5%
4	4.87	10.8	17.45	30.3	58%
5	3.14	41.4	90.50	47.0	193%
6	2.23	3.0	5.21	66.1	8%
7	6.73	2.5	5.25	21.9	24%
8	3.76	31.2	42.89	39.2	109%
9	3.83	19.9	28.38	38.5	74%
10	1.21	16.0	25.01	121.5	21%
MEAN	**3.57**		**16.96***		**59%**

2005

Site #	Mean Weight (grams)	Unadj'd FPU	D/V Adj'd FPU	Predicted FPU	% of Predicted
1	3.83	17.0	16.59	38.5	43%
2	5.07	24.5	56.86	29.1	195%
3	5.51	29.5	54.82	26.7	205%
4	6.57	24.3	48.83	22.4	218%
5	3.47	27.1	63.84	42.5	150%
6	5.18	3.8	6.33	28.5	22%
7	4.90	16.0	23.14	30.1	77%
8	4.28	32.2	50.07	34.4	145%
9	4.80	35.1	56.12	30.7	183%
10	2.09	31.6	57.43	70.5	81%
MEAN	**4.57**		**36.15***		**132%**

2006

Site #	Mean Weight (grams)	Unadj'd FPU	D/V Adj'd FPU	Predicted FPU	% of Predicted
1	2.09	73.49	121.58	70.68	172%
2	3.87	53.20	84.20	38.13	221%
3	3.56	76.75	125.52	41.45	303%
4	3.57	46.50	87.48	41.29	212%
5	2.25	80.08	117.82	65.63	180%
6	3.63	6.90	13.53	40.59	33%
7	5.61	10.79	16.57	26.31	63%
8	3.74	83.08	144.33	39.45	366%
9	3.53	66.65	116.37	41.82	278%
10	1.79	19.85	26.41	82.48	32%
MEAN	**3.36**		**64.86***		**186%**

2007

Site #	Mean Weight (grams)	Unadj'd FPU	D/V Adj'd FPU	Predicted FPU	% of Predicted
1	2.49	178.5	509.43	59.2	861%
2	2.68	40.7	63.83	54.9	116%
3	1.85	119.3	223.33	79.5	281%
4	1.99	59.5	130.90	74.0	177%
5	1.63	9.8	16.89	90.7	19%
6	2.50	2.4	4.05	59.0	7%
7	1.80	46.6	117.94	81.7	144%
8	1.47	2.5	4.24	100.4	4%
9	1.76	21.0	36.69	83.8	44%
10	1.71	4.9	6.93	86.1	8%
MEAN	**1.99**		**39.05***		**166%**

2008

Site #	Mean Weight (grams)	Unadj'd FPU	D/V Adj'd FPU	Predicted FPU	% of Predicted
1	2.49	136.6	253.43	59.1	429%
2	2.82	50.2	74.30	52.4	142%
3	2.21	78.1	165.18	66.8	247%
4	2.41	49.2	99.72	61.2	163%
5	3.59	30.7	39.03	41.1	95%
6	2.59	7.8	13.92	56.8	24%
7	2.04	57.5	104.32	72.3	144%
8	2.31	34.1	43.35	63.8	68%
9	2.37	35.1	53.40	62.3	86%
10	1.30	26.6	39.05	113.2	34%
MEAN	**2.41**		**66.09***		**143%**

2009

Site #	Mean Weight (grams)	Unadj'd FPU	D/V Adj'd FPU	Predicted FPU	% of Predicted
1	1.43	108.0	153.99	103.0	150%
2	1.87	40.2	63.65	79.0	81%
3	2.34	66.5	98.80	63.0	157%
4	1.46	136.3	203.10	100.9	201%
5	4.24	17.7	27.36	34.7	79%
6	3.12	17.5	31.10	47.2	66%
7	3.16	8.8	14.07	46.7	30%
8	2.83	10.6	13.43	52.2	26%
9	2.74	31.0	49.23	53.9	91%
10	1.37	36.4	56.36	107.5	52%
MEAN	**2.15**	**32.43**	**49.47***		**93%**

2010					
Site #	Mean Weight (grams)	Unadj'd FPU	D/V Adj'd FPU	Predicted FPU	% of Predicted
1	2.04	129.7	239.15	72.2	331%
2	3.44	28.1	44.71	42.8	104%
3	2.73	31.2	70.71	54.0	131%
4	Not sampled in 2010				
5	Not sampled in 2010				
6	1.47	38.0	83.97	100.1	84%
7	3.13	20.7	28.03	47.1	59%
8	1.82	48.5	61.36	80.8	76%
9	2.41	41.0	62.16	61.3	101%
10	2.06	31.6	41.03	71.4	57%
MEAN	**2.52**	**46.09**	**63.91**		**118%**

APPENDIX 4. Budget Information.

MATERIALS, SUPPLIES and **EQUIPMENT** purchase or rental, repairs and maintenance, construction, transportation, travel & related costs, capital

Item Item and Funder if not CRSF	Funder if Not CRSF	Unit rate	Units	Amount	
				CRSF	Other $/in-kind
Solid Inorganic Fertilizer	 HCTF LR-GB/VI	$2,500/MT	1.95	$1682	 $1,500 $1,693
Fertilizer Delivery		$500	0.73	$365	
Application Equipment		$1.96/bag	195	$382	
Vehicle Lease		$100/day	3.5	$350	
Vehicle Fuel		$100/day	3.5	$350	
Communications		$25	8	$200	
Meal Allowance		$41/day	6	$246	
Lab Analysis – water PESC VIU-AERL		 $40/sample $100/sample	 30 17	 $1200 $1774	
Lab analysis - Periphyton		$40/sample	35	$1400	
Safety		$50	2	$100	
Shipping		$30/session	6	$183	
SUBTOTAL				**$8,202**	**$3,193**

PROFESSIONAL FEES, VOLUNTEER LABOUR, project coordinator, technicians, consultants

Item Item and Funder if not CRSF	Funder if Not CRSF	Unit rate	Units	Amount	
				CRSF	Other $/in-kind
BCCF Staff – Coordination and Application/monitoring	Georgia Basin Living Rivers (GBLR)	300	14	$1,491	$2709
FN Staff - Application	Georgia Basin Living Rivers (GBLR)	200	4	$400	$400
SUBTOTAL				$1,891.00	**$3109.00**

ADMINISTRATIVE/OVERHEAD COSTS

(Office rental, courier/postage, utilities, accounting/financial services, administration fees etc. should be in-kind as they are NOT funded)

Item and Funder	Unit rate	Units	Amount	
			CRSF	Other $/in-kind
BCCF Administration on Materials and Labour	13%			$1,975
SUBTOTAL				

TOTAL BUDGET SPENT FROM CRSF	**$10,093**
TOTAL OTHER $/IN-KIND (LEVERAGING)	**$8,277**
TOTAL PROJECT COST (CRSF & Leveraging)	**$18,370**

Funding Source	*Status*	*Type (In-kind, cash, other)*	*Amount*
GBLR	Confirmed	In kind and cash	$6,777
HCTF	Confirmed	cash	$1500
FIA	Declined	cash	$10,000
BCRP	Declined	cash	$25,575.00
Total (should agree with or exceed Other and In-kind Project Budget)			$43,852.00

Did you submit your Final Report for Past CSP Project? yes