IKERT International Kootenai(y) Ecosystem Restoration Team

Kootenai River Nutrient Dosing: As Built System and Performance for 2005 Summer Season

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1. Introduction

During the period 2003 to early 2005, preparatory work for the Kootenai River dosing was undertaken. This included a design report by Ward & Associates[1] describing various configurations for the proposed gravity fed system for dosing of liquid nutrients. The use of a proposed gravity fed system, with the flow meters and valves part way down the cliff at the site selected, was described. The sizes of pipelines needed to carry the flows were computed, and the power consumption was found for the SeaMetrics flow meters.

An earlier report by Ward & Associates[2] listed the required flow rates for the two liquid nutrients (10-34-0 and 32-0-0) over the expected range of flows in the Kootenai River. Also computed were the amounts of storage needed for liquid nutrients to supply the system for 4 weeks.

During the spring of 2005 a final choice for the configuration of the system was made. In addition, it was decided to use a bank-side location for the end of pipe dosing, rather than a channel centerline location, because of the difficulty of installing an underwater pipeline.

Various routes for the pipeline from the storage tanks to the river were discussed. One possibility was to use the log chute route down the cliff; about 100 m north of the proposed location for the tanks, but this route was not selected because of possible disturbance of historic remains/artifacts along this alignment. The final choice was to place the platform on the cliff about 6 m below the location of the tanks, and to run the pipeline from there down the cliff on a diagonal, for a distance of about 270 m to the dosing site, just inside the Idaho state-line. Figure 1 shows the route and the course of the river at the site.

The final system adopted and built was very similar to that shown in the March 2005 report (see Section 3 of the present report). The main components of the system were:

A). the storage tanks, and

B). the controller-metering-pipeline system.

These are described in the following sections.

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[1] Ward and Associates Ltd. ***Kootenai River Nutrient Dosing System: Hydraulic Design and Metering***. For Kootenai Tribe of Idaho. 7 pp plus Figures. March 2005.

[2] Ward and Associates Ltd. ***Kootenai River Proposed Nutrient Dosing: Equipment Layout and Ideas***. For Kootenai Tribe of Idaho. 12 pp plus Figures. October 2004.

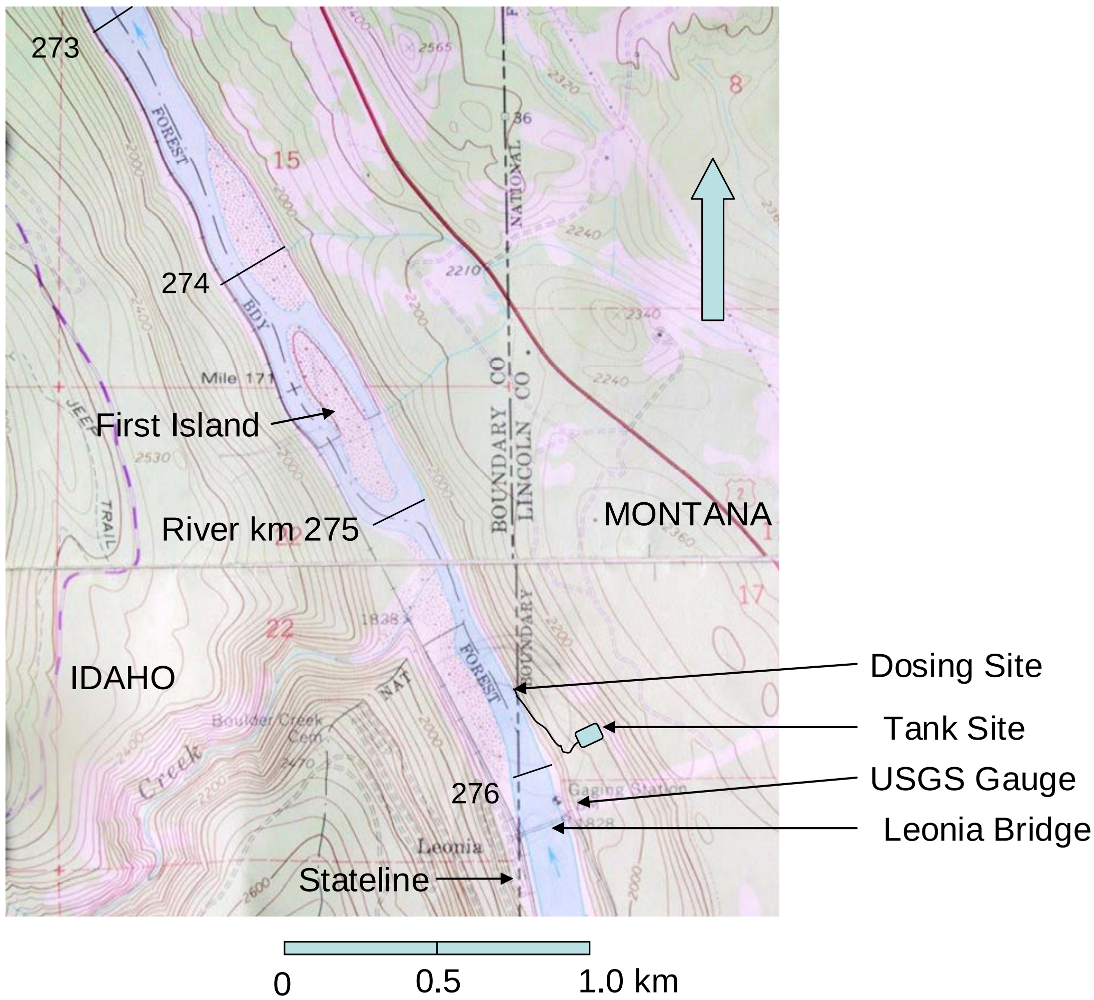

Figure 1. Kootenai River Nutrient Dosing
Main Features at the Site and Pipeline Route

2. Construction of Storage Tank System

Preliminary work was done on road improvement, and in the creation of a turning circle for the fertilizer truck (semi with trailer). Land was cleared and leveled on 31st May 2005, and lock-blocks were brought in and installed around the outside, to form a 42 ft by 42 ft perimeter (inside dimensions). A sand layer was spread over the soil at the site, and then a custom made PVC liner, 40 mil (approx 1 mm) thick was placed on the sand.

Nine large storage tanks were purchased and installed, as follows:

- 2 tanks, 2100 US gallons (7940 L) each for 10-34-0 (ammonium phosphate)
- 6 tanks, 2500 US gallons (9450 L) each for 32-0-0 (urea ammonium nitrate)
- 1 tank, 2100 US gallons for water

These tanks provided sufficient liquid nutrient for a maximum of 41 days operation for 10-34-0 (phosphate) dosing, and a maximum of 25 days operation for 32-0-0 (nitrate) dosing for the design conditions, which were:

Concentration of phosphorus after complete mixing in river:	3 µg/L
Concentration of nitrogen (as NO_3) after complete mixing in river:	30 µg/L
Flow in Kootenai River for design condition:	315 m^3/s

(***Note that only 1.5 µg/L was used as a complete mixing target for the 2005 season, and note that flows were much larger than 315 m^3/s during summer 2005).***

A general photo of the system is shown, see Figure 2.

Figure 2. Tanks for Storing Liquid Nutrient Showing Plastic Liner for Containing Accidental Spill.

Two 3 inch diameter manifold systems were assembled for connecting the tanks, and to facilitate filling and cleaning them at the end of the season. Large filters were incorporated at the intake point (see Figure 3), and these were found to be important in protecting the system from unwanted solids (an impurity in the product).

Figure 3. Filling Arrangements for Tanks Showing Connectors and Filters.

A schematic of the tank farm is shown (see Figure 4).

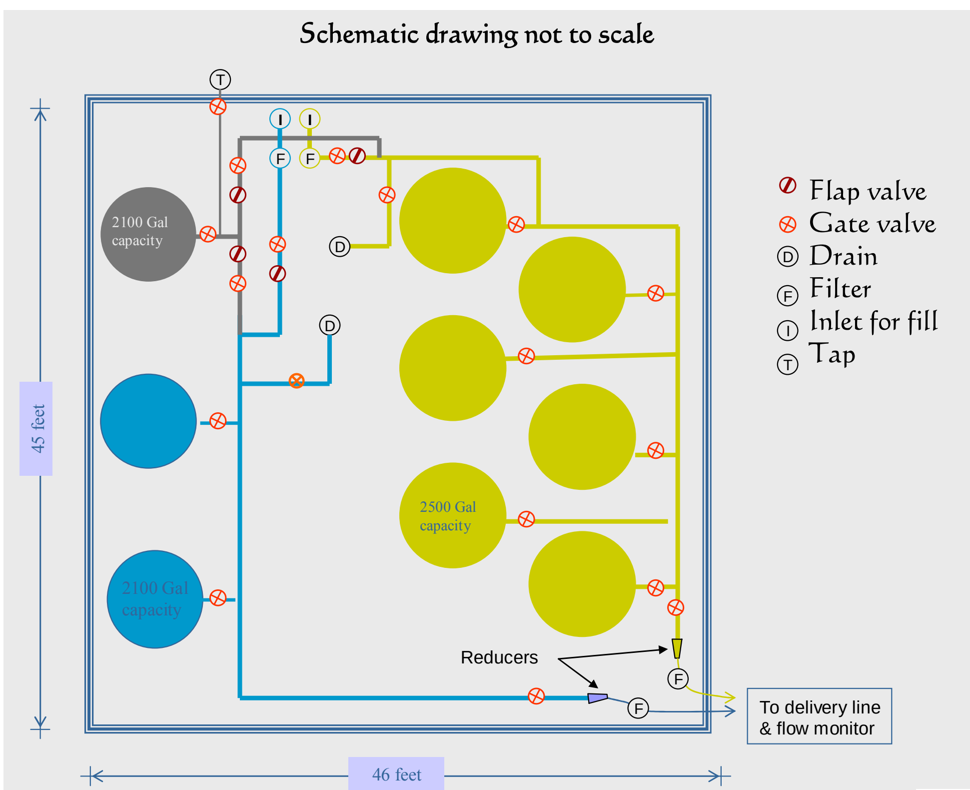

Figure 4. Schematic of Tank Farm Showing Configuration of Manifolds

The road and turnaround circle were configured so that the semi tanker truck could deliver liquid nutrients directly to the manifolds, via cam-lock connections on the end of each manifold (see Figure 5).

Figure 5. Unloading of Nutrients from Semi Trailer

Small in-line filters were placed in the $\frac{5}{8}$ inch outlet lines, to provide protection against any solid impurities that may accumulate in the storage tanks.

Figure 6. Outflow Arrangements for Nutrients, Showing Small In-line Filters

3. Flow Controller and Pipeline

The configuration of the pipeline, including the placement of the control valves and flow meters on a platform on the cliff, was as conceived in the design report (Ward & Associates Ltd., March 2005).

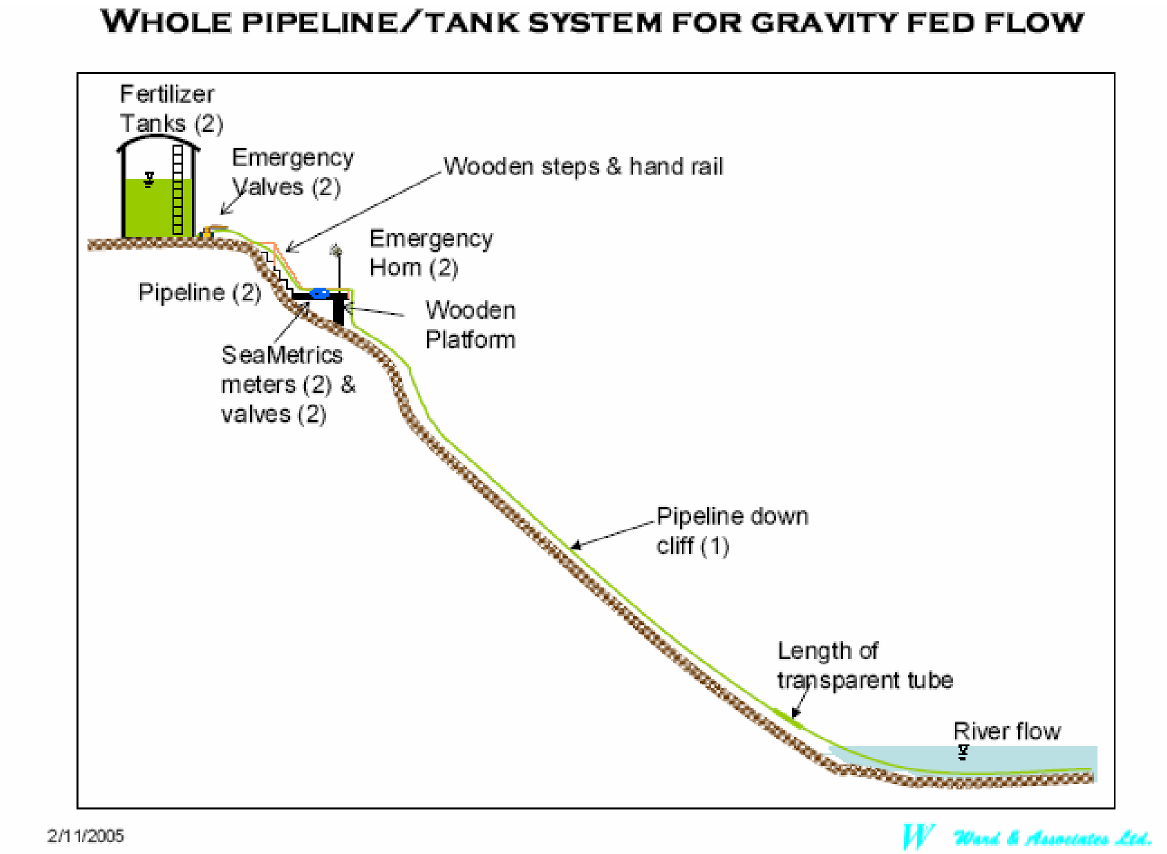

Figure 7. General Layout of Tanks Platform, and Nutrient Delivery System

A wooden platform was constructed on the cliff, at a height of about 6 m below the level of the manifolds at the tanks. The control box, and the mixing box (vacuum break box) were placed on the platform, (see Figures 8 and 9). Approximately 275 m (900 ft) of re-inforced PVC suction hose, 1 inch ID, was installed from the mixing box down the cliff to the dosing site. This hose was available in 100 foot lengths from Greenline Industrial Hose, Vancouver, B.C. Nine of these lengths were connected in series with plastic connectors and industrial quality stainless steel hose pipe clamps to form the whole pipeline. The end of the pipeline was weighted and placed on the bottom of the river, near the right bank.

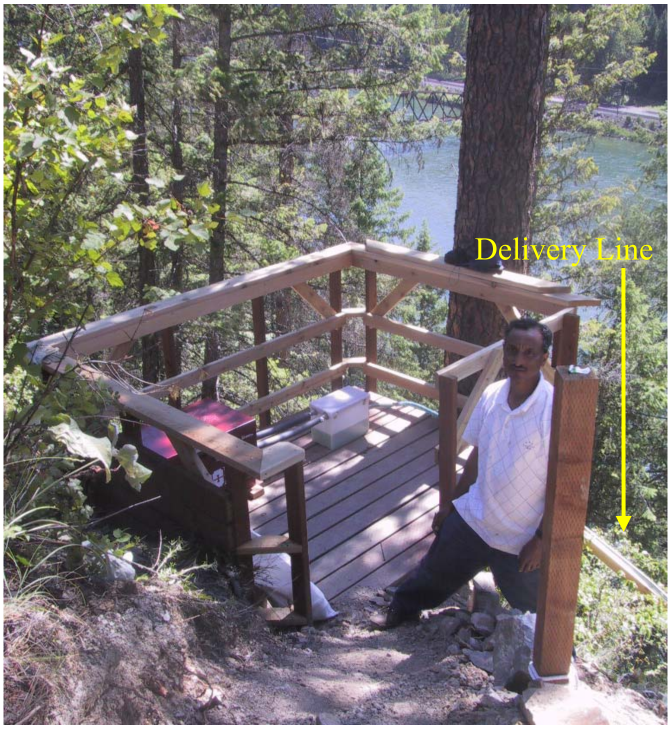

Figure 8. Platform for Control Box, Showing Delivery Line (bottom left)

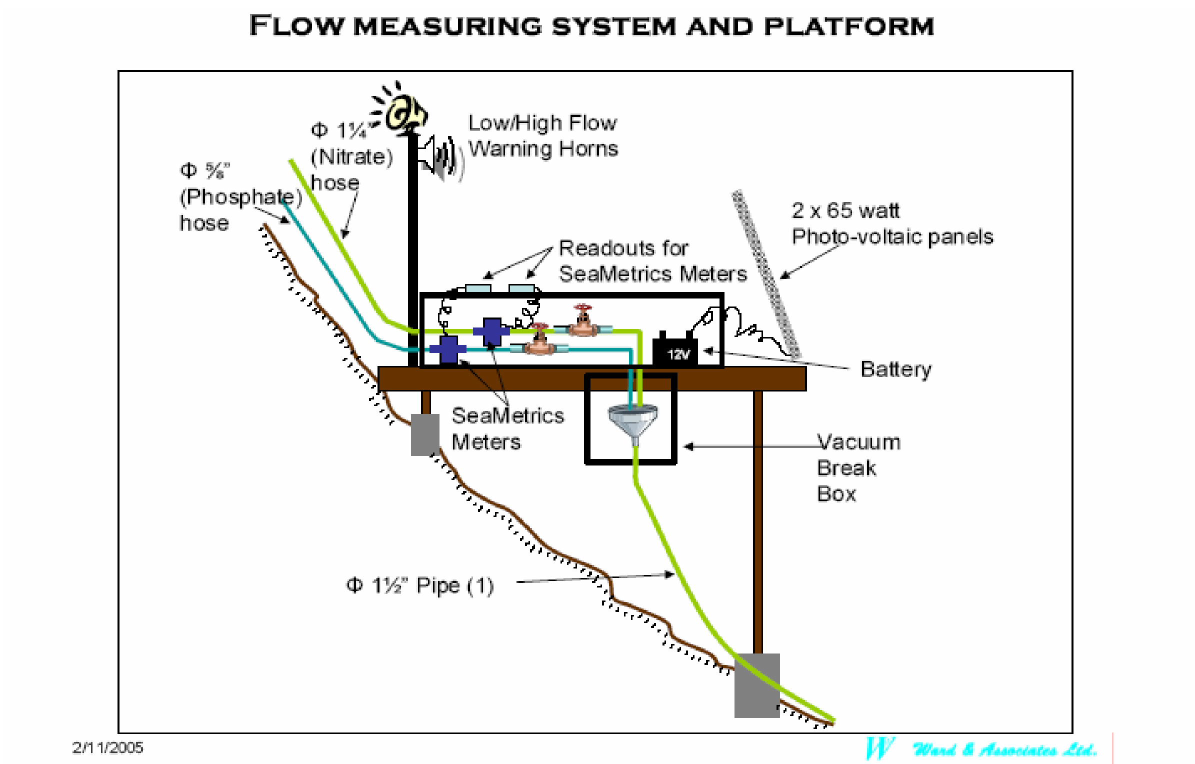

Figure 9. Schematic of Platform and Nutrient Flow Controller

The final design of the controller (see Figure 10), with SeaMetrics meters for measuring and displaying the flow rate, and with gravity flow through needle valves, was as conceived in the design report. For simplicity, both hoses from the tanks to the platform were $\frac{5}{8}$ inch diameter. The exit hoses to the mixing box were $\frac{5}{8}$ inch diameter, and the hose carrying the nutrients down the cliff-side to the nutrient dosing site was 1 inch diameter. The $\frac{5}{8}$ inch hoses were covered with styrofoam insulator tubes, to provide a measure of heat protection.

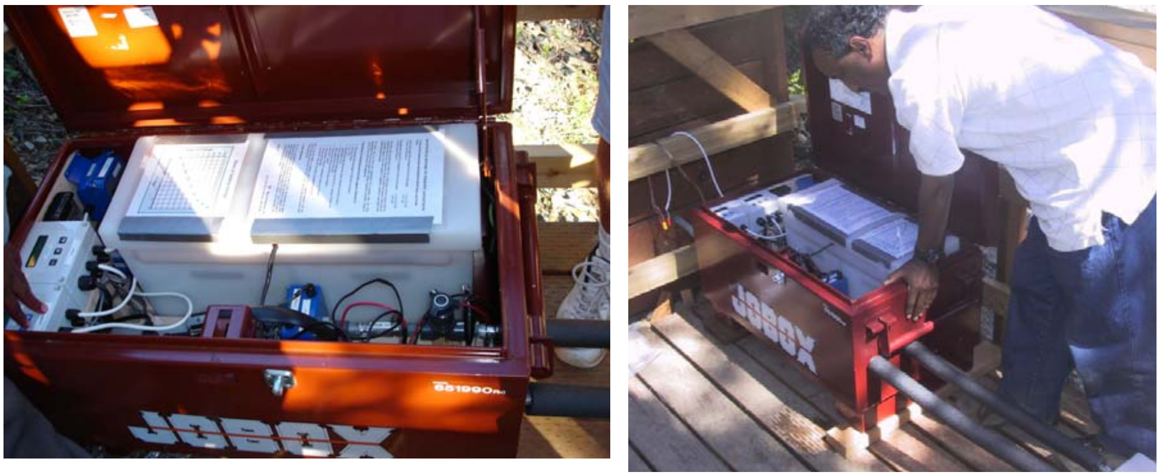

Figure 10. Nutrient Flow Controller
Showing Manually Operated Valves and Flow Meters

An improved stainless steel mixing box was installed after a few weeks operation, see Figure 11. This box incorporated orifices, so that the flow of nutrients could be measured by monitoring the head differences of the flow through orifices. This was included in the system, so that, in the event of failure of the electrical supply or of the SeaMetrics flow meters, there would be an approximate manual method of measuring the flow being released through the system.

Figure 11. Mixing Box Showing Orifice Compartments and Sight Gauge

Two 6 volt golf cart type batteries, rated at 220 Ah were installed in series with one another, and this provided sufficient energy storage for 16 days operation for one flow meter, or 8 days operation for both flow meters operating. A single 100 watt photovoltaic panel (see Figure 12), was found to be suitable for average solar conditions at the site, and was installed. A wooden mount was custom made for the panel, so that its angle could be varied according to the position of the sun at the zenith. The 100 watt solar panel was found to overcharge the batteries in periods of continuously sunny weather, so a voltage controller was installed, to reduce the electrical current rate once the batteries were fully charged.

Figure 12. Photovoltaic Panel, Showing Adjustable Mount for Sun Angle

4. Nutrient Dosing Operations in the 2005 Season

The system was tested for satisfactory operation on 12th July 2005, and opened on 13th July 2005. A decision was made for the 2005 season, to restrict the dosage of 10-34-0 so that the phosphorus concentration, after mixing in the river, was 1.5 µg/L. The amount of phosphorus naturally present in the river upstream of the dosing site was negligible.

The target ratio for N/P to prevent blue-green algae blooms was estimated, on the basis of experience in British Columbia and elsewhere, to be $N/P \geq 20$. Weekly measurements of nitrogen (as NO_3+NO_2) in the river (by sampling-lab analysis and by Hydrolab in situ measurements) showed that there was sufficient nitrogen present upstream of the dosing site (about 70 to 105 µg/L), that there would be no need to add additional nitrogen from the 32-0-0 line.

The N/P ratio in the river with this concentration of N naturally present, and P introduced via the dosing system at a flow to provide 1.5 µg/L, was about N/P = 50:1 to 70:1. This was regarded as adequate to prevent unwanted types of algae. The high concentration of ambient N in the river was found to persist for the whole summer season, and so no 32-0-0 was added during 2005. This resulted in major cost savings for the project.

For determining the flow of 10-34-0 nutrient to the river, the basic strategy was to compute and set the required flow rate on a daily basis as follows:

1. Determine river stage (feet) by reading gauge plate at Leonia gauge (key to gauging hut made available to operator by US Army Corps of Engineers)
2. Find river flow rate ft^3/s and m^3/s, using most recent rating curve for site (obtained from USGS)
3. Determine required flow rate (mL/min) for 10-34-0 for the desired concentration after dilution in river (1.5 µg/L) using a formula or graph
4. Adjust the manually operated valve in the control box (once per day or more frequently) so that the flow, as shown by the SeaMetrics flow meter, was as required from the previous step.

The Leonia gauging station rating curve was updated by USGS part way through the summer season, on 11th August 2005. The two rating curves used in 2005 are shown, see Figure 13. The updated curve differs from the immediate previous curve by less than 5%. A table of values for the updated curve (11th August onwards) is shown in Appendix 1 at the end of this report.

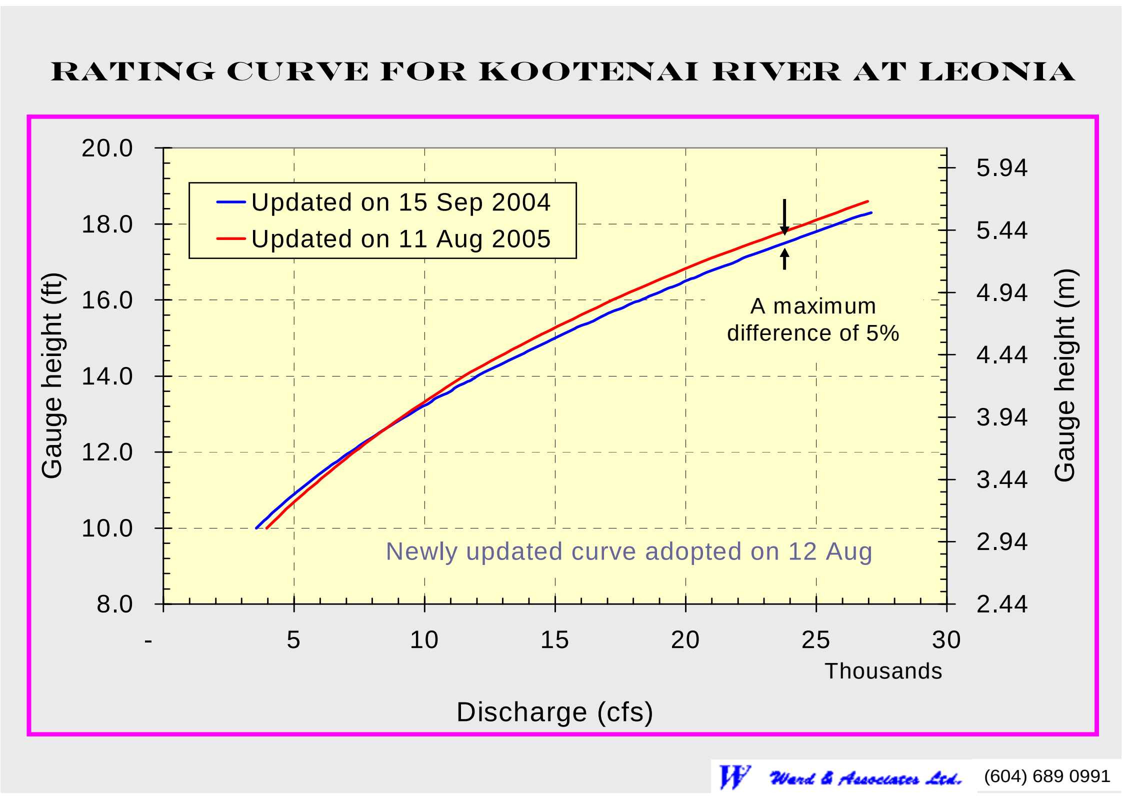

Figure 13. Rating Curves for Hydrological Station Kootenai River at Leonia (Station No. 12305000)

For step 3 of the calculation of daily nutrient flows, Figure 14 (below) determines the required flow rate in liters/minute for 10-34-0 needed to cause a concentration of 1.5 µg/L in the river, after completion of mixing across the channel. This is a linear function of the river discharge.

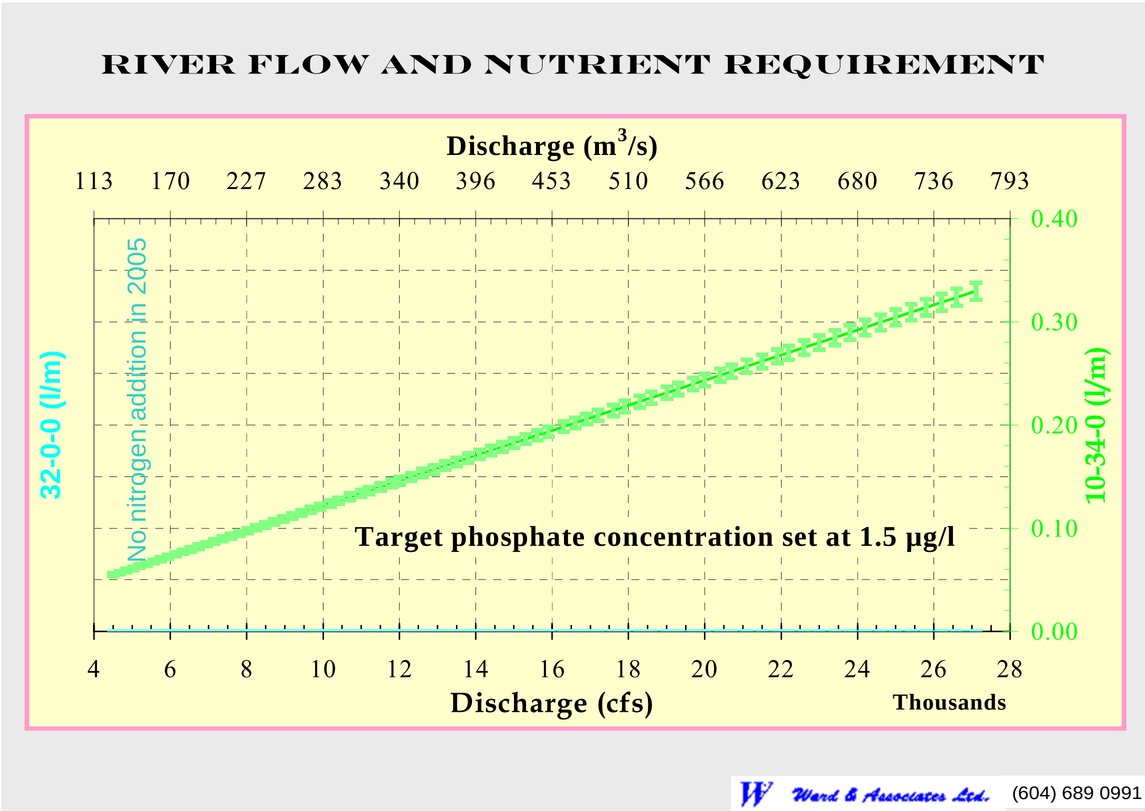

Figure 14. Flow rate of 10-34-0 Needed to Create Desired Concentration of P in the River

Working tables were designed for use of the operator, both as hard copy and as Excel spreadsheets, to assist in determining the flow rate needed for the 10-34-0. An example of the table that was prepared is shown, see Figure 15. A full table, for all flow conditions, is included as Appendix 2 of this report.

Note that the dosing rates for 32-0-0 were not needed for year 2005, because the ambient river concentration of N was sufficiently high that no additional N was required.

It was found that daily oscillations occurred in the flow dosing, apparently because of temperature changes in the tanks and the flow line. After the initial 1-2 weeks of nutrient dosing, the operator was requested to check the system every 1-2 hours during the day, and adjust the valve as needed, to provide exactly the required flow rate of 10-34-0.

Target Phosphorus concentration from 10-34-00 (µg/l): 1.5

Target Nitrogen concentration from 32-0-0 (µg/l): 30

Total Nitrogen addition from two solutions (µg/l): **31.0**

Gauge Height Reading	**Estimated River Flow** Based on Curve 23, updated on 09-09-04		**10-34-0 Ammonium Polyphosphate Dosing Rates**		**UAN 32-0-0 Ammonium Nitrate Dosing Rates**	
(ft)	(cfs)	*(m^3/s)*	(liter/min)	*(gal/min)*	(liter/min)	*(gal/min)*
15.0	15,000	*425*	0.18	*0.048*	1.80	*0.476*
15.1	15,300	*433*	0.19	*0.049*	1.84	*0.485*
15.2	15,600	*442*	0.19	*0.050*	1.87	*0.495*
15.3	15,900	*450*	0.19	*0.051*	1.91	*0.504*
15.4	16,300	*462*	0.20	*0.052*	1.96	*0.517*
15.5	16,600	*470*	0.20	*0.053*	1.99	*0.526*
15.6	16,900	*479*	0.21	*0.054*	2.03	*0.536*
15.7	17,200	*487*	0.21	*0.055*	2.06	*0.545*
15.8	17,600	*498*	0.21	*0.057*	2.11	*0.558*
15.9	17,900	*507*	0.22	*0.058*	2.15	*0.568*
16.0	18,300	*518*	0.22	*0.059*	2.20	*0.580*
16.1	18,600	*527*	0.23	*0.060*	2.23	*0.590*
16.2	19,000	*538*	0.23	*0.061*	2.28	*0.602*

Figure 15. Example of Working Table for Determining Nutrient Flow Rate

A sheet describing the step by step procedure was prepared to assist the operator download the data logger, which kept continuous track of the readings from the SeaMetrics data logger. The downloading was done periodically by the operator and the information sent to Ward & Associates for analysis.

5. Volumetric Amounts Dosed during 2005 Season

Periodically during the season, and at the end of the season, the datalogger was downloaded. Daily volume amounts in the range 480L to 140L were dosed, depending on river flows, see Figure 16.

A comparison was made (see Figure 16) between the volume actually dosed (measured with the Seametrics meter), and the "desired" amount, based on the daily flow rate in the river and the relationship shown in Figure 14. The difference in readings is a measure of the stability of flow control via the manually operated valves, the operator error, etc. At the end of the season, the 10-34-0 solution was diluted to facilitate cleaning of the storage tanks, and the manual valve was opened wide to allow release to the river. These high flows show in Figure 16, during the last few days of nutrient addition.

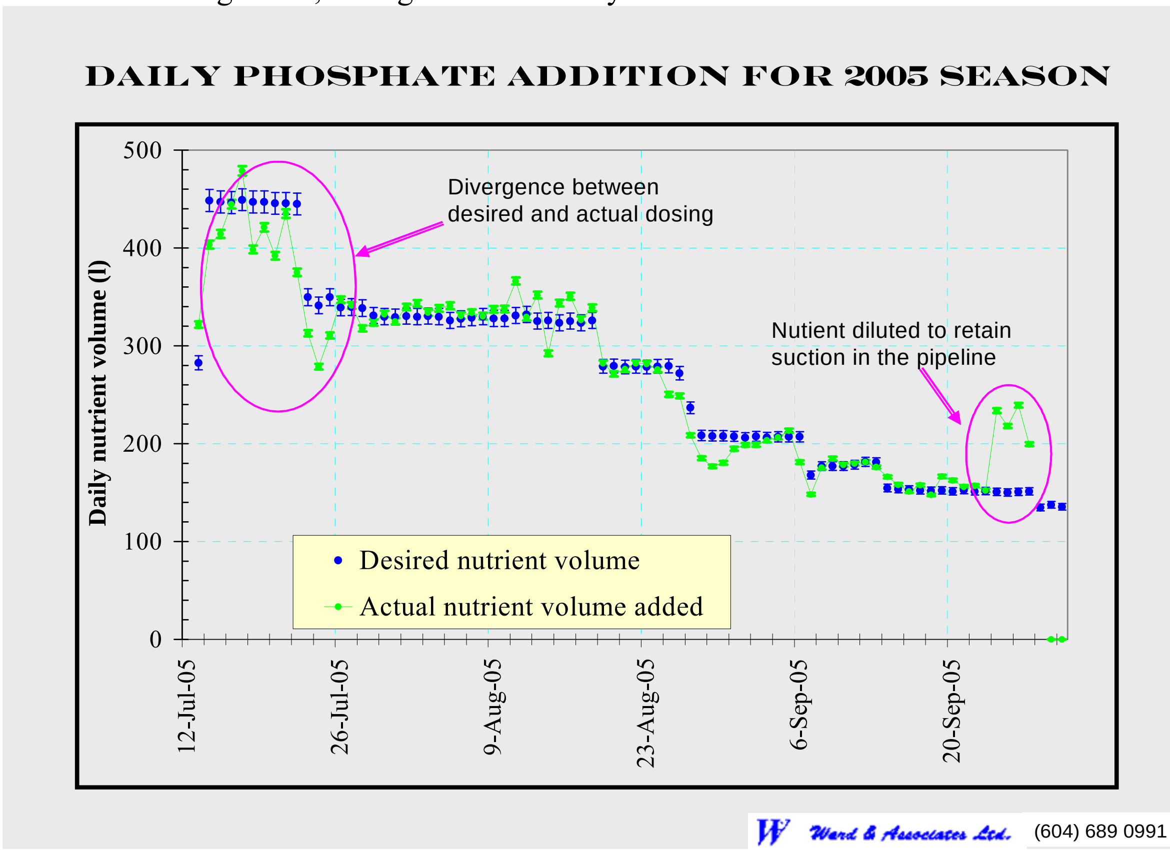

Figure 16. Daily Volume of 10-34-0 Nutrient Dosed, Compared with Desired Volume to Achieve Target Concentration of P in the River.

The cumulative total volume of 10-34-0 dosed, was plotted for the season, see Figure 17. The total volume of 10-34-0 that was dosed during the 2005 season was checked and found to be approximately 21,500 L (5,700 gallons). The cumulative total volume of 10-34-0 desired (to achieve 1.5 µg/L for all days of the season) was also plotted, see Figure 17. The discrepancy between the two volumes may be seen to be low for all dates during the season, and no larger than 7% difference.

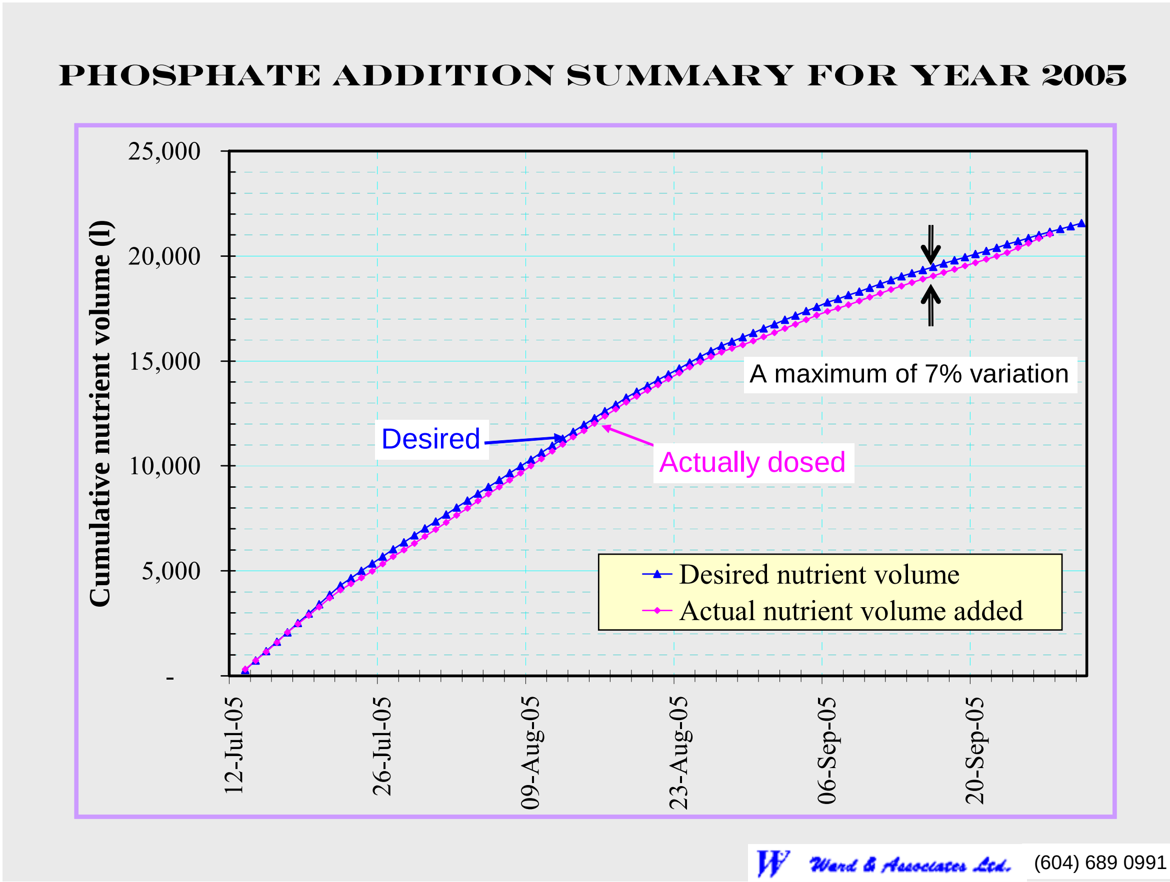

Figure 17. Cumulative Total Volume of 10-34-0 Nutrient from Start-up to Shut-down, compared with Cumulative Volume Computed (Desired Volume) to Achieve Target Concentration of P in the River

6. Winterizing the System

The system was shut down on 2nd October 2005. The tanks were cleaned out, using a small 12 volt pump to drain the tanks to the bottom. The controller was taken to the IDFG field station for storage during the winter, and the batteries were charged. The ⅝ inch pipelines were removed, and the 1 inch pipeline that traverses the cliff was left in place. The final part of the 1 inch pipeline was removed from the river. After shutdown, a roof was constructed over the tank site, to provide all year protection.

7. Recommendations

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Three main recommendations are as follows:

- A system that would provide improved nutrient flow stabilization, such as inclusion of a low energy consumption positive displacement pump, should be considered for the 2006 season.
- A transverse mixing study should be undertaken at large Kootenai River flows, if available in 2006.
- A physical limnology study should be carried out in Koocanusa reservoir, to improve our understanding of nitrogen transport and availability. Emphasis should be on measuring/understanding vertical temperature gradient, abstraction of water via selective withdrawal structure, and nitrate/conductivity gradient in reservoir.

8. Acknowledgements

This work was undertaken jointly by Ward & Associates Ltd, Kootenai Tribe of Idaho and Idaho Fish and Game. Support was provided by S.P. Cramer and Associates. Ground preparation was undertaken by the land owner. Progress that was made would not have been possible without the excellent contribution of all parties.