Report for EEM Investigation of Solutions

Confidential Report for Skookumchuck Pulp Inc.

Skookumchuk Pulp Inc.

31 March 2022

The Power of Commitment

GHD

138 East 7th Avenue, Suite 100

Vancouver, British Columbia V5T 1M6, Canada

T +1 604 214 0510 | **F** +1 604 214 0525 | **E** info-northamerica@ghd.com | **ghd.com**

Approved for Issue (stamp)

PROFESSIONAL PROVINCE OF D. J. LIDDY #33360 BRITISH COLUMBIA ENGINEER

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Deacon Liddy, P.Eng.

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1. Introduction

Skookumchuck Pulp Inc. (SPI) is an alkaline kraft mill with a five-stage bleaching operation, originally designed for production of 495 air dry tones (ADT) of pulp per day. Through plant optimization and upgrades, the mill has increased production to about 700 to 800 ADT per day.

The mill has participated in the Environment and Climate Change Canada (ECCC) Environmental Effects Monitoring (EEM) program since the 1990's and completed Cycle 8 in 2019. The results of Cycle 8 showed minor effects in both fish and benthic communities that exceeded the Environment Canada critical effects size (CES) requirements since the previous cycle (Cycle 7 completed in 2016). Although Cycle 8 was not an Investigation of Cause (IOC) according to EEM protocols, Cycle 8 identified the cause of the mild instream effects as nutrient enrichment by ammonia and phosphorus from the mill treatment system discharge. The Cycle 8 report recommended that SPI proactively undertake an Investigation of Solutions (IOS) to identify potential mitigative measures for the observed effects.

In response to SPI's request, GHD Limited (GHD) prepared a Study Plan to undertake the IOS study. This plan presented a technical program to identify appropriate solutions, based on Section 11.3 of the EEM Technical Guidance Document (TGD)

Section 2. Background below provides more detailed information on the current status of the mill operations, treatment system operations, and in particular the potential source of the nutrients. In addition, Section 2 provides the historical context of upgrades and operating revisions made to the treatment system after the initiation of the EEM program in the 1990's.

This scope of the IOS plan was to:

– Confirm the source of the nutrients
– Determine target effluent concentrations
– Identify options for controlling the nutrients
– Assess economic and technical feasibility

2. Background

2.1 Treatment System Description

Wastewater from the mill is treated in a series of lagoons, consisting of a settling pond (there are two in parallel, but only one is in use), one aerated stabilization basin (Cell #1), followed by two settling basins (Cells #2 and #3) with limited aeration, and finally a polishing pond (Cell #4). From the Polishing Pond, flow can be diverted from the Lift Station to either the Colour Clarifier or to the Kootenay River. In addition, up to about 3000 gallons per minute (gpm) of effluent can be diverted from the lift station back to Cell #1 as a recycle loop to help to control nutrient levels in the final effluent. Based on recent data, the recycle loop is typically used from late April, early May to the end of October, early November, with a typical flow of about 2000 gpm.

The mill discharge is regulated by a discharge permit from BC Ministry of Environment and Climate Change Strategy (MOE) for which the limits are presented in Table 2.1 below.

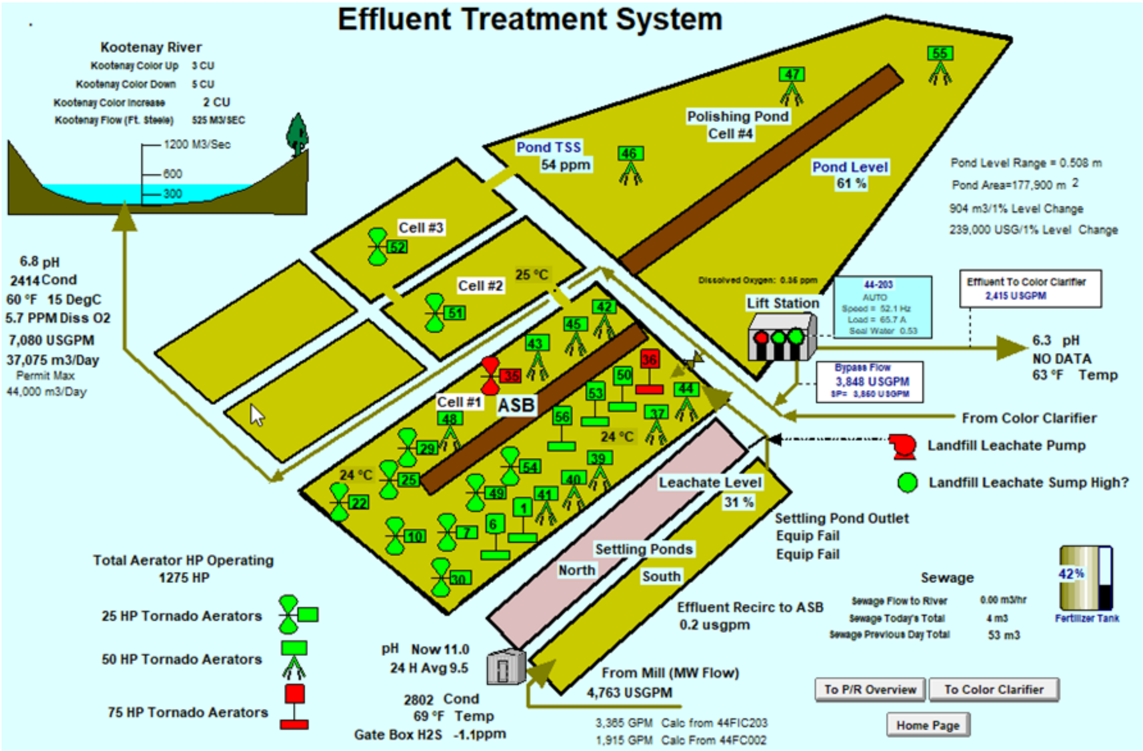

Figure 2.1 Configuration of Treatment System at SPI

Table 2.1 Summary of Current Discharge Limits

Parameter	Guideline Value
Maximum Rate of Discharge	44,000 m^3/day
Non-filterable Residue (TSS)	4,500 kg/day
Biochemical Oxygen Demand (BOD5)	3,500 kg/day
pH Range	6.5 to 8.5
Temperature	Maximum 40 Celsius
Toxicity	96-hour LC50 – pass at 100% effluent
AOX	0.25 kg/ADT

2.2 Recent History

Historic data provided to GHD indicated that on occasion the effluent discharge quality limits for BOD and TSS from the MOE have been exceeded. GHD was retained by SPI to investigate the reasons for this in 2019. In our report, it was identified that there was insufficient aeration in Cell #1, and that additional aeration was required. Over the winter of 2019-2020, SPI installed the additional aeration capacity recommended by GHD, which resulted in the BOD and TSS limits being met consistently. At present, the energy input to Cell 1 for both mixing and aeration is 1225 Horsepower (HP), in a total Cell volume of 167,720 (cubic metres (m^3). This is equivalent to 44 HP per million gallons.

Historically, the mill has used an ammonium phosphate fertilizer to provide nitrogen and phosphorus nutrients for the biological degradation of the organics in the wastewater. Following the previous EEM cycle report in 2016, SPI changed the fertilizer to a low phosphate fertilizer.

Effluent ammonia concentrations have been rising slowly but steadily over the past three or four years. As discussed in Section 2.3, these rising ammonia levels have been implicated as the cause of environmental effects in both fish and benthic effects. After the installation of the additional aeration capacity in Cell #1, the ammonia levels have risen even further. Consequently, SPI has stopped using fertilizer and is now routinely recycling effluent to provide nutrients to Cell#1.

Statistical analysis of the flow to the treatment system from December 25, 2017 to June 28, 2019 based on the data supplied by SPI is tabulated in Table 2.2. Using the 95th percentile flow rate, approximate maximum concentrations of BOD and TSS were estimated at 90 milligrams per litre (mg/L) and 120 mg/L respectively.

Table 2.2 Summary of Treatment System Feed Flow Data

Statistics	Feed Flowrate (m^3/day)
Average	33,139
Maximum	41,495
Minimum	7,165
95th Percentile	37,954

A critical factor in the successful biological treatment of any industrial wastewater is temperature. According to a report by EBS (2019), from 2018 to 2019, the average water temperature at the end of the first pass of Cell 1 was 29.3 C and 25.4 C during summer and winter respectively. These temperatures are satisfactory for good biological treatment.

2.3 EEM Context – Summary of Previous EEM Cycle Results

Initial EEM cycles at Skookumchuck leading up to Cycle 4 (2004-2007) identified that final effluent discharged from the mill to the Kootenay River caused an enrichment (eutrophication) effect on the river's biology, shown by statistically and biologically significant increases in densities and richness (# of species) of benthic invertebrates, and increased energy storage in small fish (i.e., condition and liver size) downstream of the effluent discharge relative to upstream areas (Canal Flats and Torrent) and those further downstream (Wasa). Observed enrichment effects are not uncommon for western Canadian mills that discharge to small, relatively pristine rivers such as the upper Kootenay River, due to the naturally low nutrient loads that are inherent to these systems (oligotrophic).

Although the mill contributes nutrients to the river in the forms of phosphorus (mainly orthophosphate, OP), nitrogen (mostly ammonia) and organic carbon (BOD but also organic forms of phosphorus (P) and nitrogen (N), concentrations of P and N in the Kootenay River in Cycle 4 suggested that P was likely the limiting nutrient in the river; specifically, the river biology was most responsive to the P component of mill effluent and should be the focus of an IOS study in EEM Cycle 5 to address effects observed in both fish and benthos surveys (EEM investigations for fish and benthos follow independent decision processes unless the cause is the same, as was the case for Skookumchuck).

The Cycle 5 IOS study (2007-2010) was conducted by mill personnel and focused on reducing effluent nutrient loads (primarily OP but also ammonia), through optimization of the existing effluent treatment processes and procedures. Implementation of these solutions also was supported by a treatment-optimization assessment done for the mill in 2011 by FPInnovations. Solutions to reduce nutrient discharges included enhanced nutrient and BOD monitoring across the treatment system to improve response, dredging of the settling pond, improved aeration in ASB cells, increased effluent recycling to reduce/eliminate need for supplemental nutrient additions, and surveying of the ASB basins to assess needs for sludge removal. Unrelated to the nutrients, Tembec (mill owner at the time) also contributed funding in Cycle Five to a national FPInnovations/ECCC investigation of causes of pulp mill effluent toxicity to fish, which showed large variability across mills but generally found that observed toxicity did not occur in Kraft effluents with BOD <25 mg/L (no mill-specific actions were taken at Skookumchuck from this fish study).

Following the Cycle Five IOS, a six-year Implementation of Solutions initiative was undertaken that spanned Cycle Six (2010-2013) and Cycle Seven (2013-2016). The mill implemented several of the identified nutrient-reduction solutions within the Cycle Six period; a field study of fish and benthos populations was undertaken during Cycle Seven to assess any changes in previously observed effects on in-river conditions associated with mill changes. A technical memo produced at the end of Cycle Six summarized the implementation of these solutions, including reporting of nutrient (P) loads in effluent over time. Hatfield was the implementing consultant for EEM Cycles One to Six and produced the Cycle Seven field design; implementation of the Cycle Seven field study and EEM Cycle Eight (2016-2019), also focused on field assessments of fish and benthos, were undertaken by Ecometrix.

The Cycle Seven and Eight field surveys of fish and benthos (undertaken in spring and fall of 2015 and 2018, respectively1) essentially repeated those of Cycle Four, to identify any changes in observed mill-related effects on fish and benthos. Although an enrichment signal was still clear in benthos and fish, no biologically significant effects were seen in 2014 (Cycle 7). However, in 2018 (C8) a biologically significant difference in benthos community composition (based on the Bray-Curtis similarity index) was observed despite no biologically significant differences in density or richness. The Cycle 8 report states that this may not be ecologically significant, as both reference and near field areas were dominated by chironomids, mayflies, stoneflies, and caddisflies, but had some unique taxa from these groups in each area.

Biologically significant differences consistent with enrichment also were observed in fish growth (size-at-age) and relative liver and gonad weight. Male Torrent Sculpin populations in the Near Field are had larger livers than those in the Torrent reference area; this difference exceeded the EEM critical effect size indicating a biologically significant effect. This effect was tentatively attributed to higher ammonia concentrations in the near-field area in Cycle 8 (0.024 to 0.087 mg/L) than in Cycle 7 (<0.0070 to 0.0077 mg/L), when smaller magnitude effects were observed. However, in contrast to male sculpin, female sculpin populations in Cycle 8 exhibited lower size-at-age in the near-field area than in the reference area; the magnitude of this difference also was biologically significant. Although the effect observed in male sculpin was consistent with an enrichment effect, the contrasting effect observed in female sculpin creates uncertainty regarding the cause of these contradictory effects.

Based on the observation of a continuing “mild eutrophication response pattern”, the Cycle Eight report recommended that Cycle Nine (2019-2022) focus on a second IOS cycle “to identify opportunities to optimize effluent treatment”, based on interpretation of decision trees in the current (2010) EEM TGD. Although the Cycle Seven and Eight studies were not formal Investigations of Cause, the Cycle 8 report identified nitrogen (as ammonia) in effluent as the likely driver of observed enrichment, because of clearer correlation between observed algal abundance and total nitrogen concentrations in effluent at the time of the Cycle Eight field survey. It should also be pointed out however, that concentrations of P in the river also increased from Cycle 7 to Cycle 8, which may have contributed significantly to the observed enrichment and leaves uncertainty regarding the appropriate target of potential nutrient-reduction efforts.

2.4 Review of Potential Causes of Effluent Nutrient Concentrations

The 2019 EEM results indicate that nutrients, especially phosphorus and potentially ammonia appear to be the cause of the observed fish and benthic effects, or a significant contributing factor in the case of the benthic effects. Since pulp mill wastewaters prior to treatment are known to be deficient in nitrogen and phosphorus nutrients, fertilizer typically has been added to the treatment system to provide those nutrients. That SPI has stopped the addition of fertilizer, and is using effluent recycle to provide nutrients, without apparently impacting the effectiveness of the treatment system, strongly suggests that there is a sufficient reservoir of ammonia and phosphorus nutrients in the system to allow treatment to occur without adding more. Consequently, finding the solution to the environmental effects was focused on the treatment system rather than on the mill itself.

SPI have noted a significant increase in ammonia in the effluent since the installation of the additional aerators in Cell#1. Since these aerators were installed in areas of Cell #1 that had not been actively aerated in some time, it is possible that biological and other solids had accumulated in these relatively quiescent areas. When the aerators were added, those solids would have been re-suspended and carried over to Cell #2 (or even #3) where they would have re-settled, and possibly became anaerobic due to the lower level of aeration in Cells #2 and #3. Based on experience at another pulp mill in Alberta and elsewhere in the industry, the decomposition of these solids could have released ammonia and soluble phosphorus. However, the release would probably have been of relatively short duration, likely days or weeks.

Another contributing factor is likely the accumulation of biological solids in the settling ponds and possibly the polishing basin. SPI routinely dredges the primary settling pond at the head of the system, but reportedly has not dredged any of the other ponds. There may be enough accumulated solids that have become anaerobic to generate the amount of ammonia and phosphorus now being observed in the effluent. GHD learned that there were some pond depth and/or sludge depth data available for one or two of the ponds which was used to help locate potential sources of ammonia and phosphorus within the lagoon system.

3. Scope of Work

3.1 Overall Plan for Study of Solutions

As indicated above, it appeared that the ammonia and phosphorus being released in the final effluent was being generated in the treatment system itself. However, it was not clear if there was a specific pond or area that was generating these nutrients, or if the release was from settled solids from the system in general. Consequently, the source needed to be located before any remedial measures could be identified. The approach taken to finding the ammonia source and then recommending remedial measures is outlined below:

- Confirm the source of the nutrients
- Determine target effluent concentrations
- Information review and data gap identification
- Identify and conduct additional monitoring in lagoon system as necessary, including water quality, sludge depth and composition
- Determine source of nutrients in wastewater treatment system
- Determine target effluent concentrations
- Identify means to mitigate release of nutrients from wastewater treatment system
- Assess the economic and technical feasibility of the identified solutions
- Prepare reports detailing all work completed as well as recommendations

It should be noted that GHD focused on control of N and P nutrients at source (i.e., the treatment system) as the most effective means of mitigation of the effects observed in Cycle 8. Attempting in-stream remediation was considered disruptive and costly and did not appear to be indicated in this case where the observed effects relative to Cycle 7 are minor.

3.2 Approach to Identifying Causes/Sources of Ammonia and Phosphorus Emissions

The following steps were undertaken to identify the causes and/or sources of nutrient discharges from the treatment system.

- Statistical and graphical analysis of data to identify trends in four key parameters (BOD, TSS, NH3-N, and soluble P) across all ponds and out to the final outfall; the purpose of this was to identify specific ponds or areas that are contributing significantly to ammonia and soluble P to the outfall.

– Although the mill had collected some useful data across the ponds, on review it was determined that some parameters and locations were not covered.

– Consequently, additional water quality monitoring was conducted by the mill across the treatment system from the settling basins to the outfall to identify the potential source(s) of ammonia and soluble phosphorus in the pond system.

– Depth data were available for most ponds over a period of years; these data were reviewed to determine how much sludge accumulation had occurred and over what period of time, that might contribute to release of ammonia and soluble P to the outfall.

– Various reports were made available by the mill presenting investigations made on the operation of the treatment system in the past. These were reviewed to provide insights into the current operation.

– Tentative target concentrations for effluent quality were developed based on limited available historical data from previous EEM cycle reports, as well as what specific treatment technologies are capable of achieving.

– Once the target concentrations had been estimated, GHD developed treatment train concepts capable of meeting the tentative target concentrations; block flow diagrams were prepared and used as the basis of preliminary capital cost estimates.

3.3 Identification of Sources of Nutrients

3.3.1 Sampling and Analytical Program

A sampling and analytical program was undertaken from the beginning of June 2021 to the end of August 2021, focused on six parameters – ammonia, TKN, ortho-phosphate, total phosphorus, BOD and TSS. Samples were collected at the settling pond outlet (Spout), end of the first pass in the ASB, end of Cell 1 (ASB), overflow from Cell 2 to Cell3, overflow from Cell 3 to the Polishing Pond (AB to PP), and final outfall (OF), with the objective of determining the concentration profiles of each parameter through the treatment system. Samples were collected once per week over a period of thirteen weeks. The results of the analytical program are presented in detail in Appendix A and the mean concentrations summarized in Table 3.1 below.

Table 3.1 Summary of Mean Concentrations of Analytical Parameters Through the Treatment System

	Mean Parameter Concentrations (mg/L)					
Sampling Point	Ammonia	TKN	Ortho-P	Total P	BOD	TSS
SPout	1.22	2.15	1.40	1.74	274.4	NA
End of 1st Pass	0.18	3.81	3.26	1.80	29.9	57.5
End of Cell 1	1.31	4.91	1.46	1.91	23.4	48.5
Cell 2 to Cell 3	1.82	4.43	1.36	1.88	17.7	23.2
AB to PP	2.03	4.84	1.39	1.90	16.1	18.4
OF	2.65	4.60	1.54	1.84	20.2	18.2

Ammonia

As shown in Table 3.1, and illustrated in Figure 3.1 below, the ammonia concentration in the system drops from the settling pond to a minimum at the end of the first pass in the ASB, and then gradually increases to the outfall. At the end of the Cell 1, the ammonia concentration is about half that of the outfall. It is clear from this observation that the cells subsequent to Cell 1 are contributing ammonia from the anaerobic degradation of accumulated settled solids.

This observation is consistent with previous work at this mill and is consistent with observations at other kraft pulp mills throughout North America.

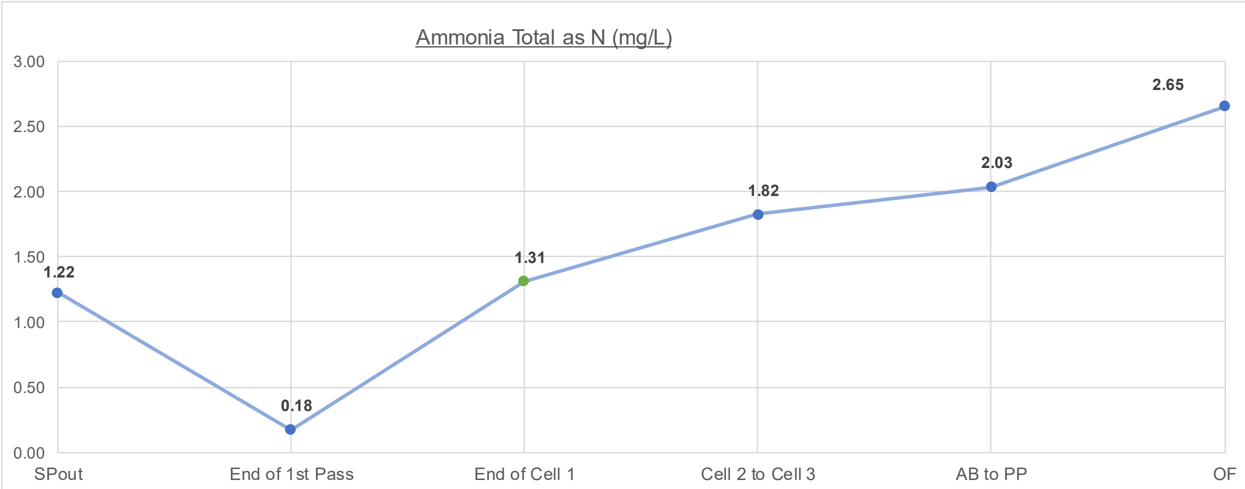

Figure 3.1 Ammonia Concentration Profile Through the Treatment System

Ortho and Total Phosphorus

Figures 3.2 and 3.3 illustrate the concentration trends for these two parameters. The graphs show relatively constant Total and Ortho P through the treatment system. These relatively constant ortho and total P concentrations were somewhat surprising. Experience at other mills has shown that phosphorus levels tend to follow the same shape of curve as the ammonia concentration profile. It is not clear why this was not observed in the Skookumchuck treatment system.

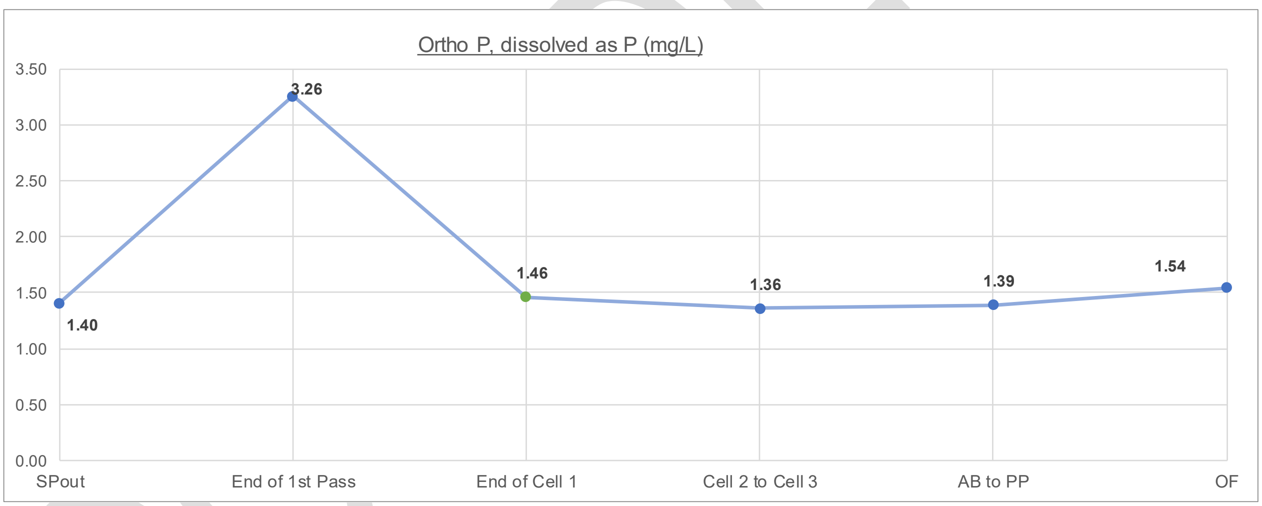

Figure 3.2 Ortho P Concentration Profile Through the Treatment System

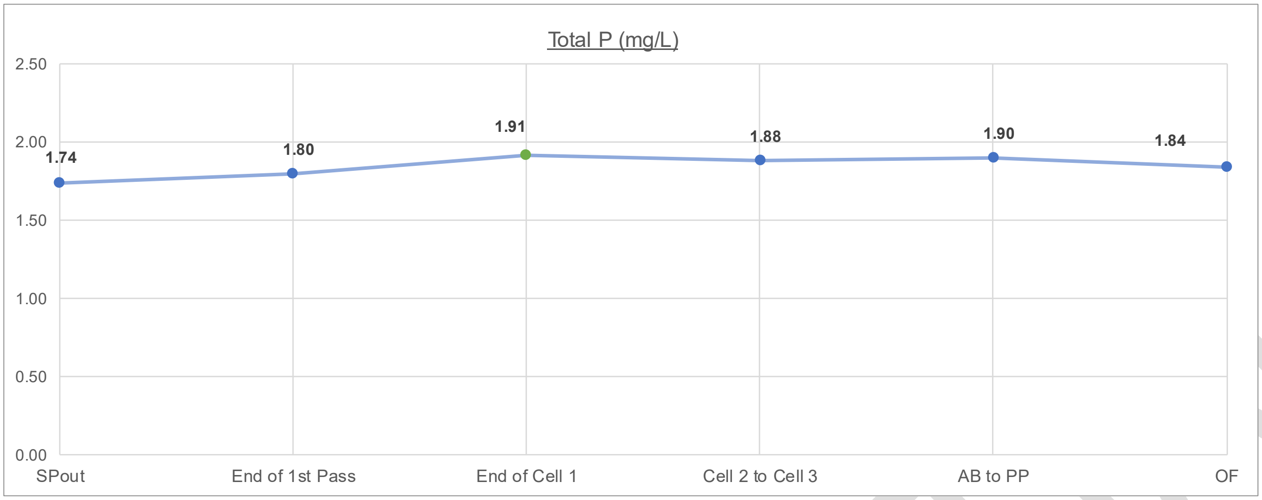

Figure 3.3 Total P Concentration Profile Through the Treatment System

BOD

As shown in Table 3.1 and illustrated in Figure 3.4, BOD concentrations decline from the settling basin outlet to the outfall from Cell 3 into the polishing basin (AB to PP), and then rise again slightly at the outfall. It would appear from the data, that BOD removal is almost complete at the outfall from Cell 1, but does decline slightly through Cells 2 and 3. However, the BOD concentration appears to be low enough at the end of Cell 1 to meet the effluent BOD discharge limit.

At the end of Cell 1, the BOD concentration measured was 23.4 mg/L, which is about 25% of the estimated maximum concentration of 90 mg/L, calculated from the effluent discharge limit of 3,500 kg/day, and the 95th percentile flow of 37,954 m^3/day.

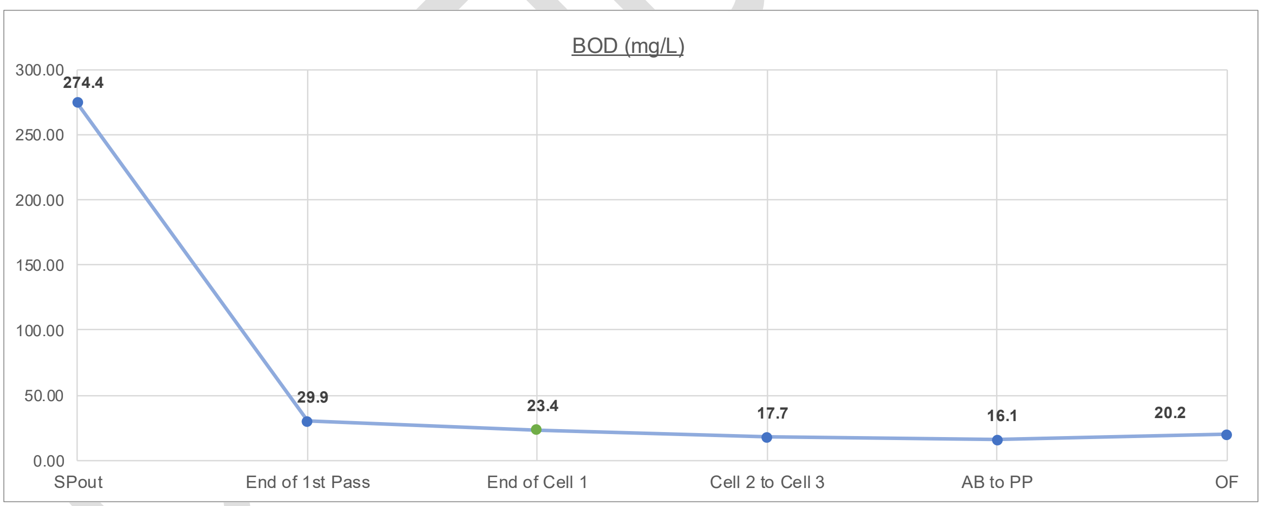

Figure 3.4 BOD Concentration Profile Through the Treatment System

TSS

As shown in Table 3.1 and Figure 3.5, TSS concentrations decline from the end of the first pass of Cell 1 to the final outfall. Concentrations in Cell 1 are more than double those after Cells 2 and 3 and the polishing pond, as would be expected as these suspended solids are the active biomass being generated in Cell1. It appears that the TSS after Cell 3 is not reduced by the Polishing Pond, being effectively constant at 18 mg/L. This concentration easily meets the estimated maximum concentration of 120 mg/L, calculated from the effluent discharge limit of 4,500 kg/day (non-filterable residue), and the 95th percentile flow of 37,954 m^3/day.

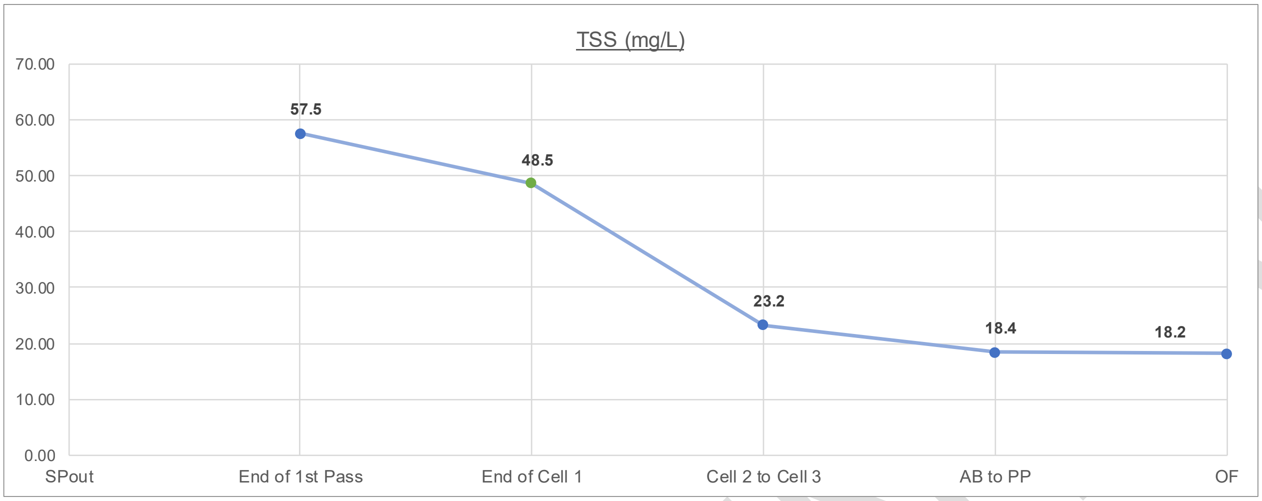

Figure 3.5 TSS Concentration Profile Through the Treatment System

3.3.2 Evaluation of Solids Accumulation in Treatment Basins

As noted above, Cells1 to 3 and the polishing pond have not been dredged in the entire history of the mill, with the result that substantial solids accumulation has occurred in some of the cells. EcoMetrix has undertaken sonar mapping surveys of the lagoons in 2012, 2014 and 2018, to determine solid accumulation over time. Figure 3.6 shows the bathymetry of the lagoons as measured by EcoMetrix in April, 2018. By way of explanation, the white areas are the shallowest water depths, which means the heaviest accumulation of solids. The dark blue areas have little sludge accumulation and are the deepest. There is a scale on the right side of the Figure which shows the free water depth above the sludge in metres.

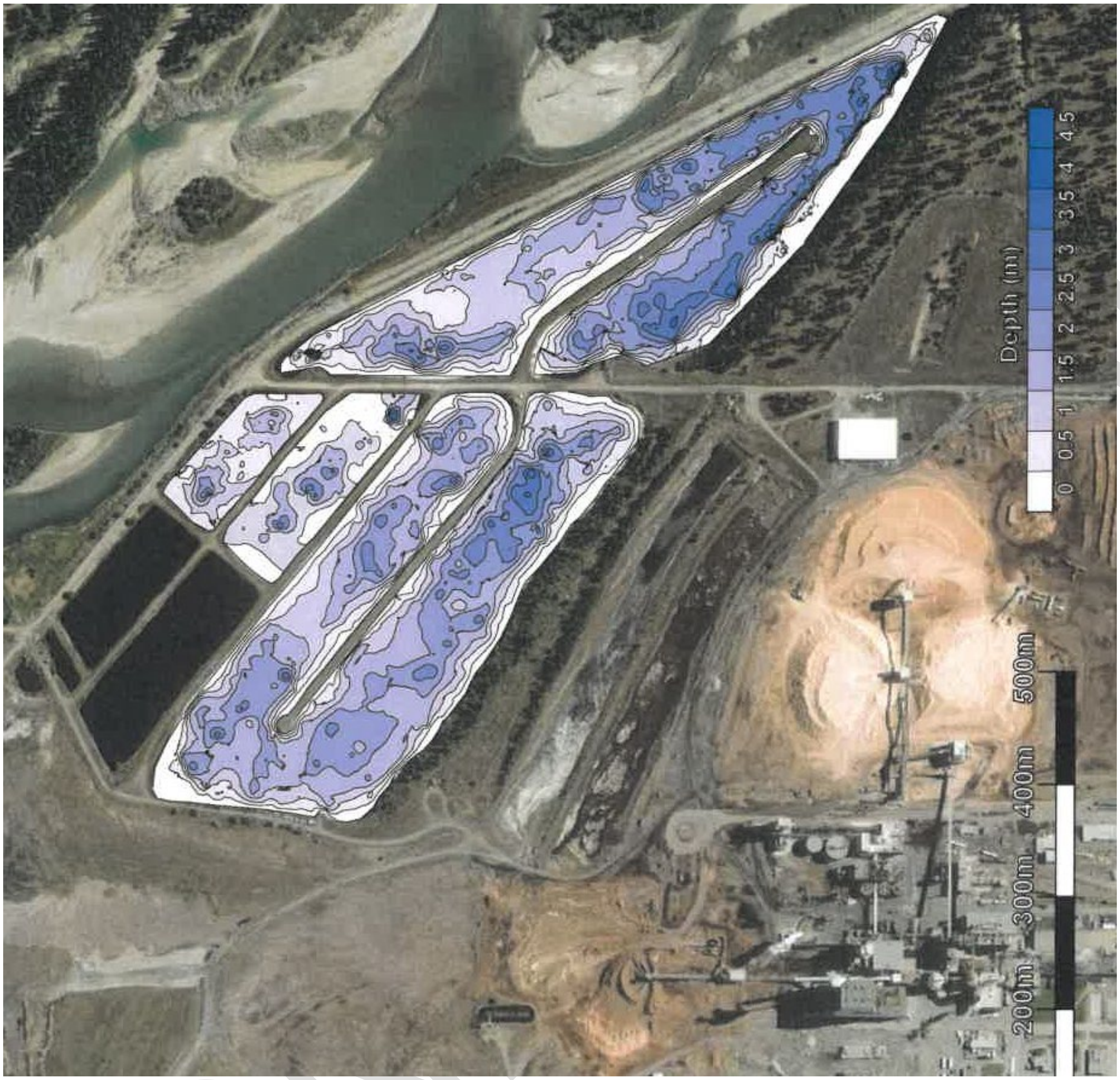

Figure 3.6 Bathymetry of the Treatment Lagoons (From EcoMetrix, 2018)

Data analysis of the EcoMetrix bathymetry results in their 2018 report, as presented in Table 3.2 below, shows that Cells 2 and 3 are about 40 to 50% full of sludge, which means their efficacy for solids separation is likely to be poor, as their retention times have been reduced by the same percentages. The poor settling is confirmed by the presence of a shallow area in the Polishing Pond near the outfall from Cell 3. It is also highly likely that this is a significant contributor to the ammonia and ortho-P found in the final effluent.

Table 3.2 Free Water and Sludge Volumes in Cells

Cell	Free Water Volume (m3)*	Surface Area (m2)*	Total Cell Volume (m3)**	Sludge Volume (m3)	Percent Sludge Volume
1	127,540	83,860	167720	40,180	24.0
2	16,230	13,550	27100	10,870	40.1
3	9,010	8,580	17160	8,150	47.5
Polishing Pond	113,970	72,030	144060	30,090	20.9

*From EcoMetrix 2018 Lagoon Bathymetry Report

**Assumes basin depth of 2 m (6.5 ft) from Sandwell Drawing CPP-D448-011 "General Layout, Polishing Basin and Supply Line"

Since these data are from 2018, prior to the aerator upgrade in late 2019, it is anticipated that the sludge volume in Cell 1 is actually now lower than that shown in Table 3.2 because of the increased mixing created by the additional aerators and displacement of the solids to down system cells. Nonetheless, based on the data shown in Figure 3.1, it appears that the settled solids in Cell 1 are contributing to the ammonia and phosphorus in the Cell 1 effluent relative to the end of the first pass, though the contribution appears to be much less than in Cells 2 and 3.

3.4 Estimated Target Nutrient Concentrations

The previous EEM study report for Cycle 7 in 2016, showed that no significant effects were identified under the operating conditions in the treatment system at the time. Final effluent quality data for ammonia, nitrate/nitrite, dissolved ortho-phosphate, total phosphorus, and dissolved total phosphorus were included in the report, and are summarized in Table 3.3 below

Table 3.3 Cycle 7 Final Effluent and Near Field Nutrient Concentrations

Parameter	Final Effluent April 2016	Final Effluent September 2016	Near Field April 2016	Near Field September 2016
Total Ammonia	1.19	3.82	0.024	0.087
Nitrate/Nitrite	<0.10 / <0.020	<0.10 / <0.020	0.108 / <0.005	0.155 / <0.005
Total Nitrogen	11.2	6.3	0.300	0.241
Dissolved Orthophosphate	0.676	0.374	0.0135	<0.005
Total Phosphorus	2.96	1.90	0.0359	0.0190
Total Dissolved Phosphorus	0.970	0.946	0.0154	<0.005

The data in Table 3.3 show that the ammonia concentration over the winter (as illustrated by the value in April) was considerably lower than that in September, the latter likely being representative of summer conditions. The Near Field ammonia concentrations appear to follow the change in the final effluent ammonia concentrations, as do the Total N concentrations. As ammonia is highly available biologically, target concentrations for ammonia may provide better control of instream enrichment.

Similarly, the phosphorus levels in the effluent also did not appear to have a significant effect on the biota in the receiving stream. While Total P concentrations in the Near Field appeared to follow the final effluent concentrations, neither the Dissolved Orthophosphate or Total Dissolved Phosphorus did. Consequently, it would appear that limiting Total P is the preferred control mechanism.

Based on the data in Table 3.3, there is significant Total P tied up in the TSS, as the Total P was significantly higher than the dissolved Total P. Removing the solids and precipitating some of the dissolved Total P would help to mitigate the effects observed in the receiving water biota.

Table 3.4 below, presents the final effluent nutrient concentrations at the time of the Cycle 8 survey. Ammonia concentrations in Cycle 7 averaged 2.5 mg/L, while those in Cycle 8 in 2019 averaged 2.7 mg/L, indicating a slight increase, which may have had some effect on the in-stream biota.

Table 3.4 Cycle 8 Final Effluent Nutrient Concentrations

Parameter	April 2019	September 2019
Total Ammonia	2.9	2.5
Nitrate/Nitrite	<0.2 / 0.070	<0.2 / 0.055
Total Nitrogen	<20	9.55
Dissolved Orthophosphate	1.08	0.0576
Total Phosphorus	2.26	2.78
Total Dissolved Phosphorus	1.55	2.88

There appears to be only a slight difference in the average Total Phosphorus concentrations between the Cycle 7 (2.43 mg/L) and Cycle 8 (2.52 mg/L) results, based on comparison of Tables 3.3 and 3.4. However, the average Total Dissolved Phosphorus concentration in Cycle 8 (2.22 mg/L) was more than double that of Cycle 7 (0.96 mg/L), which may be consistent with the in-stream enrichment observed in Cycle 8.

Using the Data from Table 3.3 as the basis, the Target Concentrations in Table 3.5 were estimated. The ammonia target was set at 2.5 mg/L which is effectively the average of the April and September 2016 concentrations in the final effluent. Similarly, the Total Dissolved P target was set at 1.0 mg/L which is effectively the rounded up average of the 2016 data. The Total Phosphorus target was set at 2.5 mg/L, effectively the average of the 2016 data.

It should be noted that these targets are preliminary only, as they do not take into consideration the dilution which occurs in the River, and which can vary significantly from year to year. In Cycle 7, dilution was 167 fold in the Near Field, or 0.60% effluent in September 2015. In Cycle 8, dilution varied from 114 fold in April to 161 fold in September, or 0.87% effluent and 0.62% effluent respectively in the Near Field. There appears to be some consistency in the September data from Cycles 7 and 8 in terms of dilution, so the selection of target concentrations based on that provides some consistency.

Table 3.5 Target Effluent Concentrations of Ammonia and Total and Ortho P

Chemical Species	Target Concentration
Ammonia	2.5 mg/L as NH3-N
Total Dissolved Phosphorus	1.0 mg/L as P
Total Phosphorus	2.5 mg/L as P

3.5 Identification of Potential Upgrade Strategies to Reduce Nutrient Discharges

Once the probable source(s) of the ammonia and soluble P were identified along with preliminary target effluent concentrations, identification of potential solutions was undertaken. Potential alternative approaches included the following:

1. Eliminating nutrient addition by fertilizer, and maximizing effluent recycle to reduce both ammonia and ortho-P
2. Use of colour clarifier for Total, Dissolved and Ortho phosphorus removal using alum
3. Dredging of the Lagoons
4. Conversion of Cell #1 of the treatment system to extended aeration or activated sludge treatment to reduce both ammonia and all forms of phosphorus.

3.5.1 Eliminating Fertilizer and Maximizing Recycle

To a degree, SPI is already doing this, as they have ceased to use fertilizer for the most part and are relying on effluent recycle loop and in-lagoon release of ammonia and phosphorus to provide the needed nutrients for BOD removal. At present the recycle loop is used during the summer months to provide nutrients. Typical recycle rate is about 2000 gpm (30% of the total flow) from late April, May to late October, November. Over the winter the recycle loop is not used to avoid cooling the lagoon temperature which is needed to maintain good biological activity in the cell and good treatment performance.

Based on effluent quality data in 2020 and 2021, this approach does not appear to be sufficient to maintain the low ammonia and phosphorus levels required to avoid the impacts observed in EEM Cycle 8. Consequently, this is not a recommended long term solution, although the practice should be continued for the foreseeable future.

3.5.2 Dredging of the Cells

Since the cells have been identified as the source of excess ammonia in the effluent at the outfall, the natural assumption would be to dredge the cells to remove the accumulated solids, which are a major source of ammonia. As indicated in Section 3.3.2, a substantial quantity of sludge has accumulated over the past 40+ years of operation, since none of the cells have been dredged to date. It is not known how much of the depth of sludge is contributing to the ammonia concentrations, but typically only the upper layer of the sludge is biologically active.

Removal of the upper layer could potentially reduce the contribution of the cell to the ammonia concentration. However, it is likely that the exposed lower layers would become biologically active once exposed. In addition, because fresh sludge is continuously accumulating, this sludge would immediately begin to decay anaerobically and release ammonia and phosphorus, so the problem would begin to re-appear relatively quickly.

Dredging of the cells potentially represents a broader environmental risk due to the long-term accumulation of potential hazardous waste in Cells 2 and 3, and possibly parts of the Polishing Basin; however, the quality of the sludge needs to be determined to confirm and plan the waste management strategy. Although the cells could be dredged, this sludge may require special disposal at high cost. Consequently, dredging of the cells does not appear to be a viable long-term solution to mitigating the instream effects of ammonia and phosphorus discharges.

3.5.3 Use of the Colour Clarifier to Remove Phosphorus

Part of the effluent treatment system at SPI is a “colour clarifier” which is used during the winter as the final step in effluent treatment to remove colour, which at low winter river flows is visible in the river. Technically, it is not a clarifier, but rather a dissolved air flotation (DAF) system. Effluent from the lift station is directed to the clarifier, where it is treated with specialized polymeric coagulants/flocculants to coagulate the colour bodies and allow them to be removed by flotation with finely divided air bubbles.

Alum (aluminum sulphate 14-hydrate) is used extensively in municipal wastewater treatment to precipitate both dissolved and total phosphorus and allow them to settle out in final (secondary) clarifiers. Since the Dissolved and Ortho P concentrations in the effluents from the different treatment cells are relatively low, alum precipitation could potentially be used to remove dissolved phosphorus in the colour clarifier. Because of its coagulating effect, alum would also cause total phosphorus in the form of biological solids to be coagulated and removed by settling or flotation.

Use of the colour clarifier for this purpose would be relatively simple to implement physically, requiring only the addition of an alum storage tank, a dosing pump, and in-line mixers to ensure proper mixing. However, the impact of the alum addition on the effectiveness of colour removal, and on the operation of the colour clarifier would need to be studied carefully in detail. Consequently, extensive bench scale testing would be needed, along with pilot and full-scale trials to provide proof that the process could achieve the desired results.

Some of the issues that would need to be examined include the following:

- Alum produces a weightier floc than polymers, so it needs to be determined if the flotation process could continue to separate the floc, or whether the floc would show a tendency to settle, thus interfering with the proper operation of the colour clarifier.
- The colour clarifier uses specific polymers to coagulate and flocculate colour bodies, so that they can be separated by fine bubble flotation; it is not clear if the addition of alum would interfere with this process or enhance it, since alum has shown some limited ability to remove colour from pulp and paper effluents; extensive bench, pilot and full scale testing would be required to assess whether this conversion could be made effectively.
- Currently, the colour clarifier is used only in the winter, in part because of cost. If it were used year-round, operating costs would increase substantially, and would be increased by the cost of year-round additional sludge disposal. An analysis of these costs would be required.
- While the use of the colour clarifier for phosphorus removal has potential, extensive studies would be required, including full scale trials, and there is no guarantee of success. The process also would have no effect on ammonia or total nitrogen in the final effluent. Since there does not appear to be definitive evidence for the actual cause of the mild enrichment in the receiving waters, this process would represent only a partial solution at best, and if only ammonia is implicated for the enrichment, this process change is not a solution at all.

3.5.4 Conversion of the Lagoon system to Extended Aeration or Activated Sludge Treatment

As shown in Table 2.1, many of the parameters measured during the summer sampling program have their lowest or near lowest concentrations at the end of Cell 1. Consequently, it would appear that there is little need for further treatment beyond the end of Cell 1. Based on GHD's previous project work, there is sufficient aeration provided in Cell 1, given the additional aerators added in 2019, to properly treat the mill wastewater. This is confirmed by the BOD data presented in Table 2.1.

The ammonia data shown in Figure 3.1 and BOD data shown in Figure 3.4 indicate that two potential approaches to modified treatment exist, as follows:

a. Extended Aeration using all of Cell 1 for treatment, creating a new cell at the end of the polishing pond to allow the use of the existing lift station and pipeline for effluent transport to two new clarifiers for final solids removal and potential phosphorus removal by alum addition; ammonia would remain low in Cell 1, and would not require further removal.
b. Activated Sludge using only the first pass of Cell 1 for aeration, a new lift station and pipeline to two new clarifiers, sludge recycle from the clarifiers to the inlet of the first pass of Cell 1. This process variation would provide similar treatment results as the Extended Aeration option, limiting both ammonia and phosphorus.

3.5.4.1 Extended Aeration

In order to convert the existing system to extended aeration, the following modifications would be required:

- Close off the end of the polishing pond with dikes at the lift station so that the lift station would be enclosed in a small basin.
- Provide a discharge pipe from the end of Cell 1 into the newly formed basin at the lift station, so that flow bypassed Cells 2 and 3 and the polishing pond.

– Install aerators in the new basin to ensure that it was fully mixed to maintain all TSS from Cell 1 in suspension; this basin would provide additional treatment and ensure that the effluent was well oxygenated.

– Build two new clarifiers across the road from the existing colour clarifier, which would provide solids removal from the effluent before discharge; if needed the effluent from the new clarifiers could be directed to the colour clarifier for colour removal in the winter. Preliminary sizing of the new clarifiers indicates they would each be 30 m in diameter.

– Provide chemical feed systems for alum and polymer at the new clarifier for two purposes; alum would be used for phosphorus removal to meet the proposed target concentration (1.5 mg/L); polymer would be provided for TSS coagulation and removal, which would ensure the TSS effluent limit would be consistently maintained.

– The existing lift station and effluent pipeline to the river would continue to be used for final discharge.

– Sludge settled in the new clarifiers would either be returned to Cell 1 by a new pipeline or returned to either Cell 2 or 3 or the polishing pond for disposal.

Figure 3.7 provides a marked-up satellite image of where the new lift station basin, the new clarifiers would be located. Figure 3.8 provides a block flow diagram of how the system would function.

It should be noted that this approach to modification of the effluent treatment system has been used at the International Paper Mill in Pensacola Florida. Because of the small particle size of the floc, relatively long clarifier retention times are required, 12 to 24-hours. For that reason, most mills convert the lagoon system into an activated sludge system by decreasing the retention time in the aerated lagoon and increasing the aeration, mainly for suspension of the mixed liquor solids.

Figure 3.7 Proposed Extended Aeration Treatment Configuration

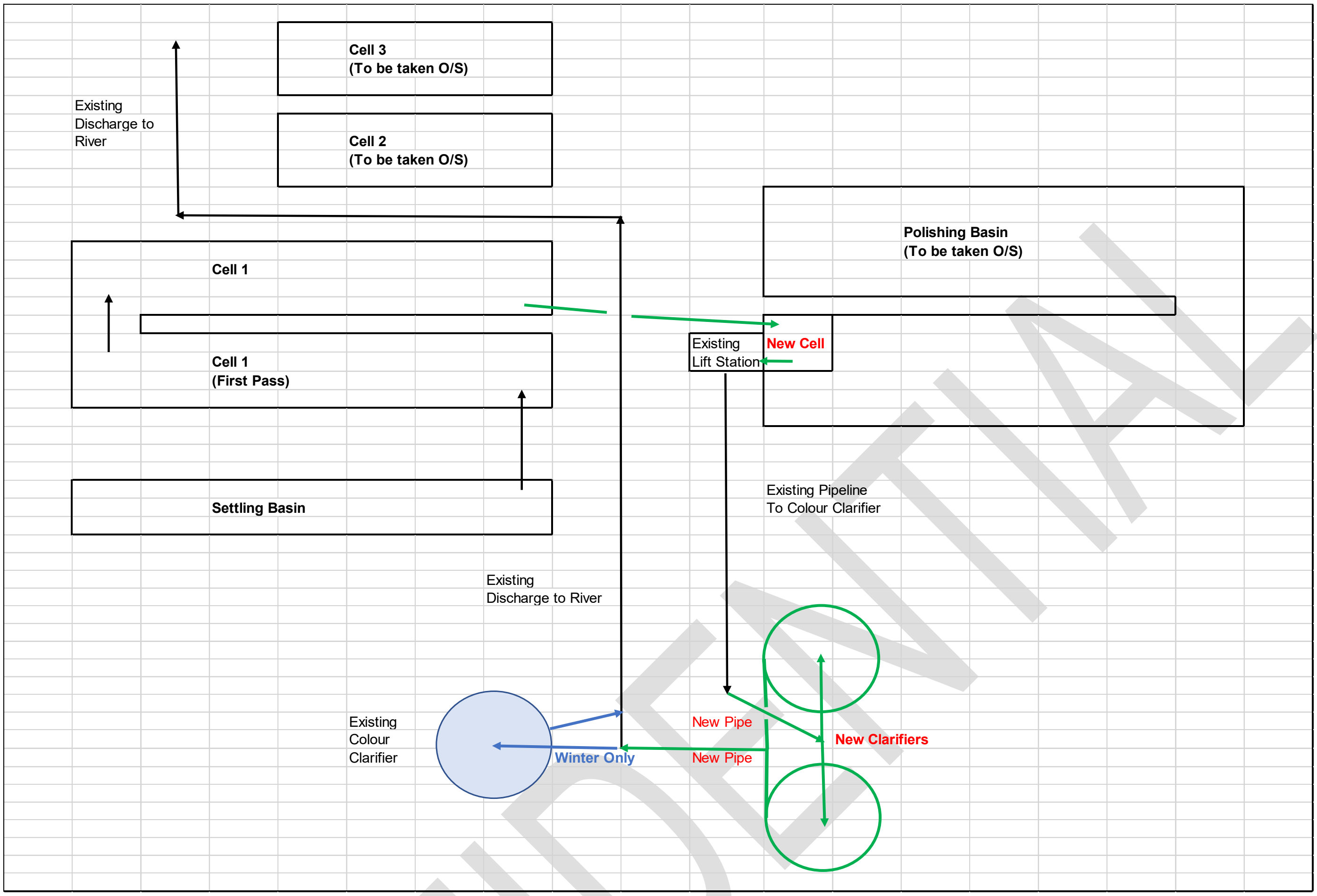

Figure 3.8 Block Flow Diagram of Proposed Extended Aeration Treatment Configuration

3.5.4.2 Activated Sludge

In order to convert the existing system to activated sludge, the following modifications would be required:

- Install a dike at the end of the first pass of Cell 1 to prevent flow into the rest of Cell 1 and onward to other cells.
- Install a new lift station in the first pass inside the dike to take flow to two new clarifiers to be installed on the other side of the road from the existing colour clarifier.
- Install additional aerators or increase the power of the aerators in the first pass to ensure that it was fully mixed to maintain all TSS from Cell 1 in suspension.
- Build two new clarifiers across the road from the existing colour clarifier, which would provide solids removal from the effluent before discharge; if needed the effluent from the new clarifiers could be directed to the colour clarifier for colour removal in the winter. Preliminary sizing of the new clarifiers indicates they would each be larger at 115 ft in diameter than the corresponding extended aeration system, since chemical addition may not be needed due to the low Ortho P concentrations at the end of the first pass of Cell 1.
- Provide sludge recycle from the clarifiers to the inlet of the first pass of Cell 1.
- Provide chemical feed systems for alum and polymer at the new clarifier for two purposes; alum would be used for phosphorus removal to meet the proposed target concentration (1.5 mg/L); polymer would be provided for TSS coagulation and removal, which would ensure the TSS effluent limit would be consistently maintained.
- The existing lift station and effluent pipeline to the river would continue to be used for final discharge.

Figure 3.9 provides a marked-up satellite image of where the new lift station, and the new clarifiers would be located. Figure 3.10 provides a block flow diagram of how the system would function.

Figure 3.9 Proposed Activated Sludge Treatment Configuration

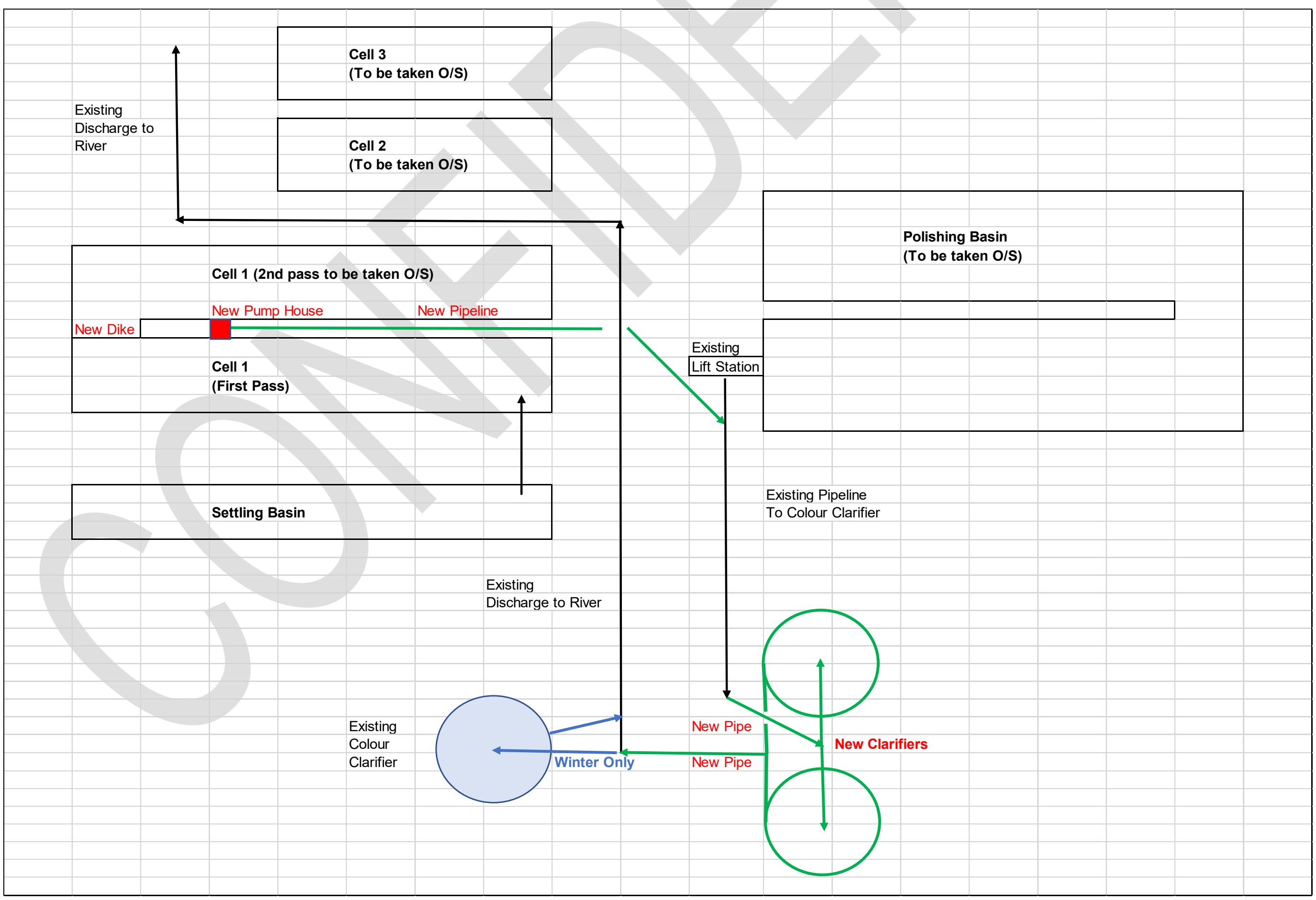

Figure 3.10 Block Flow Diagram of Proposed Activated Sludge Treatment Configuration

It should be noted that this activated sludge modification of the effluent treatment system has been used at several other mills in North America, for the specific purpose of limiting discharges of nitrogen and phosphorus nutrients to receiving waters. Specific examples include

– International Paper, Port Wentworth, GA over a quarter century ago

– Georgia-Pacific, Big Island VA, late 90s

– Foley Cellulose (GP), Perry, FL, 2010s

The latter two projects allowed the mills to meet stringent nutrient criteria. One of the major goals of the Foley upgrades was to address nutrients.

The Big Island project was described in a technical paper, which showed that the basic system was retained, including the equalization basins, aeration basin and polishing pond. A primary clarifier was added, along with a secondary clarifier. Sludge recycle from the secondary clarifier was installed to return biosolids to the inlet of the aeration basin. Similar modifications were apparently made in the other two projects, but unfortunately, there is no publicly available information on these projects, and they remain the confidential information of the companies involved. GHD knows about these due to the involvement of one of our senior staff at the time.

Since SPI already has a primary settling basin that is regularly dredged, it was determined that a primary clarifier was not necessary. The first pass of Cell 1 could continue to be used as the aeration basin, and new secondary clarifiers could be installed to provide final clarification, phosphorus removal, and sludge recycle.

3.5.4.3 Abandonment of Cells 2 and 3

In Section 3.5.2 above, one of the steps in modifying the existing lagoon system would be to bypass Cells 2 and 3 and the Polishing Pond, in effect abandoning these cells. Ultimately this would require the closure and remediation of at least Cells 2 and 3, and possibly the Polishing Pond. As mentioned above, dredging of these ponds would be extremely expensive, especially because of the potential need for hazardous waste disposal. At present, monitoring wells in the area of these cells are not showing any areas of concerns in this regard, indicating that these contaminants are not migrating. Consequently, perhaps the best approach to closure of these ponds is to leave the sediments in place and cap the ponds to minimize ingress of water and the potential for migration.

3.6 Economic Feasibility

The technical feasibility of the four options identified was established by the work described in Section 3.5 above. In this Section, economic feasibility is assessed for three of the four options. The “no fertilizer/effluent recycle” option would not require much if any capital investment, and so has not been examined. Cost estimates for the remaining three options are presented below.

The cost estimates are based on preliminary equipment and facilities lists, together with capital cost factors from AACE (American Association of Cost Estimators), specific estimates from GHD’s Aspen cost estimating software, budget equipment quotes from selected vendors, and GHD’s own project files, as well as information on dredging and the colour clarifier operating costs provided by SPI. The estimate class for these estimates is between Class 5 and Class 4, with an expected accuracy of +50% to -35%.

3.6.1 Dredging of the Lagoons

SPI dredges the settling basin on a regular basis, and so has costs for dredging and sludge disposal for that pond. Assuming that the same anchoring system and dredge depth would apply in the treatment cells, costs could be estimated for them on this basis. As identified in Section 3.5.1, substantial quantities of sludge have settled in Cells 2 and 3 and the polishing basin. The estimated cost to remove all the sludge is provided in Table 3.7 below. These estimates are based on sludge volumes estimated by EcoMetrix in 2018 and the rates provided by SPI for the settling pond. Since then, in 2019, additional aeration and associated mixing has been added to Cell 1 to improve treatment, and this has more than likely reduced the sludge volume in Cell 1 by re-suspending the sludge and allowing it to exit

Cell 1. However, at least some of this sludge would have re-settled in Cells 2 and 3, causing the volumes of sludge in those cells to increase.

Notwithstanding the potential re-location of some of the sludges in Cell 1 to Cells 2 and 3, the overall estimated cost of dredging shown in Table 3.7 is reasonable for the level of project detail. Note that this does not include disposal of potentially hazardous wastes.

Table 3.5 Estimated Costs for Dredging of Cells

Cell	Free Water Volume (m3)*	Surface Area (m2)*	Total Cell Volume (m3)**	Sludge Volume (m3)	Estimated % Dry Solids ***	Estimated Dry Solids (tonnes)	Estimated Disposal Cost ($) ****
1	127,540	83,860	167720	40,180	50.0	20,090	$ 1,004,500
2	16,230	13,550	27100	10,870	50.0	5,435	$ 271,750
3	9,010	8,580	17160	8,150	50.0	4,075	$ 203,750
Polishing Pond	113,970	72,030	144060	30,090	50.0	15,045	$ 752,250
Total Estimated Cost ($)							$ 2,232,250

*From EcoMetrix 2018 Lagoon Bathymetry Report
**Assumes basin depth of 2 m (6.5 ft) from Sandwell Drawing CPP-D448-011 "General Layout, Polishing Basin and Supply Line"
*** Low end of % dry solids from settling basin
**** Disposal cost per dry ton from settling basin dredging = $58

3.6.2 Use of the Colour Clarifier to Remove Phosphorus

As indicated in Section 3.5.3, the colour clarifier could only be used for phosphorus removal and would not provide any removal of ammonia. It would need to be run year-round and would need an alum dosing system to precipitate the phosphorus. The additional sludge generated would require disposal to an approved landfill. Estimated cost for liquid alum per year is about $800,000, and the dosing equipment cost including fibreglass (FRP) storage tank, and dosing pump would be about $120,000. Operating costs for the colour clarifier normally range from about $1,500 per day, to about $4-5,000 per day, depending on how much of the total flow is treated in the clarifier. The highest number corresponds to treatment of the full flow.

If the full flow were treated to ensure Total P and Ortho P removal to the target concentrations at a cost of $4,500 per day, total annual operating cost would be $2,442,500.

As mentioned in Section 3.5.3, extensive treatability tests (bench, pilot and full scale) would need to be conducted to determine the technical viability of this process. If SPI is interested in this approach, GHD can provide a proposal to undertake the work.

3.6.3 Conversion of the Lagoon System to Extended Aeration or Activated Sludge

As described in Section 3.5, conversion of the existing lagoon system to either extended aeration or activated sludge can provide low nutrient (both ammonia and phosphorus) levels in the effluent. Significant modifications to the treatment system would be required as discussed. The following sub-sections present cost estimates for the two options.

The construction indirects estimates include freight, field services, temporary construction, miscellaneous services, mobilization/demobilization, firewatch/spotter, start-up, scaffolding, field supervision, mark-ups and escalation. The project management and design components include both owner and contractor engineering and contract supervision.

Table 3.8 below provides a summary of the cost estimates for the extended aeration and activated sludge options. Full details of each cost estimate are provided in Appendix 1.

Table 3.6 Summary of Cost estimates for Extended Aeration and Activated Sludge Options

Parameter	Extended Aeration with Clarifiers	Activated Sludge with Clarifier
Equipment, Materials, and Direct Labour	$5,209,000	$7,300,000
Construction Indirects (20%)	$1,042,000	$1,460,000
Project Management and Design (15%)	$781,000	$1,095,000
Contingency (20%)	$1,406,000	$1,971,000
Total Estimate (excluding taxes)	**$8,438,000**	**$11,826,000**

4. Enrichment Issues and PPER Modernization & EEM Triggers

EEM requirements under the PPER have been in place since 1992. Although EEM requirements and guidance has been adjusted since that time, the most recent TGD dates from 2010 and no substantial changes have been made to the PPER itself over this nearly 30 years and nine investigative cycles, although they are currently under review (see below). Over this period, most mills (including Skookumchuck) that have progressed through the EEM iterative investigative framework have identified mill-related effects where they do occur, made efforts to address such effects through implemented solutions, and reassessed these impacts following such implementation. Nationally, key questions have been posed by industry and EEM practitioners about the appropriate direction for EEM studies for mills that have progressed through the full investigative framework and returned to the initial question of whether or not mill-related effects exist. Skookumchuck is not alone among mills in identifying ongoing mild enrichment effects associated with nutrients discharged with effluent.

Since 2017, ECCC has been engaged in a process of “modernizing” the PPER, including provisions related to EEM requirements and potentially limits for nitrogen and phosphorus in effluents. Final requirements in a modernized PPER could have direct bearing on potential actions that Paper Excellence would be required to undertake at Skookumchuck to address enrichment in the Kootenay River. Given the oligotrophic (low-nutrient) status of the Kootenay River upstream of the mill, and the sensitivity of the river to small amounts of added nutrients, it is likely that mild enrichment effects will continue to be identified downstream of the mill without ambitious engineering solutions like tertiary treatment and other technologies such as those identified in this Cycle Nine report. The regulatory need to fully eliminate such effects should be known before proceeding with such ambitious and costly solutions. It is anticipated that this clarity will be achieved through an amended PPER within the Cycle Ten period (2022-2025).

5. Demonstration of Success

Once the recommended strategy(s) have been implemented, it will be necessary to demonstrate that they are achieving the expected goals. Initially this can be demonstrated through effluent water quality monitoring to determine if the effluent quality meets the target nutrient concentrations established as the goal. It should be noted that it will take some time for the biological indicators to adapt to the reduced concentrations, which could be up to a year or two.

As pointed out in Section 4, given that there is uncertainty around whether the mild in-stream effects observed in Cycle 8 should constitute a driver for implementation of expensive engineering solutions, there may not be a need to implement the mitigative measures. If and when these measures are implemented, it will take the better part of another EEM Cycle to complete them, and then a normal field program can be implemented in the following Cycle. It is suggested that Cycle 10 focus on gathering additional information while ECCC finalizes the Modernization of the PPER, including the EEM program. Once clarity has been achieved around the necessity for implementation of mitigative measures, Cycle 11 could be used for that purpose, and Cycle 12 for Demonstration of Success.

In the meantime, SPI will be embarking on a three-year Aquatic Receiving Environment Monitoring Program (AREMP) program of in-stream monitoring for BC Environment starting in 2021, running to 2024. In-stream water quality and benthic sampling is planned for both spring and fall each year. Near Field benthic community health could be monitored to demonstrate improvements in the benthic community, specifically Bray-Curtis Dissimilarity Index.

In addition, nutrient diffusing substrates could be used to further assess enrichment of the stream to identify the nutrient causing the enrichment.

The AREMP program as planned does not include the fisheries assessments required for the EEM program. However, this could be added to the field program to provide the necessary data on male Torrent Sculpin liver weight relative to body mass, and female Torrent Sculpin body mass relative to age to satisfy the EEM requirements in the near field.

6. Conclusions and Recommendations

6.1 Conclusions

In undertaking the Investigation of Solutions process for EEM Cycle 9, a number of significant issues were encountered. This included the following;

– Neither Cycle 7 nor Cycle 8 studies were undertaken as Investigation of Cause studies. Review of the Cycle 7 report showed that although an enrichment signal was clear in both benthos and fish, no biologically significant effects were observed. However, in Cycle 8 a biologically significant difference in benthos community composition (Bray-Curtis Index) was observed, despite no biologically significant differences in density or richness. It should be noted that effects on Bray-Curtis are considered “non-prioritized” in the 2010 TGD, and do not necessarily have to lead to an Investigation of Solutions (IOS).

– although the Cycle 8 report suggested that the most likely cause of the effluent-related enrichment was now ammonia rather than phosphorus, the results of Cycle 7 and 8 studies do not clearly demonstrate this. Using EEM decision terms, observed effects seen between Cycles 7 and 8 do not confirm consistent, specific effects in both cycles or precisely identify the causative nutrients(s). Detailed data describing the sources of nitrogen and phosphorus and concentrations/loads in the final effluent were unavailable, limiting this study’s ability to identify the most appropriate and achievable solution, or combination of solutions, to reduce observed enrichment signals in the river. Additionally, potential changes on river productivity associated with specific changes in changing nutrient discharges (N or P) in effluent could not be assessed. Therefore, further uncertainty must be addressed regarding the identified potential solutions before such solutions could be implemented with confidence in expected outcomes.

GHD’s mandate from SPI in this project was to conduct an Investigation of Solutions study, and identify solutions which would mitigate the instream effects observed in Cycle 8. To that end, a total of four potential options were identified and assessed to remove nitrogen and phosphorus nutrients from the SPI effluent to reduce the in-stream impacts identified in EEM Cycle 8. These included the following:

– Eliminating the use of fertilizer to supply nutrients, and using effluent recycle to supply nutrients and reduce the effluent ammonia and phosphorus concentrations; this approach is already in play, and recent effluent data appear to show that it would not be effective in meeting the tentative proposed target concentrations

– Adapting the colour clarifier to remove phosphorus only, if it can be demonstrated that phosphorus is the causative nutrient.

– Dredging of the lagoons was considered, as the effluent ammonia and phosphorus concentrations have been found to in part caused by release from accumulated sludge in the lagoons; however, experience in the industry in North America has shown that this is not a good long term strategy as the problem re-occurs with accumulation of fresh solids over time.

– Conversion of the existing treatment system to either extended aeration or activated sludge by modifying the existing lagoons and taking the unused lagoons out of service; this approach has been found to be effective in the industry in North America

– Of these options, conversion of the lagoon system to an alternate treatment configuration appears to be the most technically sound and reliable approach. However, it is also the most costly by a significant margin.

– However, as stated above, implementation of any of these options should be postponed until the uncertainty around the revised EEM requirements, especially effluent quality criteria and whether mild in stream effects require implementation of extensive engineering solutions.

6.2 Recommendations for Cycle 10

Given the remaining uncertainties discussed above, Cycle 10 should focus on a second phase of Investigation of Solutions, supported by a targeted Investigation of Cause study regarding nutrient limitation in the Kootenay River, before any costly mitigative measures are implemented.

The following recommendations are made based on the information provided in this report:

- As indicated in the Conclusions above, a number of issues related to the Investigations of Solutions process were identified. Consequently, it is recommended that the implementation of the identified solutions not be undertaken during Cycle 10, until these issues are resolved.
- It was not entirely clear from Cycles 7 and 8 whether the causative nutrient of the mild observed effects is Nitrogen or Phosphorus or both. Consequently, implementing a specific Solution at this point is not recommended. Instead, it is recommended to undertake additional in River studies to clarify this, and then re-visit the engineering solutions in a Phase 2 Investigation of Solutions to select the one(s) that will provide the nutrient reductions needed to achieve specific goals for downstream nutrient concentrations in the River.
- Better (more frequent, more reliable, more comprehensive) monitoring of nutrients in effluent and across the effluent treatment process (including treatment-system influent), as well as in the Kootenay River upstream of the mill, would be appropriate in Cycle 10, as there doesn't appear to be good baseline data describing what is actually happening with nutrient discharges at present. A more precise understanding of effluent and river nutrient dynamics will allow more accurate assessment of any benefits that each potential solution would have on nutrient discharges and river productivity.
- Because of the disparity amongst the different nitrogen and phosphorus analytical species seen from different information sources, it is recommended that a robust analytical data base be built over Cycle 10 to provide additional data with which to assess the performance of the treatment system, as well as to meet the data needs for the modernized PPER and EEM programs. This would include:
    - ammonia, nitrate/nitrite, TKN, so that a Total Nitrogen (TN) value can be calculated for comparison to ECCC proposed concentration limits included in PPER Modernization proposals.
    - ortho-P, total dissolved P, Total P, to allow for comparison to proposed concentration limits, and to allow for speciation of rapidly biologically available Phosphorus
    - undertake this analysis at least monthly across the treatment system at the locations sampled during summer 2021, with analytical work conducted by a commercial laboratory
- It is also recommended that during Cycle 10 the mill collect water quality and nutrient data monthly from the river both upstream of the mill (possibly at the intake) and downstream in the Near Field area, so that a mass balance on the impact of the mill effluent can be established; analytical parameters should be the same as the effluent in the previous bullet and should be analysed by a commercial laboratory.
- After review of the AREMP plan for 2022, it would appear that the analytical program proposed could be used to supplement the in-stream water quality and nutrient data sampling program indicated in the previous bullet. It is important to note that the analytical parameters need to be the same between the two programs, specifically ammonia, TKN, nitrate/nitrite, Total P. dissolved Total P, and dissolved ortho P.
- To identify the potential effects that implementing one or more of the solutions would likely have on downstream river productivity, the following two scopes of work are recommended for Cycle 10:
    - An in-river study using nutrient-diffusing substrates containing growth-saturating concentrations of N or P or N+P, to confirm which nutrients are limiting/driving primary productivity (algal growth) in the river, given uncertainly from monitoring results in Cycles 7 and 8 regarding whether mill discharges of phosphorus or ammonia are driving observed increases in productivity; and
    - A nutrient mass-balance model that uses river hydrology and nutrient data and mill discharge data, simulated over a range of realistic seasonal flow scenarios and considering expected variability in nutrient loads in background conditions and mill discharges (potentially defined within a stochastic, Monte Carlo-type simulation), to identify likely downstream nutrient concentrations under different environmental conditions for

different nutrient-reduction scenarios identified by a refined Phase-2 Investigation of Solutions assessments. These predicted in-river nutrient concentrations would be compared against known growth-limitation thresholds for bioavailable P and N, in the context of nutrient-limitation information gained from the nutrient-diffusing substrates study, to identify the likely effect of specific nutrient reductions associated with various potential solutions on observed enrichment in the downstream Kootenay River.