TECHNICAL MEMORANDUM

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TO Luke Moger
Mount Polley Mining Corporation

CC Don Parsons (MPMC)

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QUESNEL LAKE WATER COLOUR

1.0 INTRODUCTION

Mount Polley Mining Corporation (MPMC) has heard concerns from local residents that Quesnel Lake has taken on a green hue. Therefore, MPMC and Golder Associates Ltd. (Golder) have evaluated potential causes of green colouration through monitoring and analysis since December 2015.

The current hypothesis is that Quesnel Lake has historically taken on a green hue in certain locations, at certain angles, and during certain seasons. Green colour in natural lakes is not uncommon in BC. Heightened awareness to the lake water quality and view is likely revealing a green hue that was occasionally present but never noticed before 2014. The following text describes the lines of evidence that support this hypothesis.

2.0 CHEMICAL CONSTITUENTS

The chemical makeup of water can affect its colour in a number of ways that are well understood. These mechanisms form the basis of spectrometry and colourimetry, which are branches of analytical chemistry. Chemicals that are dissolved or suspended in the water can transmit different colours, depending on the concentrations of the constituents, the path length through the water and the strength and wavelength of incoming radiation. The application of spectral chemistry to water colour is described mathematically by Environment Canada researchers[1]. In a companion paper[2], the same researchers used spectral chemistry to classify rivers in BC as: Type 1, dominantly snowmelt or glacial melt, perceived as blue to turquoise to green; Type 2, dominantly snowmelt and groundwater fed, perceived as green to brown; and Type 3, with high concentrations of total suspended solids or chlorophyll or dissolved organic matter, perceived as brown.

Pure water in a white or transparent vessel will transmit blue when unfiltered sunlight enters the water surface. The ultraviolet (UV) waves within the sunlight transmit the blue. If the UV waves are filtered through clouds, the remaining light energy is insufficient to transmit blue. Lakes also take on a blue hue when they reflect the blue sky above. These two factors combine to give the usually recognized blue lake colour. Divers know that this blue fades as one descends into water and the blue wavelengths are absorbed by the water above.

[1] Jerome et al. 1994. Colours of natural waters: 1. Factors controlling the dominant wavelength. Northwest Science. 68(1):43-52.

[2] Jerome et al. 1994. Colours of natural waters: 2. Observations of spectral variations in British Columbia Rivers. Northwest Science. 68(1):53-60.

Depending on the water clarity, the water can take on other shades or other colours entirely. Organic carbon impinges the well-known brown colour in many BC lakes, generally near the headwaters. Other chemicals, notably copper, tend to give the water a green or turquoise hue. Therefore, copper concentrations were examined to evaluate whether dissolved or suspended copper could be leading to the perceived green hue.

Copper concentrations were elevated in Quesnel Lake following the breach (as documented in the Post Event Environmental Impact Assessment) and increased during fall turnover in 2014. These concentrations are shown in Figure 1 and Figure 2, along with the subsequent decline to below BC Water Quality Guidelines for Aquatic Life. The water was below the copper guideline after December 2014 in Quesnel Lake and thereafter was only measured above this concentration in a few samples near the mouth of Hazeltine Creek. Since April 2015, copper has remained below all applicable BC Water Quality Guidelines at all points in Quesnel Lake (Figure 3).

The Mount Polley Mine has been discharging water within the conditions and limits in *Environmental Management Act* Permit 11678. Since discharge began on 1 December 2015, copper concentrations in Quesnel Lake have remained below guidelines, at 100 m from the diffusers and beyond.

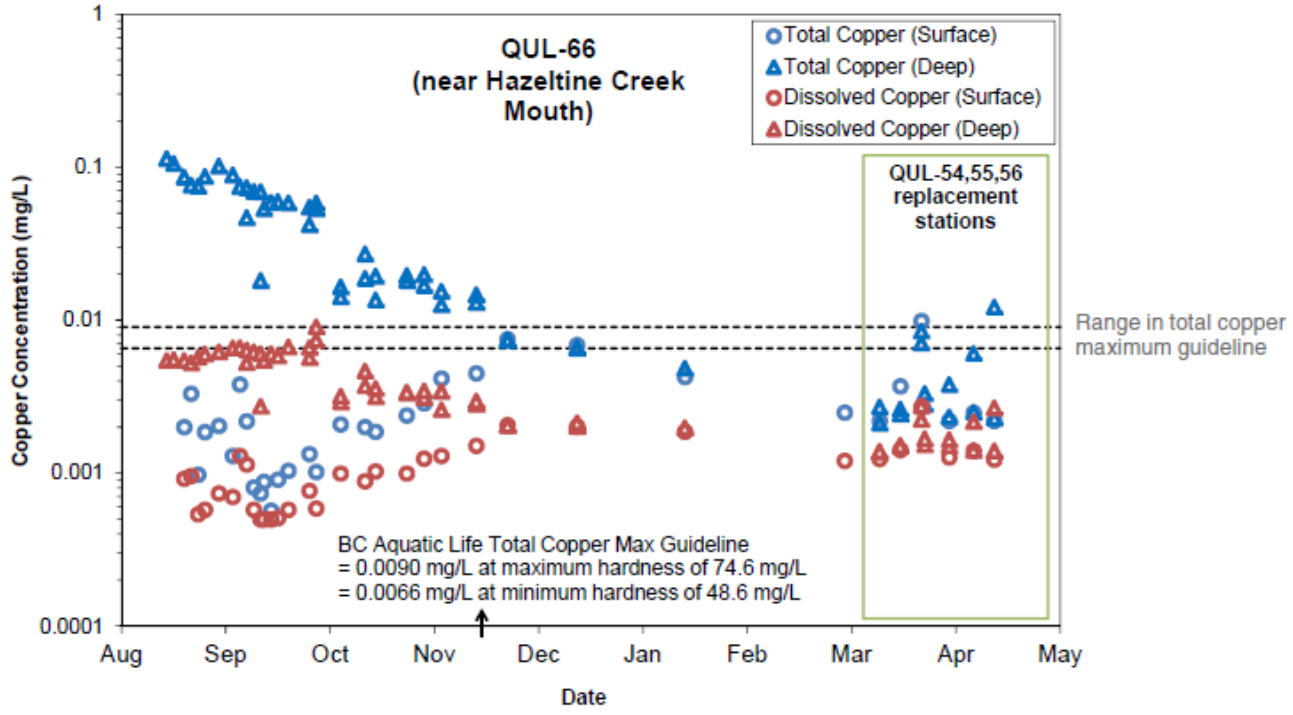
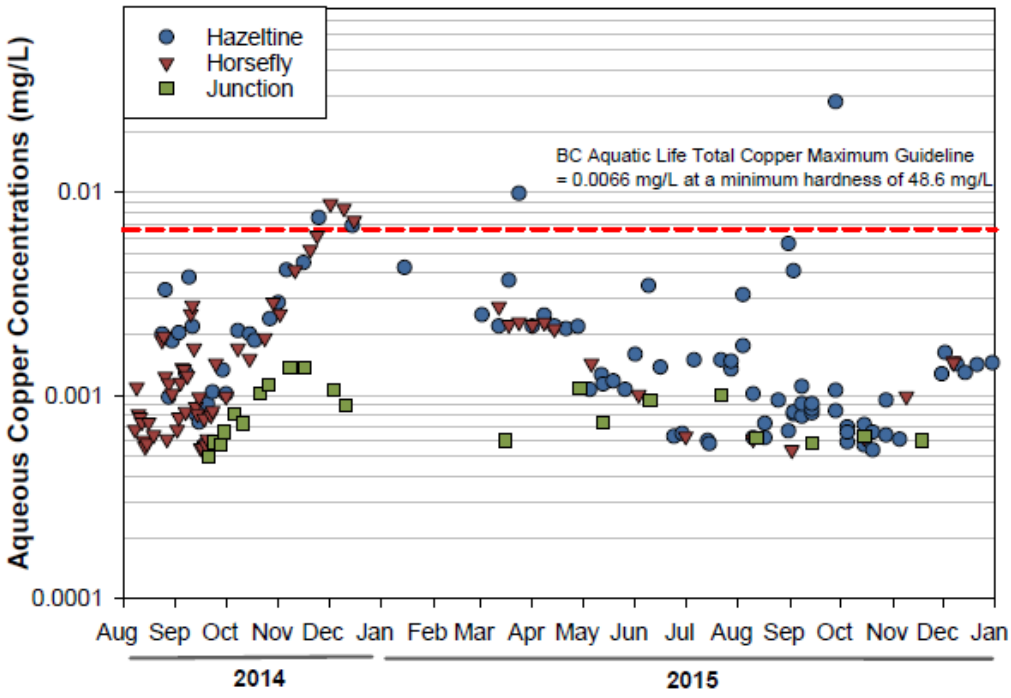


Figure 1: Total and Dissolved Copper Concentrations at Surface and Deep Site in Quesnel Lake, August 2014 to May 2015



Note: Potentially anomalous value observed in Hazeltine in May 2015.

Figure 2: Total Copper Concentrations at Surface Stations in Quesnel Lake, 2014 and 2015

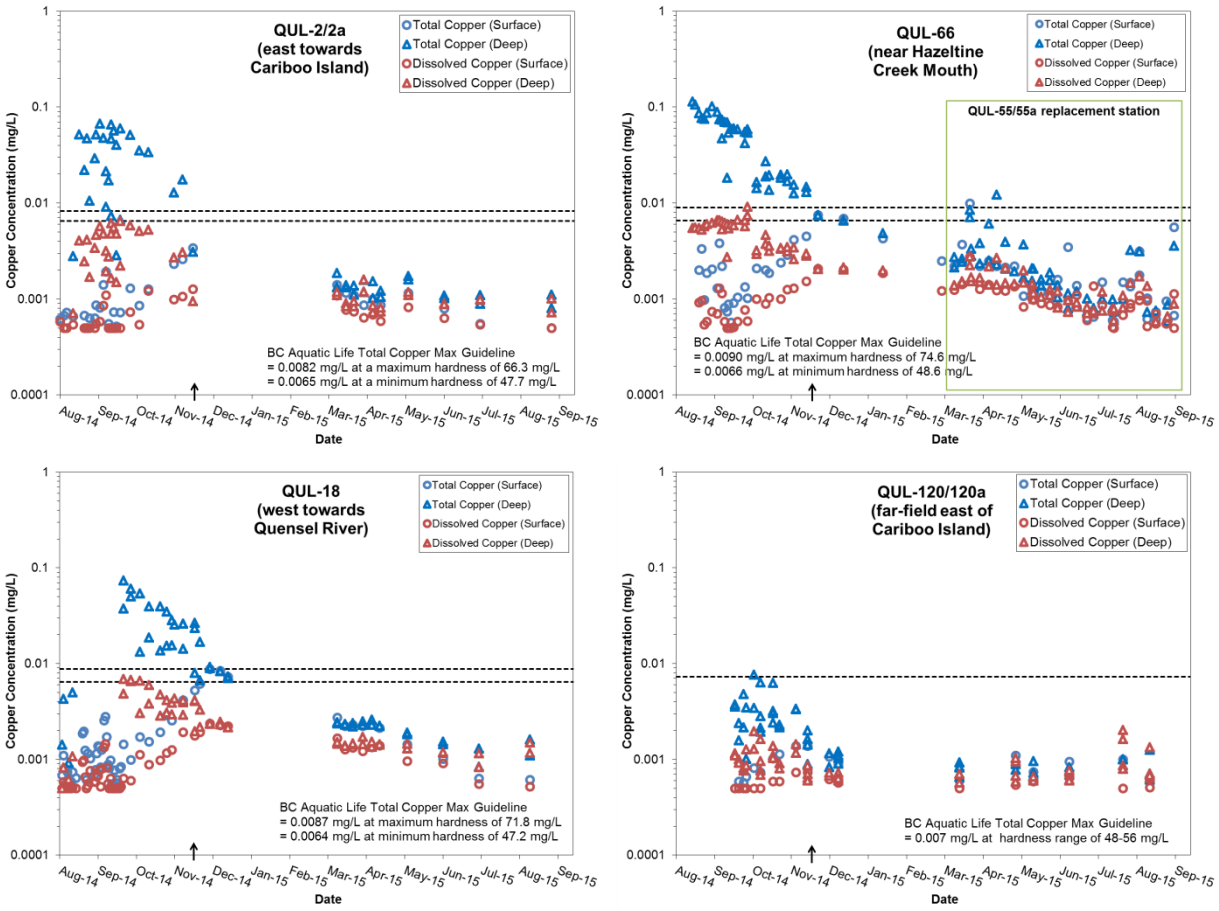


Figure 3: Copper Concentrations at Four Points in Quesnel Lake, August 2014 to September 2015

Note: Arrow represents the approximate timing of mid-November turnover in Quesnel Lake.

3.0 PLANTS AND ALGAE

Eutrophication is a well-known process that results from excessive nutrient inputs, including nitrogen and other macronutrients, but especially phosphorus. Eutrophication leads to green lake colour due to increases in phytoplankton and plant growth, which may give off different shades of green depending on the size and abundance of the phytoplankton, which include microscopic species. Eutrophication also tends to make the surface of the lake turbid, as phytoplankton scatter light.

Quesnel Lake is an oligotrophic system, meaning that phosphorus and phytoplankton concentrations are low. Similar to copper, phosphorus concentrations increased near the mouth of Hazeltine Creek at times in 2015, but elsewhere in the lake the concentrations remained well below guidelines throughout 2015 (Figure 4). This means that the green colour in the lake was likely not related to algae or other biota.

During the evaluation of nutrient concentrations in Quesnel Lake in December 2015, limnologists at the Ministry of Environment (MoE) and primary productivity specialist biologists at Golder were consulted, and they confirmed this interpretation.

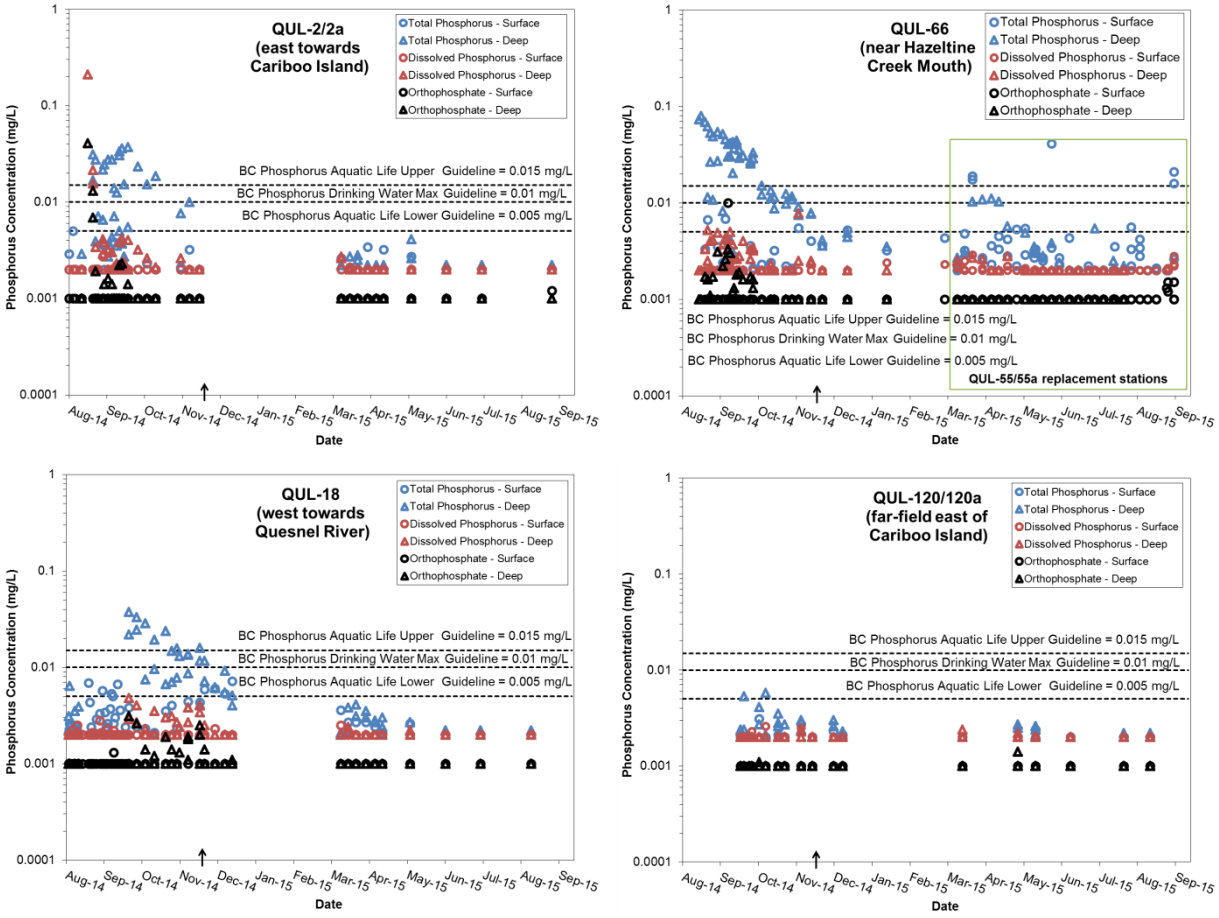


Figure 4: Phosphorus Concentrations in Quesnel Lake, August 2014 to September 2015

Note: Arrow represents the approximate timing of mid-November turnover in Quesnel Lake.

4.0 PHOTO RECORD

Aerial and satellite photographs were examined to determine whether there were discernible changes in colour from year to year or season to season in the past, but the resolution of the photos was insufficient to discern any colour change. GIS techniques were attempted to detect colours but no algorithm detected any difference.

Photos were provided in the MoE memorandum dated 17 December 2015[3]. The MoE has also investigated the green colour; the memorandum provides information in addition to what is listed here.

The MoE memorandum noted the difference in lake colour between fall of 2014 and 2015, which is evident in Photos 1 to 4. In 2014, a temporary glacial green colour was evidently due to suspended tailings material and native till mixture that was deposited in Quesnel Lake and carried downstream during and after fall turnover, coincident with the increases in copper noted above. In the 2015 photos, the water is most green where the evergreen trees are directly reflecting off the lake surface – the outline of the trees is evident around the green section.

[3] BC Ministry of Environment. 2015. Quesnel River at Likely, Green Colour Observations in the late Fall of 2015. 7 December 2015. 7pp.

The MoE memorandum noted that:

- *The 2014 and 2015 photo comparison shows a vast difference in colour and clarity of the water in the Quesnel River. In 2014 the colour was milky green (like glacial water) with limited visibility. In December 2015 the water appears green in the deeper part of the water but clear in the shallow foreshore. While the colour of the Quesnel River was green in late November/December of 2015, it was considerably different from the glacial green appearance of the water in the fall of 2014*

The MoE memorandum also included two photos (Photos 5 and 6) that were taken from the Likely Bridge. The photos show a different shade of green in the two photos, which appears to be due to the angle of the photograph. The lake appears blue in the section where the blue sky is reflecting over the hill. The memorandum notes that turbidity in the lake during this time was “very low”, at 0.5 NTU and remained below water quality guidelines throughout the 2015 fall turnover period.

Quesnel River; take upstream, off the Likely Bridge (one year apart)

Photo 3. Dec 10, 2014 (8.6 NTU)

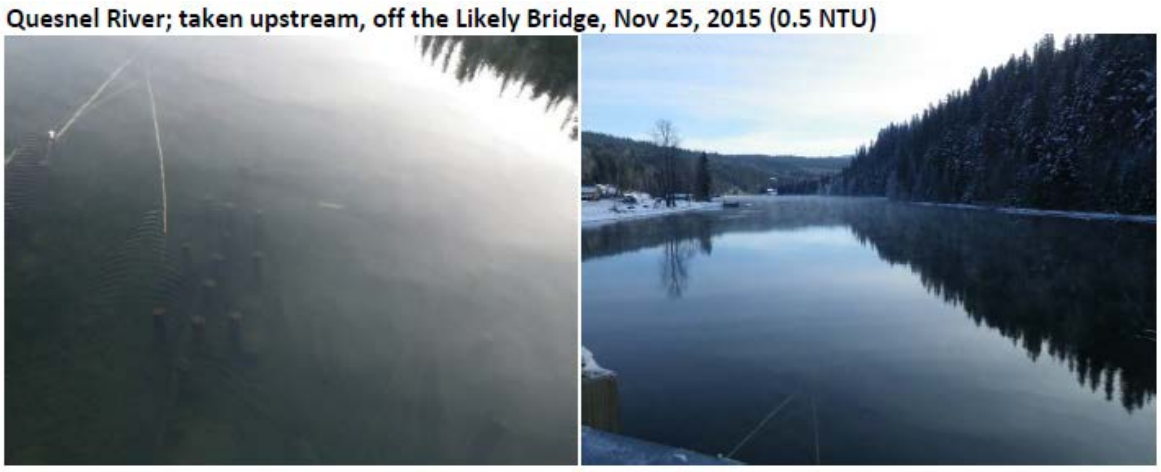
Photo 4. Dec 10, 2015 (0.5 NTU)

Quesnel River across from the Likely dock (one year apart)

Photo 5. Dec 10, 2014 (8.6 NTU)

Photo 6. Dec 10, 2015 (0.5 NTU)

Photos 1 to 4: Green Colour Apparent in Quesnel Lake in 2014 and 2015 (MoE 2015)



Photos 5 and 6: Two Shades of Quesnel Lake in Photos Taken at Different Angles from Same Location (from MoE 2015)

The milky green colour in 2014 corresponded to elevated turbidity readings throughout the West Basin of Quesnel Lake (Figure 5). The turbidity was limited to the deep stations until fall turnover in 2014, which brought turbid waters to the surface and toward Quesnel River. Internal seiches led to both of these phenomena at times between August and December 2014.

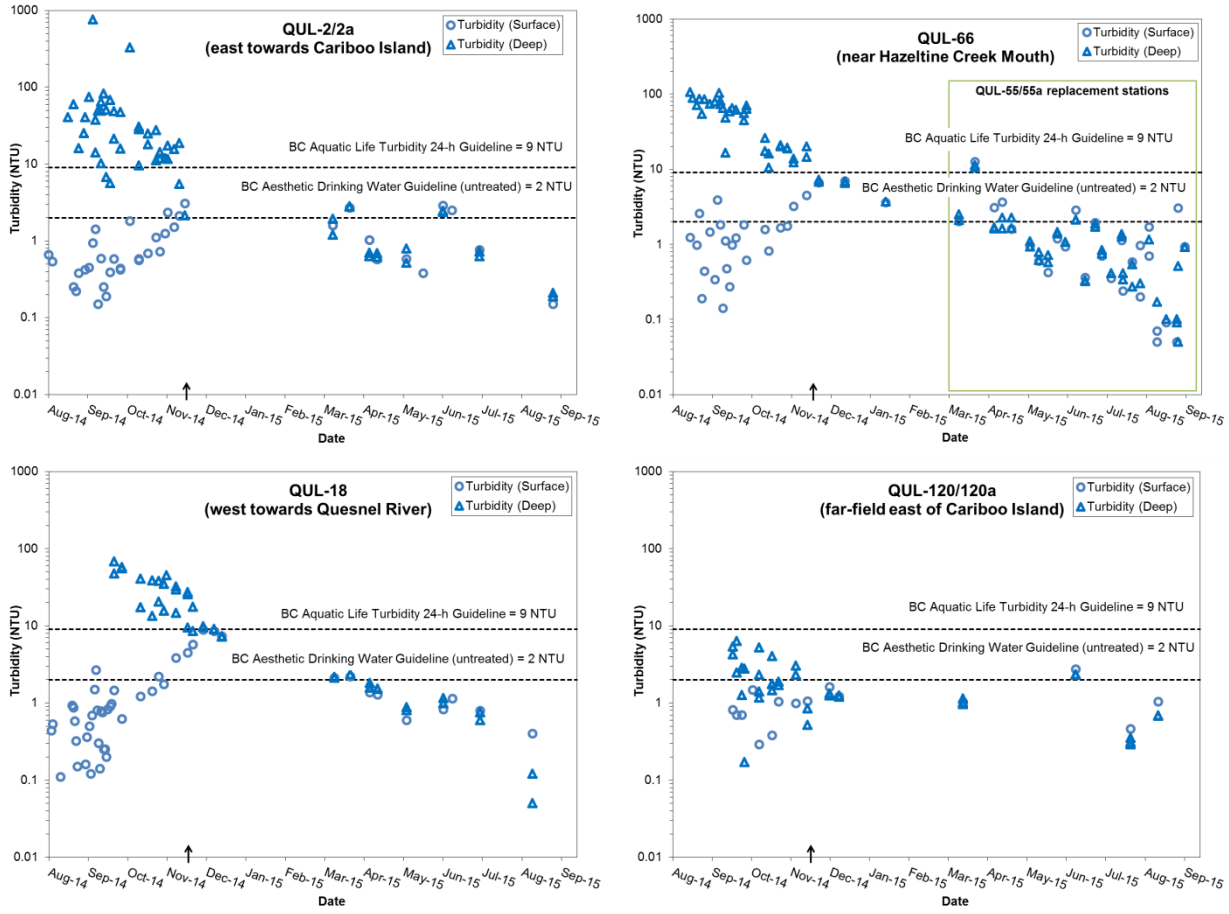


Figure 5: Turbidity Values in Quesnel Lake, August 2014 to September 2015

Note: Arrow represents the approximate timing of mid-November turnover in Quesnel Lake. Background assumed equal to 1 NTU.

The MoE memorandum also provided photographs taken by the Ministry of Transportation before 2014. In the 2013 photograph (Photo 7), Quesnel Lake appears forest green as it reflects off the forest behind.

In summary, the green colour observed in 2015 appears most prominently in areas where it reflects the forest in the background. The green is similar in shade to the lake in 2013 and unlike the milky green that occurred in 2014.

Photo 7: Quesnel Lake near Likely in August 2013 (from MoE memo)

5.0 CHRONOLOGY

Concern around the green colour in Quesnel Lake was recorded in the minutes for the 27 November 2015 Environmental Working Group. The MoE memorandum noted the first mention of this concern as 28 November 2015. This time corresponded with fall turnover in the lake, approximately one year after the first post-breach lake turnover. These stated concerns pre-date the beginning of the discharge to the lake (within the conditions and limits in *Environmental Management Act* Permit 11678) on 1 December 2015. Therefore, it is not possible that the permitted discharge could have caused the green hue.

6.0 HUMAN PERCEPTION

Water colour is an important aesthetic metric for members of the public; not just in BC, but world-wide[4]. In a study of public perception of water colour and clarity of rivers and lakes in New Zealand, researchers posed a series of questions to members of the public who were recreating around rivers and lakes. Not surprisingly, respondents favoured clear, blue water over a green hue, and green over yellow or brown. Waters were thought to be suitable for bathing and aesthetics if they exceeded 30 on the Munsell colour scale – this includes blue, blue-green, green, and green-yellow. Yellow and brown waters were only rated as suitable when the respondents knew that the yellow or brown was caused by natural factors such as humic acids.

[4] Smit et al. 1995. Human perception of water appearance. 1. Clarity and colour for bathing and aesthetics. New Zealand Journal of Marine and Freshwater Research. 29: 29-43.

7.0 CONCLUSIONS

Multiple lines of evidence support the hypothesis that Quesnel Lake has appeared green at times before 2014 but that the green hue was never noticed before the breach. Perceptions became more heightened after the breach, and the green colour was noticed more frequently than before. In the past year, the internal green colour of the lake has not changed, which means that the factors controlling light are external to the lake (e.g., reflection, cloud cover, sun angle, viewer angle, background). The green colour observed in 2015 was similar in hue to pre-2014 water.

At no time since 1 December 2015 has the Mine released any quantity of any substance that would be likely to impart a green colour on the lake. Frequent monitoring throughout the lake has confirmed that concentrations of substances that could cause a green hue are low in Quesnel Lake. The proposed discharge will also not release sufficient quantities of any substance that would impart a green colour on the lake, which can be confirmed by ongoing monitoring.

8.0 CLOSURE

The reader is referred to the Study Limitations, which follows the text and forms an integral part of this memorandum.

We trust the above meets your present requirements. If you have any questions or requirements, please contact the undersigned.

GOLDER ASSOCIATES LTD.

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Attachment: Study Limitation

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