Analysis of 2018-2020 water inflow data to Lake Hayes from Hayes Creek, and comparison to 1983/84 data from Robertson

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Summary

Using data obtained over the period March 2018 – December 2020 by FoLH and the ORC monitoring station on Mill Creek at the entrance to Lake Hayes, we establish a strong correlation between water flow rates, turbidity, solid particle and total phosphorous (TP) levels.

The relations were used to estimate that, in 2020, 2.1tonnes of phosphorous and 1.76 kilotonnes of solids flowed into to Lake Hayes via Mill Creek.

Comparison with Robertson (1984), reveals that the mean phosphorous concentration in the Mill Creek water has increased by 42% from 0.096mg/L in Robertson (1984) to 0.136mg/L in 2020. Over the same period the solid concentration in the Mill Creek water has increased by 250%; from 45.7mg/L in 1983/84 to 115mg/L in 2020.

Despite an unusually wet 12 months, Robertson (1984) recorded only 1.01ktonnes of solid arriving at the lake via Mill Creek over the 12-month study, half the amount that arrived in 2020. If 2020 had been as wet as the period that Robertson (1984) studied, the 3.0 tonnes of phosphorous would have flowed into the lake last year and 2.5 kilotonnes of solids.

Although limited by a much reduced data-set (23 data points over 2 years), there is evidence to suggest that the *e coli* levels arriving at Lake Hayes in Mill Creek could have exceeded a level of 250 MPU/100ml for more than 50% of the "warm water" months (December-April) during 2018/19 and 2019/20. In addition, irrespective of time of year, in five of the six cases where the water flow rate exceeded 0.5 cumecs, the *e coli* rate was 1000MPU/100ml or greater (the exception being a reading of 130MPU/100ml) two days after a flood peak.

While further work would need to be done on any "break point" in water flow rate which carried with it seriously high levels of *e coli* into the lake, taken at face value this limited data set would indicate that it is close to 0.5cumec. The water flow rate on Mill Creek at the entrance to Lake Hayes exceeded this value 32.7% of the time in 2020. This suggests that there is a potentially a major risk to public health which requires, at a minimum further investigation.

Overall the results from this analysis are bleak for Lake Hayes. Between studies in 1983/84 and 2018-20, the total phosphorous/cubic metre into the lake has increased by 40%, solids by a factor 2, and further there is evidence to suggest that, for 33% of the year, the water inflows to the lake could levels of e coli which could be hazardous to human health.

Total Phosphorous and Solids

We have drawn on data samples taken by FoLH (analysed by Hill Laboratories) [hereinafter FoLH data] and from the hourly records of turbidity and water flow from ORC water quality station at the FishTrap [hereinafter ORC data] on Mill Creek close to the entrance of Lake Hayes. Jun 2019

The FoLH data was drawn from 58 samples over the period Mar 2018 – Jun 2019

In addition, we used the hourly flow data from the water meter at Hunter Road, to assess the likely contribution of material from the north/west of high road (ie the catchment directly under Coronet Peak) to the inflows.

We first established correlation between water flow and turbidity in the FoLH data based on 12 samples taken over a range in flow (see figure 1 below)

We used this correlation to correct the erroneous Turbidity readings and flows greater than 2 cumecs in the other

excellent ORC data set (see figure 2 below with reproduces the data from the Sep 2018 – Dec 2020 hourly ORC data for water flow and turbidity).

The turbidity (NTU) readings (negative values) clearly breakdown in high flow rates. While the "breakdown" point is somewhat arbitrary, we choose 2cumecs as the point at which we replace the ORC turbidity readings with corrected turbidity reading based on the contemporaneous ORC water flow reading using the relation derived in figure 1. We also correct the small number of negative values in the data at low flow rates (below 0.5cumec) in the same way. Note that the relation used actually tracks the lower boundary of the relationship below 2cumecs in the ORC data above, so it represents a conservative extrapolation. Corrected turbidity values for 2020 are shown in the Annex. Note that the corrected NTU value exceeded the guidelines for clean water of 5NTU for 8544 out of 8596 samples (99.3%) in 2020. Even the remaining 0.7% are in doubt, because they all occurred close to the negative values recorded at low flow rates.

Using the FoLH data we also established robust relationships between turbidity and TP/solids as shown in the next two figures:

With these relations established, coupled with the ORC hourly water-flow and turbidity readings (corrected above 2cumecs), to estimate TP and solid arriving at the lake.

We integrated over the calendar year 2020, arriving at a total phosphorous load of 2.09 tonnes arriving at Lake Hayes from Mill Creek in 2020, and 1.76 kilotonnes of solids. The mean TP and solid concentrations in the water are 0.137mg/L and 115mg/L respectively, based on an annual water inflow of 15.3M cubic metres. The derived P/solid ratio is 0.0o119.

Applying the same relation for TP to the hourly water flow data from the ORC Hunter Road/Mill Creek meter over the period for which we have data (1 Jan 2020 – 22 July 2020) suggests that the TP contribution from above Hunter Road

amounts to 139kg, compared to 1328kg for the Fish Trap site i.e. that loading from above Hunter Road only accounts for 10% of the TP entering Lake Hayes from Mill Creek.

We compared our results with those of Robertson (1984) who also measured water inflow, TP and solids.

The Robertson (1984) data on TP and solids is shown in the figure below.

Robertson (1984) also provided information on total water inflow and mean TP for the 12-month study. Using this information and the correlation derived above we can make the following direct comparison between our analysis of 2020 data and the results of Robertson (1984) study in 1983/84.

Inflow via Mill Creek	This study (2020)	Robertson (1984)
Water inflow (cumec)	1.53E+07	2.20E+07
Phosphorus (tonnes)	2.09E+00	2.11E+00
Solids (tonnes)	1.76E+03	1.01E+03
TP (mg/L)	1.36E-01	9.60E-02
Solid concentration (mg/L)	1.15E+02	4.57E+01
P/solid ratio	1.19E-03	2.10E-03

Over the period between these studies, the TP in the Mill Creek water has increased by 40%, and the concentration of total solids have increased by a factor of 2.5. We note that the Robertson (1983) study was conducted over an unusually wet year, so the TP and solids entering the lake are higher than they might other have been during a more normal year. Indeed, if 2020 has been as wet as the period over which Robertson (1984) conducted his study, 3.0 tonnes of phosphorous and 2.54 kilotonnes of solids would have flowed into Lake Hayes via Mill Creek.

For comparison, a study based on data obtained at the Fish Trap site in by Caruso (2000) noted a mean TP of 0.065mg/L and an annual phosphorous load of 395kg. This is approximately half the TP found in this study, and about 40% lower than in the study of Robertson (1984) Caruso also reports that it is low compared to NIWA data obtained in 1994-95 or 0.173 mg/L.

Caruso (2000) derived an annual phosphorous load into the lake from Mill Creek substantially lower (a factor 4-5) than either this study or Robertson (1984). This was driven in part

by the lower TP, but also lower annual total volume of water (12.7Mcumec) and (potentially) the number and characteristics of flood events during the year.

For reference, the total annual water .7.flow into Lake Hayes recorded at the Fish Trap site from 2000 to 2020 is presented in the Annex.

E coli

During to challenges in timely dispatch/measurement of samples, the data on *e coli* is much more fragmentary. The entire sample is based on 23 samples taken between March 2018 and July 2019.

We first show the samples taken during times of average-low flow on Mill Creek at Lake Hayes.

This shows an apparent yearly variation, due most likely to water temperature.

During Dec-Apr months in 2019 and 2019 *e coli* exceeded 200MPN for over half (5/9) of measurements taken and were at or exceeded 150MPN/100ml for two-thirds of the measurements taken.

We choose to separate the data at water flow rates, based there is a marked change in results about 0.5cumec. Although only, based on 5 data points, every *e coli* measurement in this water flow regime is elevated (greater than 100 MPN/100ml), particularly considering the time of year (April, May, June and July).

Four of the five points display extremely high values of *e coli* (greater than or equal to 1000MTU/100ml). The exception being the data taken one day after the major flood event in July 2020, which itself had approximately ten times the mean value for the time of year.

From this data, it appears that there is evidence to suggest:

1) For over half warm water months (Dec-Apr), *e coli* may exceed the safe limit.
2) *e coli* far exceeded the safe limit during times of high flow. Based on the data currently available, this rate appears to begin at around 0.5cumecs, a value which was exceeded 33% of the time based on the ORC water flow data. Further work would need to determine when the "high flow" break point for large *e coli* numbers actually occurs - e.g. a flow rate of 1cumec is only exceeded 2% of the time. Nevertheless, the two samples taken when the creek was flowing at 0.5-0.6cumecs both returned an *e coli* measurement of over 1000MPN/100ml.

At the very least this data would suggest that e coli inflows to Lake Hayes from Mill Creek potentially pose a public health risk which warrants further investigation.

Annex