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MEMORANDUM

Date: 8 June 2020

From: Dr Greg Burrell and Megan Brown (Instream)

To: Katie Noakes (Waterways Ecologist, CCC)

CC: Dr Belinda Margetts (Principal Waterways Ecologist, CCC)

Subject: **Turbidity Logger Comparison Following Field Deployment**

1. INTRODUCTION

Turbidity loggers measure and record turbidity over time and they are therefore useful water quality monitoring tools in rivers. However, laboratory tests have shown considerable variation between different makes and models of turbidity sensors (Hughes et al. 2019). Christchurch City Council (CCC) owns four turbidity loggers: two Observator Analite NEP495 loggers and two YSI EXO3 multiparameter probe loggers. All four loggers have been deployed in the Ōpāwaho / Heathcote River at various times over the last two years, primarily associated with a dredging project in the river's tidal reaches. More recently, the CCC Land Drainage team deployed two telemetered Observator Analite NEP5000 loggers to monitor dredging impacts. In addition, Environment Canterbury (ECan) also has a telemetered NEP5000 logger permanently deployed near Buxton Terrace. Preliminary analysis of data from the different loggers suggested they were recording data differently, so CCC commissioned Instream Consulting to compare results of the three different logger models deployed in the river.

This memorandum compares turbidity data collected from the three different logger models deployed in the Ōpāwaho / Heathcote River. Further advice regarding turbidity monitoring is found in the turbidity recording document that forms part of the National Environmental Monitoring Standards (NEMS 2017).

2. METHODS

The three different turbidity loggers being compared here are:

- Observator Analite NEP495 – owned by CCC
- Observator Analite NEP5000 – owned by ECan
- YSI EXO3 multiparameter probe – owned by CCC.

The ECan NEP5000 logger is permanently deployed at the bridge near Buxton Terrace (Figure 1, Figure 2) and the two CCC loggers were temporarily deployed nearby. The CCC loggers were attached to two warratahs driven into the bed near the true left (west) bank, and the loggers were positioned so that they were horizontal, at an approximately 45 degree angle to the bank, with the sensor end pointing downstream. Loggers were fastened to each waratah with plastic cable ties. To provide additional security, each logger had a safety chain attached to a separate waratah driven into the bank, with each end of the chain secured with shackles (previous experience has shown the value of having a safety chain backup). The NEP495 loggers were deployed with and without a bespoke protective cover made of PVC pipe, while the EXO3 logger was deployed with the factory-provided protective cover throughout the monitoring period (Figure 3 and Figure 4).

Figure 1: Location of turbidity loggers.

The NEP495 and EXO3 loggers were calibrated prior to deployment using three-point calibration, with the turbidity standards ranging from 0 up to 1,000 NTU for the NEP495 and 1,010 FNU for the EXO3. This calibration range was considered appropriate for measuring the range of expected turbidity values in the Ōpāwaho / Heathcote River. The ECan-owned NEP5000 logger was also calibrated prior to deployment using three-point calibration for the turbidity range typically encountered in the river (pers comm. Rachel Herbert, ECan).

The CCC logger deployments were timed to coincide with forecast rainfall, in anticipation of increased turbidity, and they were set to log at 15-minute intervals. Downloaded data were compared graphically and plotted against water level data provided by ECan for the Buxton Terrace flow recorder. Summary statistics were compared for each logger during each data logging period. In addition to computing median, minimum, and maximum turbidity statistics, we also calculated the percentage of observations exceeding 5 and 20 NTU / FNU. These turbidity values were chosen as relatively low and moderately high turbidity triggers, based on literature values (Quinn et al. 1992; Rowe & Dean 1998; Rowe et al. 2000).

Figure 2: Footbridge near 219 Eastern Terrace where the turbidity loggers were deployed.

Figure 3: NEP495 (upper) and EXO3 logger (lower), both in their deployed state with protective covers on.

Figure 4: As per figure above, but with the protective covers removed.

3. RESULTS AND DISCUSSION

3.1. Overall, how do results from the different loggers compare?

All three loggers followed a similar pattern of increased turbidity associated with periods of increased river flow and water level (Figure 5). Data from the EXO3 and NEP5000 loggers tracked closely together, whereas turbidity readings from the NEP495 dropped faster following the turbidity peak. In addition, the two NEP loggers showed considerably more variability in turbidity readings than the EXO3 logger (Figure 6). For example, over a 24 hour period on 15 November 2019, mean turbidity readings for the NEP495, NEP500, and EXO3 were 19.1 NTU, 25.7 NTU, and 18.0 FNU, respectively, and on average, turbidity readings varied from one reading to the next by 5.3 NTU, 2.9 NTU, and 0.9 FNU, respectively. The fluctuations recorded by the two NEP loggers are too large and erratic to reflect actual variations in river turbidity. Potential causes of this variability are discussed further in Section 3.2 below.

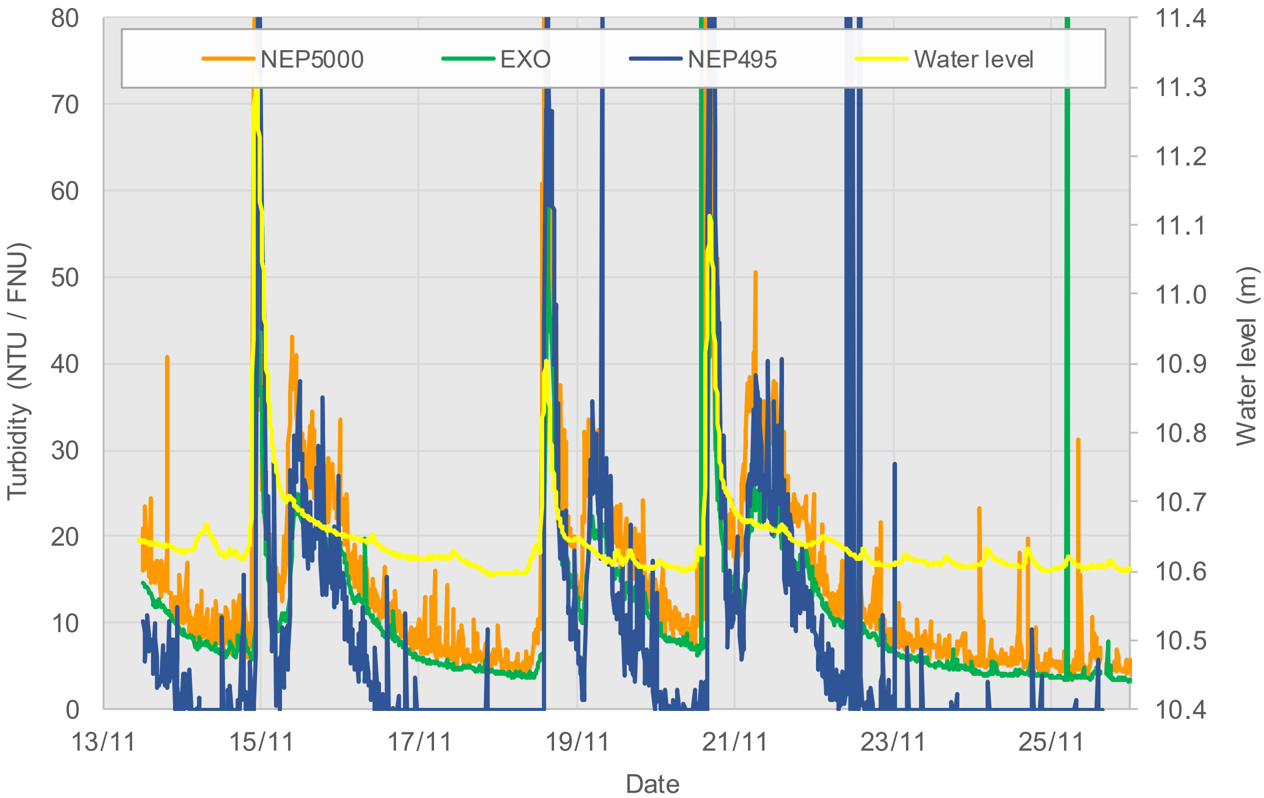

Figure 5: Comparison of the three turbidity logger models over several rain events, indicated by increased water levels. The vertical axis has been truncated, to allow easier comparison of turbidity readings. The NEP495 data shown are for the logger with a protective cover attached.

As turbidity levels dropped below around 20 NTU, turbidity readings dropped more rapidly for the NEP495 logger than for the other two models. When the NEP5000 and EXO3 loggers were recording below approximately 8 NTU/FNU, the NEP495 logger returned turbidity readings of zero, which appear unrealistically low (Figure 5 and Figure 6). This is a pattern we had observed in previous deployments of the NEP495.

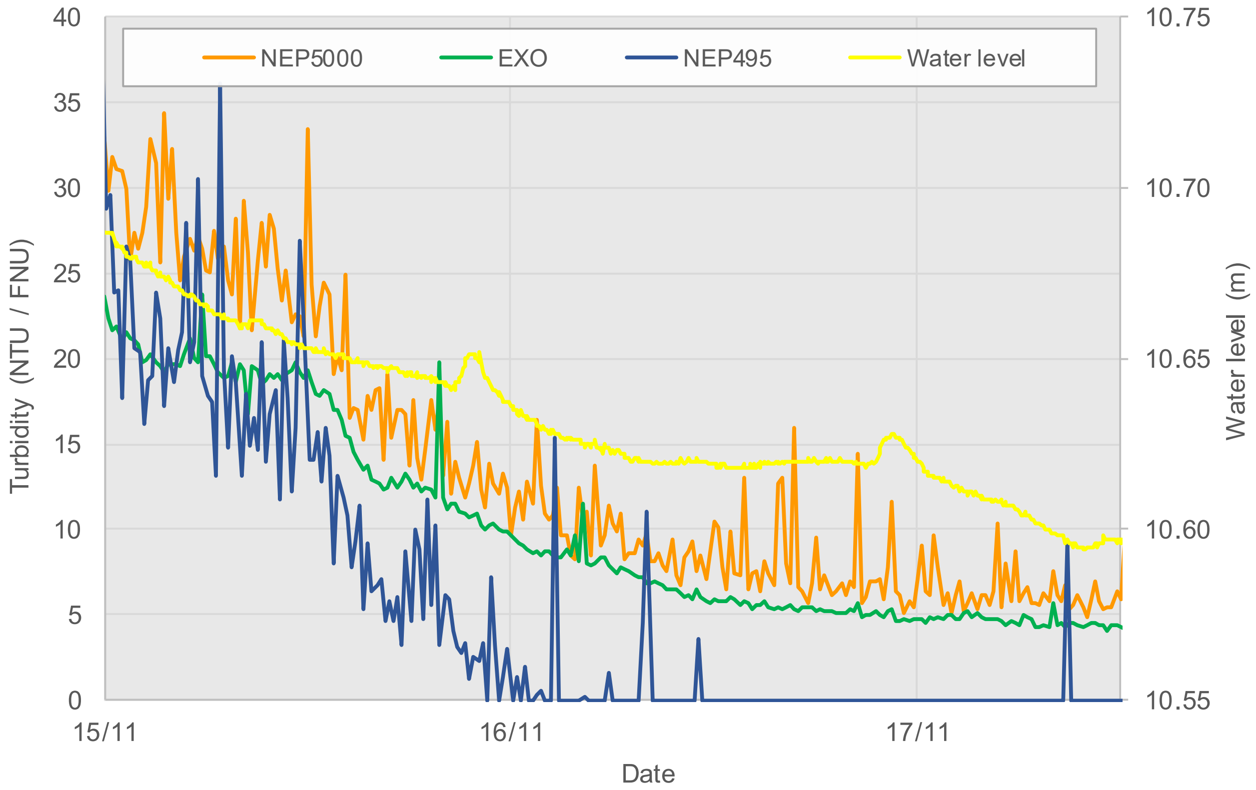

Figure 6: As per the previous figure, but focussing on a shorter period of time and lower turbidity levels, to highlight fluctuations in turbidity readings in the two NEP logger models compared to the EXO3 logger.

3.2. Why is there variation amongst the different loggers?

A recent study by Hughes et al. (2019) found considerable variation in results from different turbidity loggers under laboratory conditions. Their study included the NEP5000 and the YSI EXO1, an earlier model of the EXO3 used in our study. In their study, Hughes et al. (2019) concluded that *"…even very subtle differences (e.g., different tolerances used in the manufacture of components) in sensor design can influence sensor response"*, resulting in substantial differences in the results recorded between different turbidity sensors. Their laboratory findings explain at least some of the variability between turbidity loggers compared in our study.

Key potential additional sources of turbidity variation in the field include logger placement and sensor fouling. All three loggers in this study were in close proximity, so their position in the river was an unlikely source of measurement error. The EXO3 user manual recommends deploying the logger vertically, to avoid stagnation if left unattended for long periods of time (Xylem 2020). The manual notes that inherent risks with horizontal logger placement include sediment build up and flooding events. Potential issues with horizontal logger placement were mitigated during this relatively short term study through regular checks of the loggers, ensuring they were placed in sufficient current to avoid sediment build up or stagnation, and avoiding deployment during major flood events.

We were concerned that the bespoke cover for the NEP495 loggers may have affected readings, so we compared two NEP495 loggers beside each other, one with and one without the cover attached. Figure 7 shows that the protective cover on the NEP495 in fact reduced turbidity fluctuations compared to the uncovered sensor, which was affected by long strands of filamentous algae growing up from the riverbed and wafting over the sensor. This macro-fouling of the uncovered sensor was identified during a site visit and the filamentous algae removed, which immediately reduced the large turbidity fluctuations (Figure 7).

The smaller range of turbidity fluctuations observed with the NEP495 and NEP5000 loggers could have been caused by biofouling (biofilms growing on the sensor surface) or simply measurement errors. Turbidity fluctuations were evident from the time of logger deployment for the NEP495 logger, so biofouling was unlikely to be the cause. In addition, all three logger types are equipped with sensor wipers to help prevent biofilm growth. Differences in measurement error between loggers may be caused by differences in their optical properties, their physical structure, or by the type of software they use to capture and process the data. Regardless of the cause, small turbidity fluctuations can be edited out of a dataset by applying a smoothing function or numerical filter, as discussed in the NEMS turbidity document (NEMS 2017). However, no form of data correction can be applied in the situation where a logger returns zeros across a range of low turbidity readings, as was the case for the NEP495 loggers in this study.

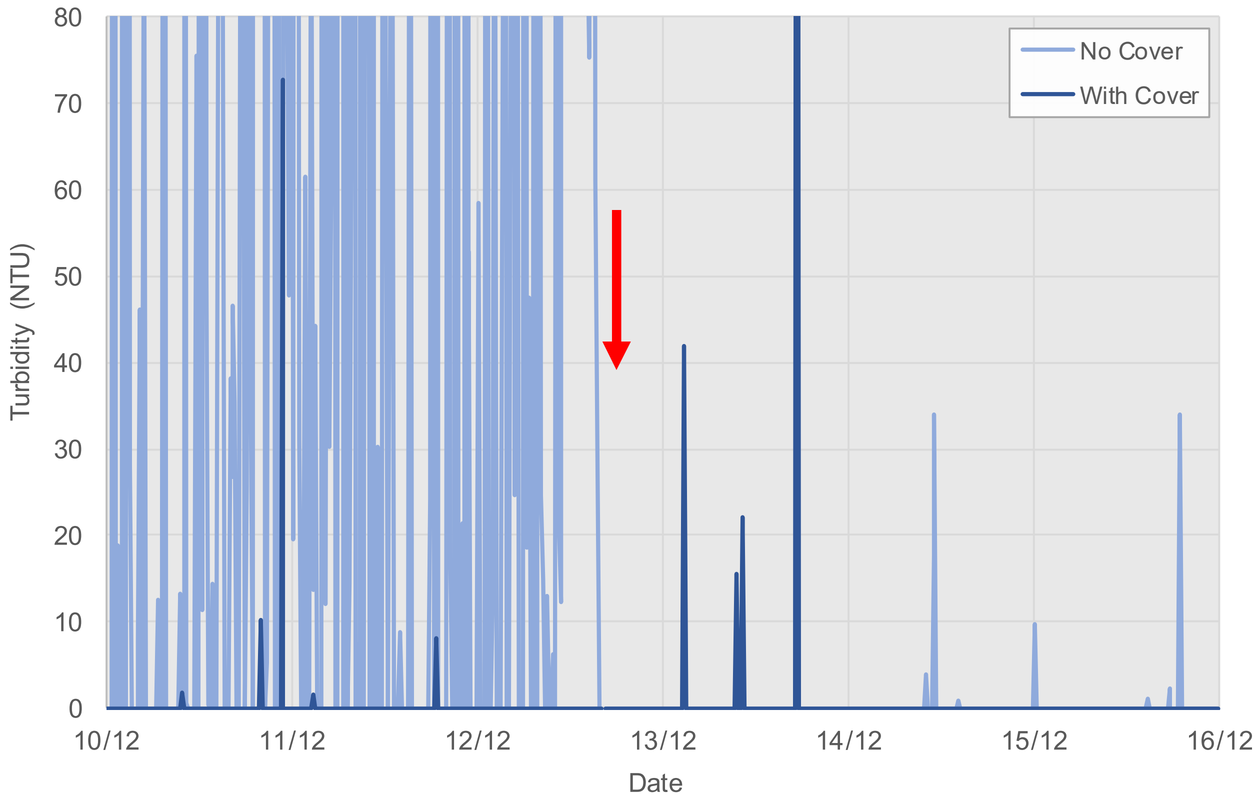

Figure 7: Impacts of fouling from filamentous algae on NEP495 loggers deployed with and without a protective cover. The red arrow indicates when the filamentous algae issue was identified and cleared. The vertical axis has been truncated, to allow easier comparison of turbidity readings.

3.3. How do compliance statistics compare?

Turbidity loggers can be used to generate statistics for comparison against various environmental guidelines or standards. When comparing results from the different loggers deployed over three separate time periods (Table 1), there are some clear patterns:

- Without the protective cover, the NEP495 logger recorded higher maximum values than with the cover on, for each of the three monitoring periods.
- Fouling from filamentous algae during the “no rain” period resulted in a much higher percentage of readings exceeding 5 or 20 NTU for the NEP495 logger with no cover.
- The NEP495 results consistently over-reported low levels of turbidity, indicated by a low percentage of observations exceeding 5 NTU compared to the other loggers.
- Median, minimum, and maximum and percent exceedance statistics for the NEP5000 and EXO3 loggers were of a similar order of magnitude. However, they differed too greatly to be comparable for compliance purposes without some form of correction to the underlying data.

Table 1: Summary statistics for turbidity loggers deployed under different conditions. Turbidity units are NTU for NEP495 and NEP5000, and FNU for EXO3. Percent is the percent of readings exceeding a given turbidity.

Logger Model & Weather Conditions	Median	Min	Max	Percent over 5 NTU / FNU	Percent over 20 NTU / FNU
No Rain					
25/11/19 to 12/12/19					
NEP495 - Cover	0.0	0.0	73	2	0
NEP495 - No Cover	5.1	0.0	2031	50	41
EXO3	3.0	2.0	242	8	1
NEP5000	4.1	2.2	111	28	1
One rain event					
12/12/2019 to 19/12/19					
NEP495 - Cover	0.0	0.0	334	24	14
NEP495 - No Cover	0.0	0.0	1236	22	14
EXO3	2.5	2.0	263	30	10
NEP5000	3.6	2.2	122	35	17
Multiple rain events					
13/11/19 to 25/11/19					
NEP495 - Cover	0.2	0.0	846	37	15
NEP495 - No Cover	3.3	0.0	1740	44	19
EXO3	8.3	3.3	211	76	12
NEP5000	11.3	3.6	105	95	26

3.4. Can the data be adjusted, so they are more comparable?

As noted above, differences between turbidity sensors are common and data transformations can often be applied to the data, to directly compare results from different loggers. Multiplying NEP5000 data by 0.75 or the EXO3 data by 1.3 resulted in results that were directly comparable, although fluctuations were still evident in the NEP5000 data (Figure 8 and Figure 9). No correction could be usefully applied to the NEP495 data. That is because the NEP495 logger recorded excessively high turbidity values and because it under-estimated low turbidity levels.

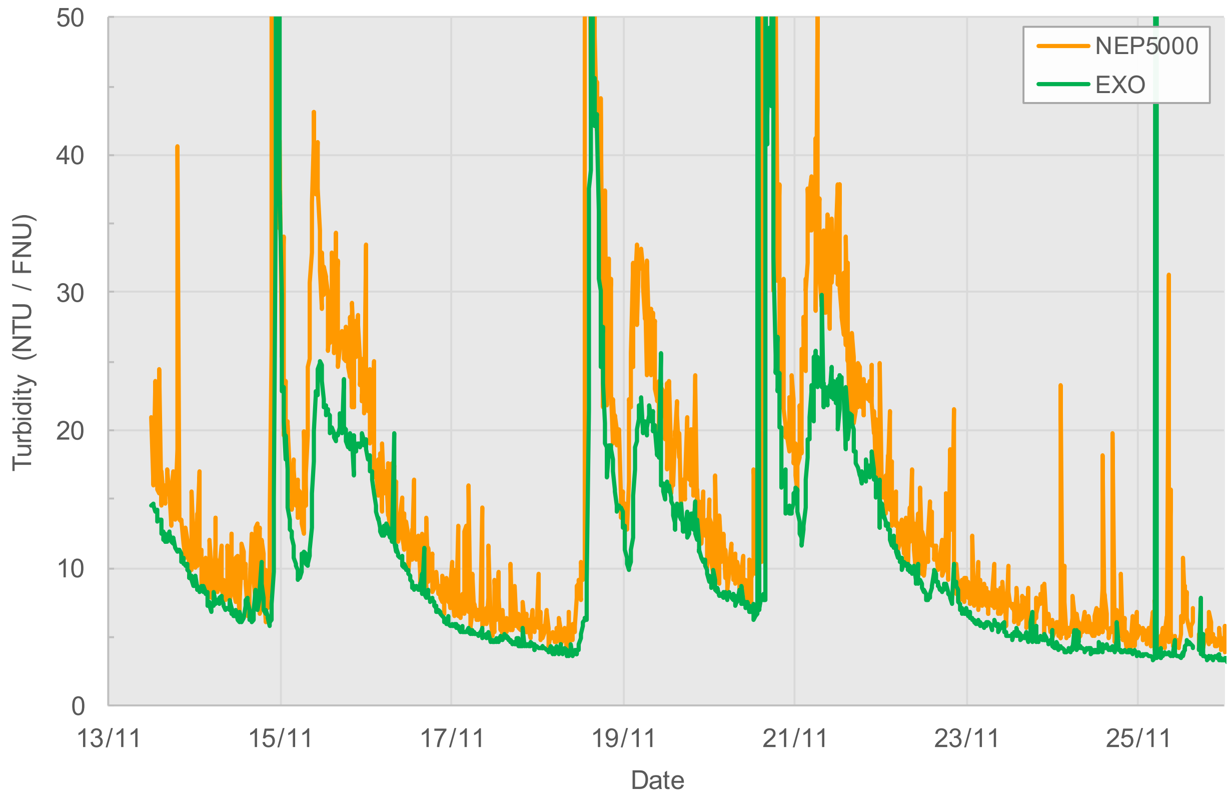

Figure 8: The NEP5000 logger consistently recorded higher and more variable turbidity than the EXO3 logger. The vertical axis has been truncated, to allow easier comparison of turbidity readings.

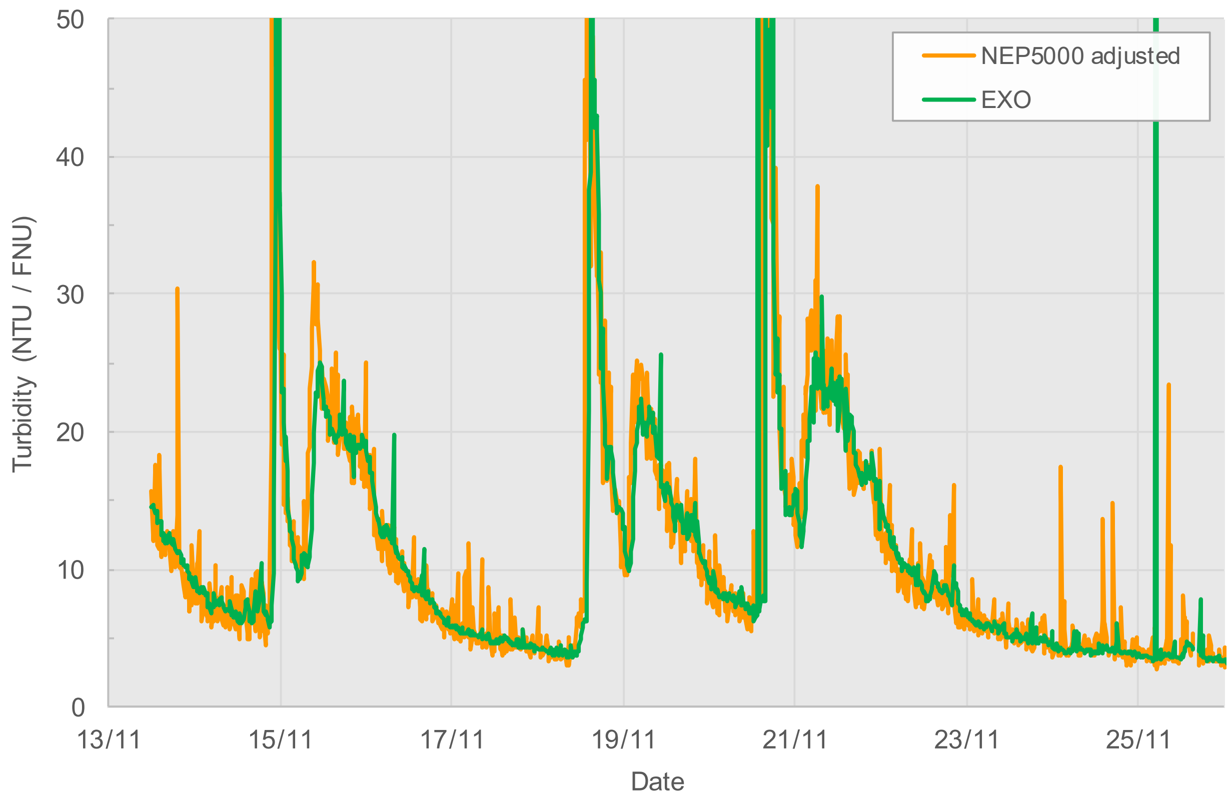

Figure 9: The same plot as above, but with the NEP5000 data adjusted by a factor of 0.75.

3.5. In what situations should the different loggers be used?

All three of the loggers compared are suitable for monitoring turbidity, provided they are appropriately maintained and calibrated, and provided their limitations are understood by the user. It is always preferable to use the same model of turbidity logger when comparing turbidity upstream and downstream of an activity, so that there is at least a consistent measurement bias for both instruments. If using the same model of turbidity logger is not possible, then readings from one or both the loggers will likely need to be adjusted so they are more directly comparable.

We recommend CCC considers the following paragraphs when deciding which logger is appropriate to use for a given situation.

Observator Analite NEP495

This logger would be best suited to monitoring potentially large impacts of activities on turbidity. That is because both the NEP495 loggers we tested consistently under-reported turbidity readings below around 20 NTU and frequently reported values of zero when the other loggers were recording between 0 and 8 NTU. An example where this logger might prove useful would be for preliminary investigations into impacts of weed clearance activities on turbidity. In such a situation, the goal would be to obtain preliminary data to determine whether there is a potential issue with high turbidity that is worthy of further investigation. Using the logger for compliance purposes is not recommended, given its lack of accuracy at lower turbidity levels. The logger should always be deployed with some form of protective cover, to avoid impacts of fouling on turbidity measurements.

Observator Analite NEP5000

This logger was suitable for measuring turbidity over the range of values typically expected in Christchurch rivers. Although it showed greater turbidity fluctuations than the EXO3, these fluctuations were overall relatively small and they could be removed during post-processing of the data. The data were easily adjusted to allow direct comparison with the EXO3 logger. The NEP5000 loggers currently deployed by CCC in the Ōpawaho / Heathcote River provide sufficiently robust data for monitoring dredging impacts on turbidity.

YSI EXO3 Multiparameter Probe

This logger is suitable for accurately measuring turbidity over a wide range of values and it can also be used to measure other parameters, such as dissolved oxygen. Turbidity readings from the EXO3 fluctuated less than the other loggers we tested and it was less prone to recording random turbidity spikes. The data were easily adjusted to allow direct comparison with the NEP5000 logger. The combination of turbidity and dissolved oxygen logging abilities could be used to monitor impacts of activities that affect both water quality parameters, such as sediment removal in small streams or groundwater dewatering discharges.

4. REFERENCES

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