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NEW WEB-BASED TOOL FOR CHARACTERIZATION OF HISTORIC VARIATION IN WATER QUALITY STATE AND ASSESSING MAINTENANCE OF CURRENT STATE

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An important requirement of the National Policy Statement for Freshwater Management (NPS-FM) is that regional councils (RCs) must ensure that water quality must be 'maintained' (where outcomes are being meet) or 'improved' (where degraded) in all waterways.[1]

The NPS-FM defines 'maintain or improve' relative to a "baseline state". The baseline state is defined as the best water quality of:

1) the state on the date a regional council set a freshwater objective, or
2) the state on 7 September 2017

In New Zealand, almost invariably the current state of water quality is defined as the median of 5-years' worth of monthly grab-sampling data. This is generally regarded as a good compromise between robustness (i.e., 'averaging' temporal variation) and a contemporary (i.e., relevant) assessment period. Based on this '5-year' standard, the baseline standard would be taken as the 5 years of data prior to setting freshwater objective, or the 5 years prior to September 2017.[2]

While this sounds relatively straightforward, importantly, the NPS-FM states that the "baseline state may be expressed in a way that accounts for natural variability".[3] Natural variability caused by climate cycles / oscillations have been shown to contribute significantly to water quality trends (Snelder et al. 2022a). Snelder et al. (2021b) developed models that related observed water quality trends (over different time durations) to climate variation (i.e., the Southern Oscillation Index, SOI) and mean (and changes) of productive land use in catchments. What the authors found was that across 10-year windows, land use signals were generally swamped by the greater influence of climate variation.

This finding by Snelder et al. (2021) and others, has implications for freshwater water management in NZ. For example, in regional council plans, water quality state is typically defined as a precise value, often reported to two (or even three) decimal places, which fails to account for natural variation. For example, using the total nitrogen (TN) concentration time-series for the Waikato River site at Huntly (Waikato@Huntly), the 5-year moving median

[1] Given the requirements to grade the state of sites, in my opinion the ability to assess whether water quality has or has not been maintained (relative to a baseline state) is largely limited to monitored water quality sites. It is, therefore, important that regional councils has monitoring networks that adequately reflect/represent receiving water environments and anthropogenic pressures in the region.

[2] Generally water quality state is determined using calendar years (Jan to Dec), hence presumably this would be interpreted as using monthly data for the years 2013-2017 (inclusive).

[3] Clause 3.10(4) of the NPS-FM (2020).

(black line, Figure 1) shows marked variability, ranging from 0.6 to 0.7 mg/L over the 15-year period.

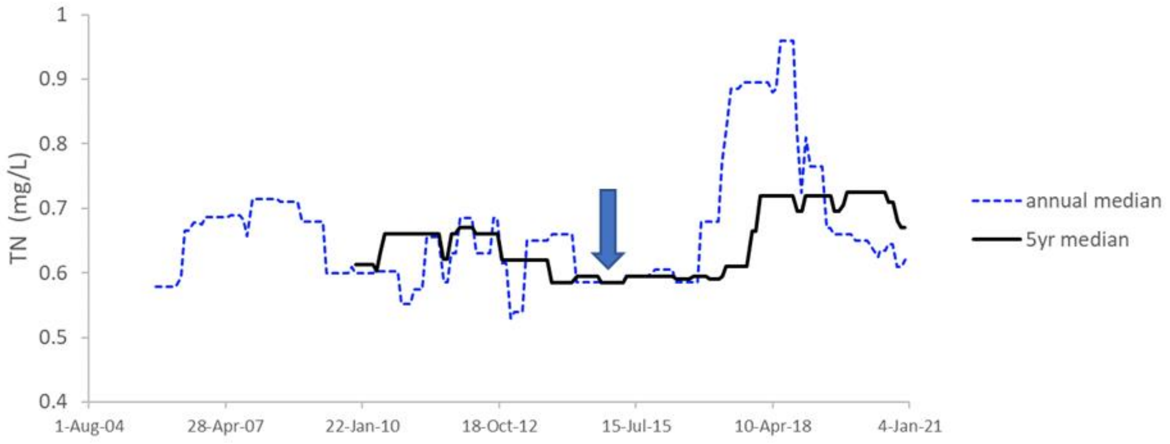

Figure 1. Moving annual median (blue dashed) and 5-year median (solid black) of total nitrogen (TN) at Waikato River site at Huntly. The blue arrow indicates value used to define 'current state' in the Waikato-Waipa plan change (PC1), which used median from calculated from 2010-2014 (inclusive).

This presents a problem for regulators because depending on the date used to define the current state, the 5-year median could coincide with minima of maxima. This would result in a current state estimate that is too conservative (minima) or too permissive (maxima) relative to the 'true' central tendency of the data.

For example, using the PC1 current state period, Waikato@Huntly is a TN concentration of 0.585 mg/L. If this current state concentration is better than the target state, then this concentration must be maintained. If it is worse than the target state, then this state determines the relative (%) reduction required, and hence influence policies and rules to achieve the required level of reduction.

However, it is apparent from the time-series (Figure 1) that the PC1 current state is likely to represent a 'lower bound' of natural variation, and therefore likely to increase to at least levels observed pre-2012 (5-yr medians). In this case, less than 4-years later, the annual median (blue dashed line) increased 50% (c. 0.6 to 0.9 mg/L) and the 5-yr median increased 25% (0.59 to 0.72 mg/L). By the end of this time-series (2020 inclusive), the annual median has return to around 0.6 mg/L, and 5-year median (with a 2–3-year lag) has reduced to 0.67 mg/L.

Currently there are no tools available that allow the user to explore time-series data, and estimate a 'compliance interval' that defines an upper and lower bound for the baseline state of water quality. The idea being that variation in water quality state within this 'compliance interval' would be largely consistent with water quality being maintained.

What we did

To this end, DairyNZ and Cawthron have co-developed a web-based, interactive tool for exploring historic variation in water quality 5-year medians. The R-shiny tool is linked to the LAWA surface water quality data set (current to 2020 inclusive). The tool can be accessed from: https://goodwin.shinyapps.io/NPCPApp/. Once at the landing page, the user identifies a site of interest on map (Figure 2), and then can select a water quality variable of interest (which includes all indicators included in the LAWA database, including nutrients, turbidity, visual clarity, and *E.coli*).

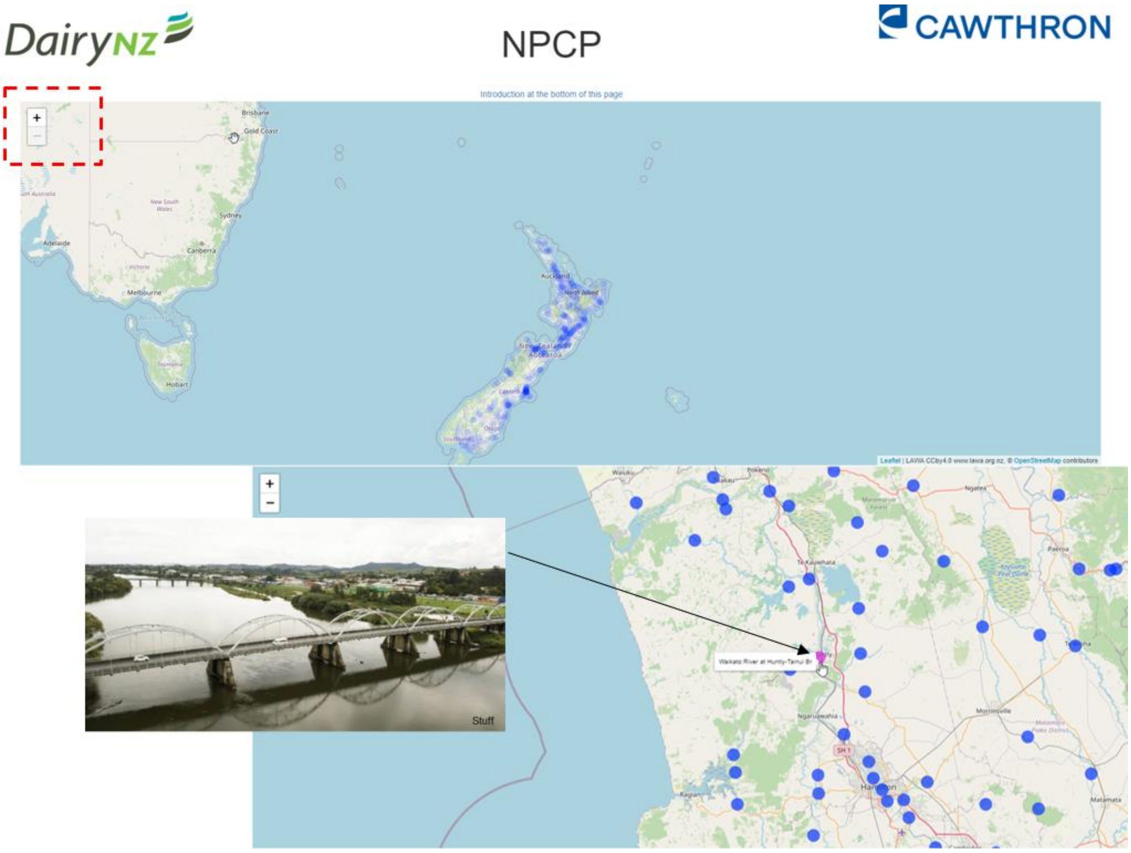

Figure 2. The NPCP tool (Non-parametric change point analysis) interface that uses LAWA data. Top shows the landing page, and lower shows how the use can zoom into the map and select any regional state-of-environment monitoring site from the LAWA database. Selected site shown in the Waikato River at the Huntly-Tainui Bridge (Waikato@Huntly).

The tool allows the user to define an assessment point – for example, the most recent year of complete water quality data when a regional council is developing a plan change. The tool then uses all data prior to this assessment period (i.e. 'historic' data) to calculate a median for the historic ('before') data prior to the user defined assessment point (Figure 3).

In Figure 3 the assessment period selected was Dec 2014 in order to estimate a compliance interval and median for a theoretical PC1 'baseline state' for Waikato@Huntly. The user can also vary the compliance interval using a second sliding bar to select a *percentile absolute deviation*. If the default value of 50th percentile is used (i.e. median absolute deviation, or MAD), then the compliance interval comprises 50% of time-series medians. Figure 3 shows a compliance interval based on a 75th absolute deviation, meaning that compliance interval comprises three-quarters of the 5-yr median values. Values within (or better than) the compliance interval are shown as green markers, while medians that are above (worse) than the upper bound are shown as red markers.

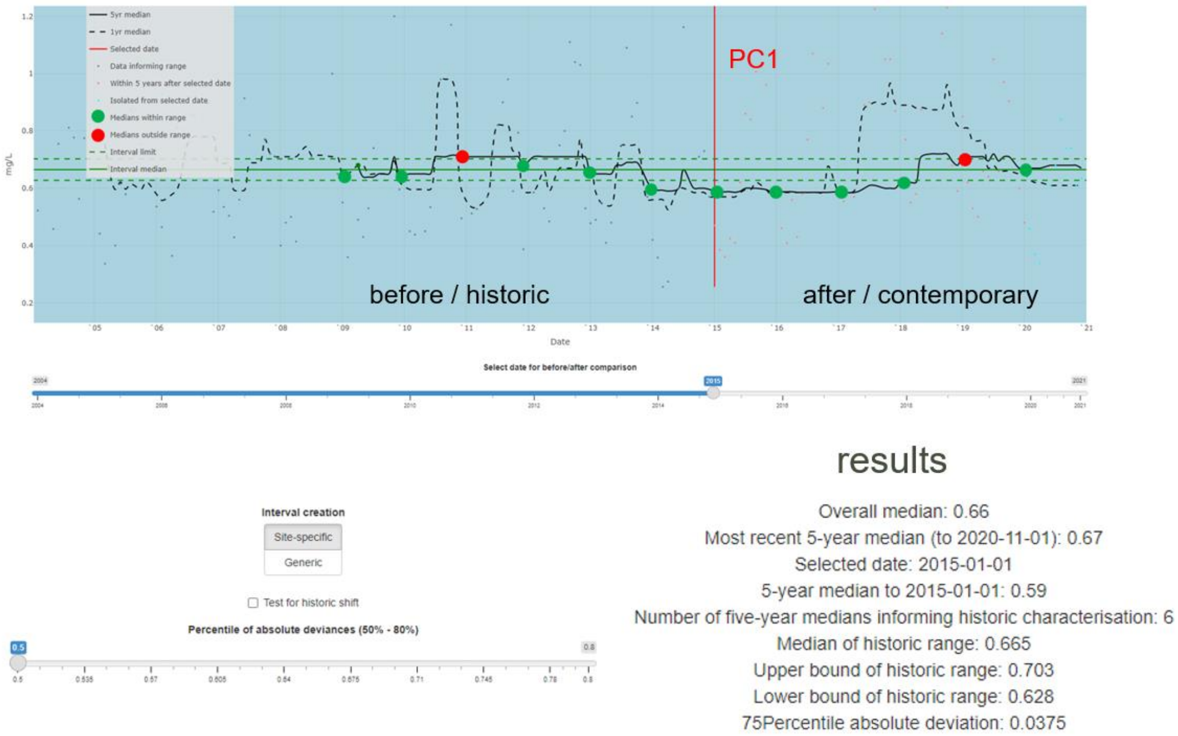

Figure 3. Screen shot showing output screen for Waikato@Huntly site where the user has specified an assessment point of 2014 (inclusive) using the slide bar under the time-series. The user can define the size of the compliance interval by adjusting the percentile of absolute deviation (from 50th to 80th percentile). In this example, a 75th percentile compliance interval has been selected. 5-year medians within (or better than) the compliance interval are shown as green markers, whereas 5-yr medians worse than the upper bound of the interval are shown as red markers.

The results from the non-parametric analysis are displayed, and include the latest 5-yr median, the historic median (pre-assessment data), the overall median (all data) and the upper and lower bound of the historic median (defined by the user-defined percentile of absolute deviation).

Recall that this PC1 current state TN concentration for Waikato@Huntly was 0.59 mg/L. Using the NPCP tool, the median for historic data (c. 2006-2014) is 0.67 mg/L with a lower and upper bound of 0.63 and 0.70 mg/L, respectively. This indicates that while the 2018 5-year median for TN exceeded the upper bound, the 2019 and 2020 5-year medians were back within the compliance interval and consistent with TN concentrations being maintained.

The tool is very much a 'beta' version and requires more testing, but it does provide a methodology for defining baseline states with a compliance interval that reflects natural variation in the 5-year median. This, in our opinion, is a more robust method than relying of 5-year medians values to define regulatory baseline states. The compliance intervals are consistent with recognition that short-duration datasets (i.e. <10 years) are highly influenced by climate (i.e. factors external to anthropogenic factors), and respond to clause 3.10(4) in the NPS-FM (2020) that states baseline states can be expressed as a range to reflect natural variation.

References:

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