**Overview design of lake scenario builder**

## Introduction

The Lake catchment Scenario Builder web application (WebApp) will allow the user to simulate impacts of on-land mitigations and land use changes in the catchment of lakes and predict the associated changes to key in-lake water quality indicators: nutrients (nitrogen and phosphorus), phytoplankton biomass and visual clarity (Secchi depth). These types of simulations are important technical information for developing policy in the context of the National Policy Statement for Freshwater Management (NPS-FM) implementation. The WebApp makes use of national or regional models so that lakes are modelled consistently. The WebApp includes all lakes for which the surface water catchments are reliably defined based on the national digital drainage network (DN2.4) and includes both monitored and unmonitored lakes.

## Analyses undertaken by WebApp

The Scenario Builder WebApp includes three types of analyses that are integrated and accessed in one application (Figure 2). The types and their purpose are:

1. Current state: to (1) define the boundary of the lake catchment (2) describe the current land use composition of the lake catchment (3) access and visualise the available monitoring data describing the current state of four indicators for the lake (in-lake median TP, TN, phytoplankton and Secchi depth) (4) obtain estimated average annual load of total nitrogen (TN) and total phosphorus (TP) discharging to lake, (5) use estimated TN and TP loads discharged to lake and lake models to predict the current state of the lake for four indicators (in-lake median TP, TN, phytoplankton and Secchi depth).
2. Land Use Mitigation: to estimate and visualise the potential water quality improvements (predicted changes to the indicators) achieved by mitigations applied to existing land in the catchment;
3. Land Use Change: to estimate and visualise potential changes to water quality resulting from changes to the existing land use mix in the catchment.

The ‘current state’ analysis is carried out first, by selecting a lake. The user may then explore scenarios that involve land use mitigation or land use change, or both combined, to estimate the impacts on the selected water quality indicator.



Figure 1. **The three types of analyses that can be performed with the Scenario Builder WebApp and the associated outputs.**

## Overview of analytical steps

1. User selects a lake
2. The input DN2.4 segments to the lake are retrieved from the data that Chris McBride is supplying. Hereafter, I refer to these as the input segment(s). I don’t know yet what this data will look like. It may be one segment only (which would be the segment that best represents the lake outlet) OR it may be multiple segments that intersect the lake polygon. Note that this lake-segment data from Chris will determine how many lakes the App can represent.
3. The boundary of the catchment upstream of the input segment(s) is obtained by tracing the upstream network.
4. The composition of the land in the catchment as defined by the typology of Srinivasan *et al.* (2021) is obtained in the same manner as for the river Scenario Builder.
5. If the lake is monitored, the available indicator values are retrieved from a database (in-lake median TP, TN, phytoplankton and Secchi depth). Unless there is better information on lakes held by LAWA, I would use the national analysis of lake state and trends produced for MFE by Whitehead *et al.* (2021).
6. Predictions of the **current** TN and TP yields for the input segment(s) are extracted the from a dataset of the national current river nutrient load model. The national current river nutrient load model is fully described by (Snelder *et al.* 2023). The model is a random forest regression fitted to mean annual loads calculated at ~330 monitoring sites distributed across NZ. The loads were expressed as yields (by dividing by upstream catchment area; kg ha-1 year-1) and fitted to various environmental characteristics of the upstream catchment (e.g., climate, topography, land cover). The predicted current yields for the input segment(s) are converted to predicted current input loads by multiplying by the catchment area.
7. The predicted **current** input loads are used to predict the **current** in-lake concentrations of TN and TP (as median values). The details of this are provided in Appendix A.
8. The predicted **current** in-lake concentrations of TN and TP are used to predict the **current** in-lake Chlorophyll and Secchi depth. The details of this are provided in Appendix B.
9. The user then specifies a mitigation and/or land use change scenario. This step will occur in the same manner as for the river Scenario Builder.
10. The WebApp will calculate the current load and the scenario load TN/TP load in the same manner as for the river Scenario Builder and will calculate the change in the load (ΔLoad) as (current -scenario)/current.
11. The ΔLoad is applied to the **current** input loads to estimate the scenario input load (**scenario** input load = **current** input loads x ΔLoad).
12. Step 7 is then repeated using the **scenario** input load to obtain the **scenario** in-lake concentrations of TN and TP (as median values).
13. Step 8 is then repeated using the **scenario** in-lake concentrations of TN and TP to obtain the **scenario** in-lake Chlorophyll and Secchi depth.

## References

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## Appendix A - predicting in-lake concentrations of TN and TP

Predictions of in-lake concentrations of TN and TP are made by coupling estimated input loads with empirical lake nutrient loading models of Abell et al. (2019). The primary input to the models of Abell et al. (2019) is the mean flow weighted concentration of TN and TP (hereafter TNin and TPin). These values are obtained by dividing the estimated input loads of TN and TP by the mean annual inflow volume. Annual inflow volumes for each lake is obtained from estimates of mean flow made for every segment of the drainage network by Booker and Woods (2014).

For each lake, the in-lake concentration of TN and TP is predicted using the following default models from Abell et al. (2019, equation 8 and equation 6):

Equation 1

Equation 2

Where *TPlake* and *TNlake* are median concentrations of TN and TP (mg m-3), k1, Δk1, k2, and all β are fitted parameters, τw is water residence time (years) derived from the FENZ database (Leathwick *et al.* 2010), and is the maximum depth of the lake derived from the FENZ database. The variable 𝑑 is a dummy variable that indicates whether a lake is shallow (𝑑 = 0) or deep (𝑑 = 1). The same threshold as (Abell *et al.* 2019) of >7.5 m were used to define deep lakes. The coefficients k1, Δk1, and k2 are values of 0, 0.44, and 0.13, respectively. The coefficients , , are 1.6, 0.54 and -0.41, respectively.

Note that when the predictions from these models are back transformed, by raising to the power of 10, the results are multiplied by retransformation bias correction factors of 1.34 (TP) and 1.16 (TN). These values were obtained from Table 5 and Table 8 of Abell and van Dam-Bates (2018), respectively.

Note that the above two models are the *default*. In some regions, newer models have been defined. Those models will be similar to those described by Equation 1 and 2 and are to come!

## Appendix B - predicting in-lake concentration of chlorophyll and lake Secchi depth

Predictions of in-lake concentrations chlorophyll and lake Secchi depth made by coupling in-lake concentrations of TN and TP with empirical models of (Abell and van Dam-Bates 2018).

For each lake, the in-lake concentration of chlorophyll and lake Secchi depth is predicted using the following default models from Abell et al. (2019, equation 8 and equation 6):

Equation 3

Equation 4

For Equation 3, *TPlake* and *TNlake* are median concentrations of TN and TP (mg m-3) that can be either observed values or predicted values derived using Equation 1 and 2. The coefficients , , in are -1.8, 0.70(TN) and 0.55(TP), respectively (Abell and van Dam-Bates 2018). Note that when the predictions from Equation 3 are back transformed, by raising to the power of 10, the results are multiplied by retransformation bias correction factors of 1.12.

For Equation 4, is the median concentrations of chlorophyll (mg m-3) that can be either observed values or predicted values derived using Equation 3. The variable 𝑑 is a dummy variable that indicates whether a lake is shallow (𝑑 = 0) or deep (𝑑 = 1), where shallow lakes are defined as z*max* ≤ 20 m. The last term of Equation 4 represents resuspension (in shallow lakes). In this term, the variable *Fetch* is the maximum lake fetch (m), and *U* is the mean windspeed (m s-1), based on analysis of regional climate data by Leathwick et al. (2010). Both of these variables are obtained for each lake from the FENZ database. The coefficients , , and and in Equation 4 are 3.46 (intercept), -0.74(Chla), -0.79 (d) and -0.35 (resuspension) (Abell and van Dam-Bates 2018).